INTRODUCTION TO ELECTROMAGNETIC SPECTRUM OPERATIONS

The Air Force operates throughout the range of military operations (ROMO) in the warfighting domains of air, space, and cyberspace. Control of air, space, and cyberspace provides the joint force with freedom of action while reducing vulnerability to enemy attacks from those domains. The electromagnetic spectrum (EMS) transcends all physical domains, and in order for the joint force to gain and maintain control in all domains, a degree of superiority in the EMS is required to conduct operations against peer- and near-peer adversaries in contested environments. Modern warfare is highly dependent on the EMS and maintaining an advantage within this discipline is necessary to enable joint force commanders (JFCs) to gain tactical, operational, and strategic advantage. Our platforms, weapon systems, and kill chains rely on the EMS – a reliance increasingly challenged by competitors and adversaries. For this reason, a comprehensive understanding of the EMS and operations within it is critical to gaining and maintaining the desired degree of control in the EMS.

INTRODUCTION

The EMS is a physical domain that exists regardless of human interaction and has physical and temporal properties, similar to the warfighting domains, which we interact with and influence. EMS-enabled capabilities are essential elements of military operations—critical enablers of multi-domain synergy. The EMS is organized by frequency and defines the types and categories of electromagnetic (EM) energy existing within the universe. The EMS is the range of frequencies of EM radiation from zero to infinity. It consists of oscillating electric and magnetic fields characterized by frequency and wavelength. The EMS is usually subdivided into frequency bands (typically 26 alphabetically designated bands) based on certain physical characteristics, including radio waves, microwaves, millimeter waves, infrared (IR) radiation, visible light, ultraviolet radiation, x-rays, and gamma rays. This includes all EM radiation, manmade and naturally occurring, that exists from below the earth’s surface (e.g., extremely low frequency radio to communicate with submarines) continuing deep into space (e.g., X-band communications with deep space probes), that can affect the movement, maneuver, employment and operation of joint forces.

Electromagnetic spectrum operations (EMSO) comprise all coordinated military
actions to exploit, attack, protect, and manage the electromagnetic environment (EME) to achieve the commander’s objectives. Electromagnetic warfare (EW) is a type of fires as well as an enabling capability. Within EMSO reside the specialties of electromagnetic warfare (EW) and electromagnetic spectrum management (ESM). EMSO refers to all actions taken in the EMS or involving the EMS regardless of their nature or adversary involvement. EW refers to military action in which forces use radiant and directed EM energy to obtain and maintain situational mastery of the EMS, by protecting spectrum-dependent systems, networks and operations; tactically sensing the operational environment (OE); and attacking where necessary, at a time and place of their choice.

Note on the Terms “Electronic” vs. “Electromagnetic”

Air Force language has evolved from using the term “electronic warfare” (and related terms such as “electronic attack,” “electronic protection,” etc.) to refer now to “electromagnetic warfare.” The legacy term, “electronic,” speaks to actions to attack and protect the electronic circuits associated with radios and radars. With expanded use of the electromagnetic spectrum (e.g., infrared applications, lasers, microwave and satellite communications, computers) the broader term “electromagnetic” is more technically accurate. This evolution also anticipates a similar change in joint doctrine.

To compete and win against peer and near-peer adversaries in modern conflict, the joint force should place a high priority on achieving control of the EMS in order to ensure freedom of action in all other domains. The EMS transcends all physical domains and the information environment simultaneously, and the lack of EMS superiority may allow adversaries to deny our access, degrade the capabilities of our EMS-dependent systems, and use the EMS to disrupt our operations. Airmen should know what portions of the EMS in which they are operating and understand how their use of the spectrum affects friendly as well as adversary systems. It is also vital that Airman recognize how Air Force EMSO fits into the larger picture of joint electromagnetic spectrum operations (JEMSO) to leverage joint capabilities and understand how to integrate and deconflict EMS activities.

Peer and near-peer competitors have advanced EMS capabilities that they are continuously improving and integrating capabilities in all domains, which present growing challenges to the joint force’s ability to achieve objectives. The Air Force brings specific capabilities to the joint force to enable the degree of control in the EMS that facilitates control of other domains. Clearly defined domains help identify the conditions and capabilities under which systems and personnel conduct operations, but do not mandate or imply command relationships.

Devices whose functions depend upon the EMS are used by both civilian and military organizations and individuals for intelligence, surveillance, and reconnaissance (ISR); communications; positioning, navigation, and timing (PNT); sensing; command and
control (C2); attack; ranging; data transmission; and information storage and processing. Warfighting in the EMS is not new. Competing powers have witnessed America’s dominance on the battlefield and perceive our reliance on the spectrum as a vulnerability. These competing powers have organized, trained, and equipped forces to engage and maneuver within the EMS, in order to gain military advantage. Some have invested heavily to counter America’s radar, navigation, communication, and data link advantages. In some instances, the US has not kept pace, and our technological advantages are eroding. The joint force may not be able to operate effectively if it allows adversaries to achieve EMS superiority at times and places of their choosing.

However, the Department of Defense (DOD) also cannot afford to defend or harden every node and position, nor can it address all capability gaps by simply countering adversaries’ moves. The DOD must generate overmatching EMS sensing, maneuver, and engagement capabilities that collectively present an impasse for any potential adversary. Ultimately, the US must contest, then gain and maintain, superiority in the EMS.

The joint force is dependent on the freedom of maneuver in the EMS across the ROMO. To prevail in future conflicts, the Air Force should support the joint force’s efforts to win the fight for EMS control. It requires significant integration between the spectrum management community, Service components, combatant commands, and allies. Achieving this superiority is complicated by increasing civilian and military EMS use, electromagnetic operational environment (EMOE) congestion, and the growth of EMS threats (See figure, “Control Challenges in an EMS Contested or Congested Environment”).

The DOD requires an overmatching, offensive approach to EW that will place our
potential adversaries in a dilemma: they will either have to invest heavily to defend their growing reliance on the EMS, or invest heavily to achieve offensive capability parity with the US. Airmen should develop EMS awareness, engagement, and maneuver capabilities that span and connect all other domains and enable operations (e.g., suppression of enemy air defenses, counterspace, ballistic and long-range missile defense), and within the shared space between the EMS and cyberspace. This will allow them to render adversary sensors, networks, and decision processes ineffective, preventing adversaries from responding effectively in real time. The Air Force supports the joint force’s endeavors to exploit broad portions of the EMS, automatically manage waveforms and power levels as necessary, and employ adaptive technology to negate adversary capabilities. Global dependence on the EMS offers the joint force increasing opportunities to exploit new attack vectors through all phases of conflict. Dominant EW expertise and capabilities can negate adversary situational awareness and command and control, and develop kill-chain targeting solutions affecting enemy operations in all domains.

Spectrum-dependent commercial and military systems have become ubiquitous since World War II. This dependence will necessitate that future combatants contend for EMS superiority in every phase of conflict. The three divisions of EW, electromagnetic protection\(^1\) (EP), electromagnetic warfare support\(^2\) (ES), and electromagnetic attack\(^3\) (EA), form the capabilities with which the joint force gains EMS superiority. EMS superiority is the degree of advantage in the EMS that permits the conduct of operations at a given time and place without prohibitive interference, while affecting the adversary’s ability to do the same. EW has had strategic consequences in every conflict from World War II through current operations.

Modern conflict may often depend on achieving competitive advantage within a contested EMS environment. Competitive advantage in battle is rooted on foundational actions—developed and maintained institutional expertise, advanced technical training, and actively preserved core competency relevance. Our peer and near-peer adversaries organize, invest, and train to challenge and control the EMS as a dedicated military profession.

**Overview of Electromagnetic Spectrum Operations**

The EMS is the range of all frequencies of EM radiation and consists of oscillating electric and magnetic fields characterized by frequency and wavelength (see figure, “The Electromagnetic Spectrum”).

The EMS is:

- **Physical.** It is part of the physical environment characterized by frequency, energy,
and time. It can be managed, occupied, and selectively controlled like the air, land, maritime, space physical domains, and cyberspace. Natural and man-made factors affect actions in and through the EMS just as in the air, on land, at sea, in space, and in cyberspace.

**Pervasive.** The EMS is pervasive and permeating, linking all domains. The wide range of effects that can be created through EMS operations makes it a potent force multiplier.

**Constrained.** Physics, policy, and technology frame the use of the EMS. Each type of EM radiation has unique physical properties that dictate its use (e.g., short- or long-range communications, sensing). Use of the EMS is subject to international law, as well as domestic law and policy. Technology bounds those portions of the EMS that are accessible and exploitable.

**Dynamic.** The potential speed of EMSO may provide a decisive advantage by enabling commanders to make decisions, conduct operations, and create effects more rapidly than the enemy.
Air Force Operations and the Electromagnetic Spectrum

The Air Force is critically dependent on the EMS across all functions and domains. To prevail in the next conflict against a peer- or near-peer adversary in a contested environment, the joint force must win the fight for EMS superiority. Achieving the desired level of control is complicated by increasing joint EMS-use requirements, EMS congestion, and growth of EMS threats. The Air Force, as part of the overall joint force, conducts its part of integrated JEMSO in order to achieve unity of effort, resulting in the required degree of EMS control.

For further information on EMS superiority, see the *National Military Strategic Plan for Electronic Warfare*, and the *Joint Concept for Electromagnetic Spectrum Operations*.

Rapid advances in EMS technologies have led to an exponential increase in commercial and military EMS-enabled and dependent capabilities. This proliferation, coupled with the US military’s heavy reliance on the EMS and the low entry costs for adversaries, poses significant military challenges to the commander, Air Force forces (COMAFFOR), who is usually also the joint force air component commander (JFACC), or the joint force space component commander, and ultimately for the JFC. Integrated EMSO are required to achieve the desired degree of EMS control, which may be an essential or even decisive aspect of all joint operations.

EMSO are versatile in that they are capable of achieving effects in their own right and enabling effects within other domains. An example of a direct EMS effect is the offensive jamming of an enemy radar system, denying that system the use of the EMS. An enabled effect might be the delivery of an information operations message via radio broadcast. This is an enabled effect rather than a direct one in that the message is not inherently tied to the EMS and could be delivered via other means, such as airdrop or human-delivered pamphlets, where the jamming effects are, by necessity, conducted within the EMS.

The scope of EMSO is global and extends from below the earth’s surface into space. Unfettered access to selected portions of the EMS is critical for weapon system effectiveness and protection of critical assets. It is important to realize that EMSO includes not simply radio and radar emanations, but all EM energy propagating through free space as well as EM signals transmitted through contained mediums such as wiring or optical fiber. As such, operations within the EMS can be hindered by adversary action, environmental factors, or conflict with friendly EMS systems. These factors should be taken into account when planning to operate in the EMS, so that proper mitigation, deconfliction, integration, and countermeasures are in place to ensure continued operations.

The Electromagnetic Environment (EME) is, “the resulting product of the power and time distribution, in various frequency ranges, of the radiated or conducted EM emission levels encountered by a military force, system, or platform when performing its assigned mission in its intended OE” (Joint Publication [JP] 3-85, *Joint Electromagnetic Spectrum Operations*). Notall
EM radiation encountered by forces will impact operations. Friendly forces should prepare to operate in highly contested and non-permissive EME and understand EMSO’s potential to increase force effectiveness. Intentional and unintentional emissions from military forces as well as the natural environment, may aggravate the EME’s contested nature. EM interference and hazards to personnel, ordnance, and volatile materials may be caused by electromagnetic pulse (EMP), as well as natural phenomena, such as the effects of sunspots, lightning, and precipitation static. For example, clouds, sun glint, ground reflections, moisture, and dust can degrade performance of systems operating in the IR and optical frequencies. Atmospheric conditions can distort radar signals causing track errors, extending the detection ranges or creating “holes” in radar coverage. Rain and frozen precipitation also affects microwave transmissions by attenuating and scattering the signal. Even disturbances on the sun and in the upper atmosphere can create radiofrequency interference in radars and satellite links, impact high-frequency radio and satellite communications, and degrade Global Positioning System accuracy. Planners using forecasts of terrestrial and space environmental conditions can exploit or mitigate these effects to their advantage over an adversary.

**The Electromagnetic Operational Environment** is the background EM radiation and the friendly, neutral, and adversarial electromagnetic order of battle (EOB) within the EM area of influence associated with a given operational area (JP 6-01, *Joint Electromagnetic Spectrum Management Operations*). The EMOE is a complex composite of the EM conditions, circumstances, and influences that affect the employment of capabilities and the decisions of the commander. This includes systems which are currently radiating as well as those that may radiate (i.e., systems on the EOB that have not been observed radiating).

**Electromagnetic Environmental Effects (E3).** “The impact of an EMOE upon the operational capability of military forces, equipment, systems, and platforms is referred to as E3” (JP 3-85). All systems that operate in the EMS are susceptible to E3. The EME experienced by the Air Force are continuously changing as existing systems are modified, new systems are installed, units change proximity, adversaries transmit, or natural phenomena occur. When platforms, associated systems, and equipment (e.g., avionics, ordnance, fuel) are exposed to an EME different from those for which they were designed and tested, the potential for safety, interoperability, and reliability problems increases. Planning for E3 is critical to address E3 issues such as hazards of EM radiation in operations. These include EM compatibility, EM vulnerability, EM interference (EMI), EMP, hazards of EM radiation to personnel, hazards of EM radiation to ordnance, hazards of EM radiation to fuels, and natural phenomena effects such as lightning and precipitation static. EMSO planners review joint EMS-dependent systems for EM vulnerability, compatibility, and interoperability to identify/quantify the potential impact of E3. Critical system failure during execution can result from failing to account for E3 in planning and mitigating

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4 This definition is identical to existing joint doctrine except in the use of “electromagnetic” instead of “electronic.” The reason for this change can be found in the “Note on the Terms ‘Electronic’ vs. ‘Electromagnetic’” in this section of the publication.
potential EMI.

**EMS Congestion.** The EMS typically encountered today is congested due to the increasing density of EM emitters. Myriad interests (such as cell phone and wireless internet providers) continue to expand their EMS footprint, reducing the open EM areas conducive to Air Force use and maneuver within the EMS. Other civil uses and other government entities consume large portions of the spectrum outside of DOD.
The Electromagnetic Threat. Worldwide, tens of thousands of EMS-dependent weapons systems exist and are constantly being proliferated and enhanced. Current EMS threats include systems that can detect, exploit, deny, disrupt, and deceive virtually all multinational operational capabilities, including navigation, communications, and sensors. Destructive EM weapons that directly attack personnel, sensors, platforms, C2, and infrastructure have been fielded or are under development. Concurrently, adversaries seek access to secure communications and use navigational and sensing systems to facilitate their attacks. Adversaries also have access to off-the-shelf systems, and are prepared to use them, potentially without regard to legal constraints. All of these threats to freedom of action in the EMS should be accounted and planned for in order to support and achieve the JFC’s objectives. The worldwide proliferation of weapon systems, designed to counter US and multinational EMS-dependent capabilities (e.g., weapon seekers, navigation, communications), impact joint functions and overall mission success. Additionally, the operational viability of low cost directed energy (DE) weapon systems is growing, further complicating risk assessments and mission success by holding personnel, platforms, and infrastructure at risk. Enemy use of commercial off-the-shelf systems to hide among civilians increases the targeting difficulty of US and multinational planners.

Electromagnetic Spectrum Operations (EMSO) are military actions undertaken to exploit, attack, protect, and manage the EMOE. These actions include all joint force transmissions and receptions of EM energy. EMSO provides the guidance and processes to prioritize, integrate, synchronize, and deconflict all EMS actions across the joint force, enabling unity of effort. The COMAFFOR designates an electromagnetic spectrum control authority (EMSCA) and exercises unity of command for Air Force forces in the EMS through a Non-kinetic Operations Coordination Cell (NKOCC), facilitated by electromagnetic battle management (EMBM) to integrate and synchronize Air Force EMS use and to allow decentralized execution of EMS activity. The EMSCA provides centralized direction through the EMS control plan (EMSCP). EMSO is employed in both an offensive and defensive manner in support of the commander’s objectives.

Offensive EMSO are intended to project power by the application of force in and through the EMS. Offensive EMSO are authorized via an EMS control order (EMSCO). Offensive EMSO are planned, prioritized, integrated, synchronized, and deconflicted along with all other forms of offensive operations in all other domains. The intent of offensive EMSO is to disrupt deny, deceive, degrade or destroy the adversary’s ability to use the EMS.

Defensive EMSO are employed in and through the EMS to either protect joint forces from physical attack or defend friendly EMS capabilities from enemy EA. Defensive EMSO respond to unauthorized activity or alerts or threat information and leverage law enforcement, intelligence, counterintelligence, and other military capabilities as required. Defensive EMSO is accomplished using a layered, adaptive, defense-in-depth approach, incorporating emission control and mutually supporting elements of digital and physical protection.
Joint doctrine provides collective terms encompassing the EW operations described above with spectrum management. These terms are joint electromagnetic spectrum operations and joint electromagnetic spectrum management operations (JEMSMO).

Electromagnetic Battle Management and Control in the EMS

To control is to dominate the EMS, directly or indirectly, so that friendly forces may exploit or attack the adversary and protect themselves from exploitation or attack. Control is accomplished through applications of EA, ES, and EP. EA limits adversary use of the EMS; EP secures use of the EMS for friendly forces; and ES enables commanders’ ability to identify and monitor actions in the EMS throughout the OE.

EMBM is the methodology used to ensure effective control of the EMOE. While control of the EMS through the proper application of EW is advantageous, improperly using EW without coordination with other entities that require use of the EMS may result in EM interference or EM fratricide. Consequently, these results might lead to unintended effects like disruption of friendly cyberspace and information networks. Additionally, an ill-timed jamming package may highlight an otherwise unseen force or deny the use of a frequency by friendly forces. An incorrect or wrongly interpreted radar warning receiver indication may cause friendly forces to react unnecessarily. EMBM is the dynamic monitoring, assessing, planning, and directing of EMSO in support of the commander’s scheme of maneuver. EMBM proactively harnesses multiple platforms and diverse capabilities into a networked and cohesive sensor-decision-target-engagement system, as well as protect friendly use of the EMS, while strategically denying benefits to the adversary. The goal is a balance among the needs of the intelligence, operations, and communications communities to prioritize, deconflict, and ultimately maximize the advantage of our capabilities in the EMS to dominate through EMSO.
Concept for EMBM in relation to EMSO

KEY:
C2 – Command and control
EMS – Electromagnetic spectrum
The counter-electromagnetic spectrum (EMS) mission integrates offensive and defensive operations to attain and maintain a desired degree of control and protection of the EMS. Counter-EMS operations can be conducted across all domains and determine the level or degree of control of the EMS. **Control of the EMS describes a level of influence in the EMS relative to that of an adversary, and is typically categorized as parity, superiority, or supremacy.** The degree of control lies within a continuum that can be used by any combatant. This can range from a parity (or neutral) situation, where neither adversary can claim control over the other, to EMS superiority, to EMS supremacy, all depending upon the situation and the **joint force commander's** (JFC’s) concept of operations. The figure, *Control in the EMS Continuum*, illustrates the degrees of operational area control required for air and space operations, and illustrates their relationship.

![Control in the EMS Continuum](image)

The required degree of control of the EMS is typically a degree of EMS superiority that enables the successful execution of joint operations. Operations such as
electromagnetic attack (EA); electromagnetic protection (EP); electromagnetic warfare support (ES); suppression of enemy air defenses (SEAD); considerations for the use and defense against electromagnetic pulse (EMP); lasers and other directed energy (DE); and information operations (IO); will likely depend on some degree of EMS superiority. Normally, counter-EMS operations are classified as offensive or defensive. Counter-EMS operations can be conducted across the tactical, operational, and strategic levels of war by any component or element of the joint force. The JFC’s objectives and desired effects determine when, where, and how these operations are conducted to gain the required degree of control of the EMS.

**EMS Parity.** EMS parity is described as a condition in which no force has control of the EMS. This represents a situation in which both friendly and adversary land, maritime, air, space, and cyberspace operations may encounter significant interference by the opposing force. Parity is not a standoff, nor does it mean maneuver has halted. On the contrary, parity may be typified by fleeting, intensely contested battles at critical points during an operation with maximum effort exerted between combatants in their attempt to achieve some level of favorable control.

**EMS Superiority.** EMS Superiority is that degree of control in, through, and from the EMS by one force that permits the secure, reliable conduct of operations at a given time and place in the EMS without prohibitive interference from the opposing force, while affecting the adversary’s ability to do the same. EMS superiority may be the critical enabler to superiority in other domains. EMS superiority may be localized in space and in time, or it may be broad and enduring.

**EMS Supremacy.** EMS supremacy is that degree of control in, through, and from the EMS that permits operations at a given time and in a given place without effective interference from opposing forces, while affecting the enemy’s ability to do the same. EMS supremacy may be localized in space and in time, or it may be broad and enduring.

Control of the EMS hinges on preventing prohibitive or effective interference to friendly forces in the EMS from enemy forces, which would prevent friendly forces from creating their desired effects. EMS supremacy prevents effective interference, which does not mean no interference exists, but any attempted interference can be easily countered or should be so negligible as to have little or no effect on operations. While EMS supremacy is most desirable, it may not be operationally feasible. EMS superiority, even local or mission-specific, may provide sufficient freedom of action to create desired effects. Therefore, commanders should determine the minimum level of control of the EMS required to accomplish their mission and assign an appropriate level of effort to achieve it.
Electromagnetic warfare (EW)\(^8\) is waged to secure and maintain freedom of action in the electromagnetic spectrum (EMS). Military forces and other entities are dependent on the EMS to sense, communicate, strike, and dominate offensively and defensively across all warfighting domains. EW is essential for protecting friendly operations and denying adversary operations within the EMS.

“The term EW refers to military action involving the use of electromagnetic (EM) energy and directed energy (DE) to control the EMS or to attack the enemy” (Joint Publication [JP] 3-85, *Joint Electromagnetic Spectrum Operations*). This is not limited to radio or radar frequencies but includes infrared (IR), visible, ultraviolet, and any other free-space electromagnetic radiation such as wireless cyberspace applications. EW is critical in gaining freedom of action within contested and congested environments.

EW consists of three divisions: electromagnetic attack\(^9\) (EA), electromagnetic warfare support\(^10\) (ES), and electromagnetic protection\(^11\) (EP). All three contribute to operational success across the operational environment. Proper employment of EW capabilities produces the effects of detection, denial, deception, disruption, degradation, exploitation, destruction, and protection. Capabilities inherent in the EW divisions can be used for both offensive and defensive purposes and are coordinated through electromagnetic battle management (EMBM).

EW operations have developed over time to exploit the opportunities and vulnerabilities inherent in the physics of EM energy. The principal activities used in EW include the following: countermeasures, EMBM, EM compatibility, EM deception, EM hardening, EM interference resolution, EM intrusion, EM jamming, electromagnetic pulse (EMP), EMS control, EM intelligence collection, EM masking, EM probing, EM reconnaissance, EM security, EW reprogramming, emission control,

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\(^8\) For the reason these terms have been changed from "electronic" to "electromagnetic," see “Note on the Terms ‘Electronic’ vs. ‘Electromagnetic’ in, "Introduction to Electromagnetic Spectrum Operations," this publication.

\(^9\) Ibid.

\(^10\) Ibid.

\(^11\) Ibid.
operations in order to be effective. Additionally, the scope of these operations is global and extends from below the earth’s surface into space. **Unfettered access to selected portions of the EMS is critical for weapon system effectiveness and protection of critical assets.** EW is a force multiplier that can create effects throughout ROMO. When EW actions are properly integrated with other capabilities, synergistic effects may be achieved, minimizing losses and enhancing effectiveness.

Air Force electromagnetic warfare operations embody the art and science of employing military capabilities to achieve objectives through control of the EMS. EW exploits weaknesses in an adversary’s ability to operate and applies force against the adversary’s offensive, defensive, and supporting capabilities across the EMS. An effective EW strategy requires an integrated mix of passive, disruptive, and destructive systems to protect friendly weapon systems, components, and communications systems from the enemy’s threat systems.

Electromagnetic warfare is tied closely to advances in technology. Technology enabled the utilization of the EMS to communicate through radios as a practical standard in the
early 1900s, and developed in aviation to enable navigation in all conditions. The advent of radar and its proven effectiveness early in World War II started the “move–countermove” developments of radar, sensors, jammers, and countermeasures. Shortly after the development of radar, chaff was developed as a countermeasure.

Concurrently, airborne jammers were developed to minimize the effectiveness of radar. The Cold War witnessed the development of radar with effective EP. Further EA developments were designed to defeat these protective measures. Conflicts in Vietnam and the Middle East provided deadly reminders of the necessity for effective EW against advanced threats and of the intense effort required to counter these threats. Current technology has given rise to new enemy capabilities, which includes the use of microwave and millimeter wave technologies, lasers, electro-optics, digital signal processing, and programmable and adaptable modes of operation. It also includes the use of IR, visible, and ultraviolet frequencies and that part of the EMS where DE weapons might function. More recently, EW responded to emerging threats by countering improvised explosive devices and satellite communications. Anticipating future technological developments is vital for EW and the survivability of friendly forces.

Electromagnetic Warfare in Information and Cyberspace Operations

EW’s relationship to information operations (IO) is as an information-related capability (IRC). IO does not “own” individual capabilities, but rather employs IRCs in an integrated manner to create effects contributing towards a specified end-state. EW creates effects throughout the ROMO. Therefore, those planning and executing EW operations should be aware of the intent of other IRCs such as military deception, military information support operations and operations security to lessen the chance of compromise. EW’s integration with other IRCs through IO is vital to ensure the capabilities complement rather than conflict with each other.

Cyberspace operations require both wired and wireless links to transport information. Any wireless link requires access to the EMS and therefore requires coordination and synchronization between EW and Air Force information network operations in order to maximize and potentially achieve synergistic effects. For more on electromagnetic warfare’s role in cyberspace operations see JP 3-85.

Directed Energy in Electromagnetic Warfare

DE is an umbrella term covering technologies that relate to the production of a beam of concentrated electromagnetic energy or atomic or subatomic particles. Directed-energy warfare is military action involving the use of DE weapons, devices, and countermeasures to incapacitate, cause direct damage or destruction of enemy equipment, facilities, and personnel, and/or to determine, exploit, reduce, or prevent hostile use of the EMS through damage, destruction, and disruption” (JP 3-85). It also includes actions taken to protect friendly equipment, facilities, and personnel and to retain friendly use of the EMS. Applications of DE include: laser, radio frequency, and particle beam. DE can be applied to conduct EA, ES, or EP. For example, a laser designed to blind or disrupt optical sensors is EA. A warning receiver designed to detect
and analyze a laser signal is ES. A visor or goggle designed to filter out the harmful wavelength of laser light is EP.

**Operational Requirements**

The level of EW involvement will always depend on the specific requirements of the mission. **EW is task oriented.** Operational objectives, the tactical situation, the effectiveness and availability of combat systems, and the prevailing domestic and international political climate determine the appropriate application of EW capabilities. EW planning is not just the automatic addition of a specific jamming pod or escort package for a mission. Each task may require a specific EW response in order to create a desired effect. Commanders and their staffs must consider the threat and assets available to support EW objectives.

**Intelligence, Surveillance, and Reconnaissance (ISR)**

A critical enabler of successful military operations is a thorough knowledge of enemy capabilities derived from near real time information, focused for the operational commander, as well as long term operational, scientific, and technical intelligence information gathered over a period of time. Knowledge of the enemy's projected military capabilities is required to avoid surprise. Accurate intelligence is needed to gauge the intent of an adversary, and this intelligence must be transmitted to the users in a timely manner. Intelligence, surveillance, and reconnaissance are critical force multipliers when applying lethal and nonlethal effects of airborne, space, and cyberspace EW.

**Exploitation of the EMS**

Most modern military systems, from support systems to weapons systems, exploit the **electromagnetic operational environment** (EMOE) to function optimally by sensing the EME and/or using EM energy to communicate through it. Sensing systems support intelligence collections, situational awareness, targeting, etc. EMS sensors can be active (e.g., air-to-air radars, laser target designators) or passive (e.g., radar warning receivers, IR weapons seekers). Communications systems support Air Force C2, weapons control links, information dissemination, etc.

**Commanders should know their own EW capabilities and those of potential adversaries.** New technologically advanced weapons systems are being fielded in increasing numbers. Adversaries recognize potential vulnerabilities of US EMS-dependent systems. Seeking to take advantage of this fact, some potential adversaries have organized to attack our critical weapons systems control functions and associated communications nodes. Many countries have been purchasing modern and capable weapons systems from a variety of sources. In addition, terrorists may acquire highly sophisticated and dangerous weapons. To counter these possibilities, commanders and their staffs must become well versed in the development and employment of weapons systems and the EW capabilities, to include navigation warfare, of all possible adversaries. Numerous
ISR systems and methods are used to collect the data needed to build the various electromagnetic databases required to effectively employ EW. Advanced processing and exploitation systems, with man-in-the-loop management and oversight, transform the data into usable intelligence, while survivable communications grids bring the intelligence to the operational user. As in all military operations, defining and managing intelligence requirements are critical to EW. Since many collection methods require EMS access, ISR operations should be coordinated, deconflicted, and synchronized with EW operations through EMBM and JEMSMO processes.
Electromagnetic warfare (EW) consists of three divisions: electromagnetic attack (EA), electromagnetic warfare support (ES), and electromagnetic protection (EP). All three contribute to operational success across all domains. Capabilities inherent to the EW divisions can be used for both offensive and defensive purposes and are coordinated through electromagnetic battle management (EMBM).

**Electromagnetic Attack**

“EA is the division of EW involving the use of electromagnetic (EM) energy, directed energy (DE), or antiradiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy operational capability”. EA prevents or reduces an enemy’s use of the electromagnetic spectrum (EMS) through denial, degradation, disruption, deception, and destruction for offensive or defensive purposes.

**Offensive EA** is generally employed at the request and onset of friendly force engagement of the enemy and, in many cases, suppress a threat for a limited period. Examples include active applications such as EM jamming, meaconing and intrusion; expendable decoys; anti-radiation missiles; directed energy (DE) and high-energy weapons including lasers, radio-frequency weapons, high-power microwave, and electromagnetic pulse (EMP); delivery of electromagnetic cyberspace attacks; and navigation warfare.

**Defensive EA** activities use the EMS to protect personnel, facilities, capabilities, and equipment. Examples include employing self-protection and force protection measures such as flares, chaff, low-observable technologies, towed decoys, protection jammers, and DE infrared (IR) countermeasures.
Electromagnetic Warfare Support

“ES is the division of EW involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate sources of intentional and unintentional radiated electromagnetic energy for the purpose of threat recognition, targeting, planning, and conduct of future operations” (JP 3-85). Commanders, aircrews, and operators use ES to provide near real time information to supplement information from other intelligence sources. Additionally, ES information can be correlated with other intelligence, surveillance, and reconnaissance (ISR) information to provide a more accurate picture of the electromagnetic operational environment—and therefore a better understanding of the battlespace. This information can be developed into an electromagnetic order of battle (EOB) for situational awareness and may be used to develop new countermeasures. Development of these countermeasures is supported by updates to the Electronic Warfare Integrated Reprogramming (EWIR) database. The EWIR process enables reprogramming of EW systems to provide operational commanders with a timely and accurate means to respond to changes in the EMS and maintain the capability to effectively detect, classify, and counter enemy threats. The relationship between ES and signals intelligence (SIGINT), which includes electromagnetic intelligence and communications intelligence, is close because they share common functions of search, interception, identification, location, and exploitation of electromagnetic radiation. The distinction lies in the type and use of information, and who has tasking authority. ES resources are tasked by or under direct control of operational commanders. The operational commander may have authority to task national SIGINT assets to provide ES or may have direct operational control over tactical resources capable of providing ES. In either case, ES is distinguished by the fact that the operational commander determines aspects of resource configuration required to provide ES that meets immediate operational requirements. SIGINT is tasked by national authorities. The passive nature of ES allows it to be effectively employed during peacetime.

Electromagnetic Protection

“EP includes the actions taken to protect personnel, facilities, and equipment from any effects of friendly, neutral, or enemy use of the EMS, as well as naturally-occurring phenomena that degrade, neutralize, or destroy friendly combat capability” (JP 3-85). Examples of EP include frequency agility, changing pulse repetition frequency, emission control (EMCON), and EM hardening (to include EMP hardening). Integration of EP and other security measures can prevent enemy detection, denial, disruption, deception, degradation or destruction. Friendly force reliance on advanced technology demands comprehensive EP safeguards and considerations.

17 For the reason these terms have been changed from "electronic" to "electromagnetic," see “Note on the Terms ‘Electronic’ vs. ‘Electromagnetic’” in, “Introduction to Electromagnetic Spectrum Operations,” this publication.
Proper frequency management is a key element in preventing adverse effects (e.g., jamming friendly forces) from friendly actions. Much of the success of EP occurs during the design and acquisition of equipment. EMCON is a passive application of EP.

**EW Effects**

EW involves the use of EM energy and DE to control the EMS or to attack the enemy. Military forces depend on the EMS for applications that include: intelligence; communication; positioning, navigation, and timing; sensing; command and control (C2); attack; ranging; data transmission; and information and storage. Control of the EMS is critical to the success of military operations.

EW has offensive and defensive aspects that work in a “move-countermove” fashion. Often, these aspects are used simultaneously and synergistically. In the same way air, space, and cyberspace superiority allows friendly forces the freedom from attack, freedom to maneuver, and freedom to attack, the properly coordinated use of EW allows friendly forces to use the EMS. As an example, the offensive denial of a C2 network by EM jamming disrupts the adversary’s ability to control forces that would otherwise engage a friendly strike force. The proper use of EP allows friendly radar and communications to continue operating in the presence of enemy jamming. The proper employment of EW involves various applications of control to achieve detection, denial, deception, disruption, degradation, exploitation, protection, and destruction.

**Detection**

Detection is identification of potential enemy EM emissions through use of ES measures (JP 3-85). It involves assessing the electromagnetic environment (EME) to include radar and radio frequencies; electro-optics and lasers; and the IR spectrums using active and passive means. It is the first step in EW because effective mapping of the EME is essential to develop an accurate EOB. The EOB is

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20 For the reason these terms have been changed from “electronic” to “electromagnetic,” see “Note on the Terms ‘Electronic’ vs. ‘Electromagnetic’” in, *Introduction to Electromagnetic Spectrum Operations,* this publication.
critical for EW decision making and for using the EMS to meet mission objectives. The various means of detection include on-board receivers; space-based systems; unmanned aircraft; human intelligence; and other ISR systems. Detection supports all divisions of EW and enables the avoidance of known hostile systems. When avoidance is not possible, it may become necessary to deny, deceive, disrupt, degrade, or destroy the enemy's electromagnetic systems or capabilities.

Denial

Denial is defined as the prevention of access to or use of systems or services (JP 3-85). In an EW context, it is the prevention of an adversary from using EMS-dependent systems (e.g., communications equipment, radar) by affecting a particular portion of the EMS in a specific geographical area for a specific period. Denial involves controlling the information an enemy or adversary receives, preventing the acquisition of accurate information about friendly forces. Denial is accomplished through EA; expendable countermeasures; destructive measures; network applications; tactics, techniques, and procedures; and EMCON.

Deception

Deception is measures designed to mislead the adversary by manipulation, distortion, or falsification of evidence to induce the adversary to react in a manner prejudicial to the adversary's interests (JP 3-85). Through the use of the EMS, EW manipulates the decision-making loop of the opposition, making it difficult to distinguish between reality and the perception of reality. If an adversary relies on EM sensors to gather intelligence, deceptive information can be channeled into these systems to mislead and confuse. Deception efforts should simulate as many adversary information sources as possible to create the desired effects. Multi-sensor deception can increase the adversary's confidence about the "plausibility" of the deception story.

Deception efforts are coordinated with the military deception officer and considered during development of a deception plan, the information operations plan, and the overall operations or campaign plans. Operational security is critical to an effective deception.
EM deception as it applies to EW is the deliberate radiation, re-radiation, alteration, suppression, absorption, denial, enhancement, or reflection of EM energy in a manner intended to convey misleading information to an enemy or to enemy EM-dependent weapons, thereby degrading or neutralizing the enemy’s combat capability. There are three types of EM deception: manipulative, simulative, and imitative.

**Manipulative.** EM deception involves an action to eliminate revealing or to convey misleading EM telltale indicators that may be used by hostile forces. EM manipulation may involve low observable technology used to reduce radar returns, simulation of threat signatures from nonlethal platforms, and communication and non-communication signals used to splinter displays or convey threat activity. Manipulative electromagnetic deception can be used to cause the enemy to misdirect ES and EA assets and, therefore, cause fewer problems with friendly communications. In this application it is an EP technique.

**Simulative.** EM deception is action to simulate friendly, notional, or actual capabilities to mislead hostile forces. Simulative EM may involve using airborne expendables to simulate false targets or transmitting deceptive EA techniques to mask the true location of a target.

**Imitative.** EM deception introduces EM energy into enemy systems that imitate enemy emissions. Any enemy receiver can be the target of imitative EM deception. This might be used to screen friendly operations through the use of repeater jamming techniques.
In general, EW deception planning determines how to use EM means to mislead the adversary and create an advantage for friendly forces.

**Disruption**

*Disruption is to interrupt the operation of adversary EMS-dependent systems (JP 3-85).* Effective disruption limits adversary capabilities by degrading or interfering with the adversary’s use of the EMS to limit the enemy’s combat capabilities.

Disruption is achieved by using EM jamming, EM deception, EM intrusion, and physical destruction. These will enhance attacks against hostile forces and act as a force multiplier.

**Degradation**

*Degradation is to reduce the effectiveness or efficiency of adversary EMS-dependent systems (JP 3-85).* Employing EM jamming, EM deception, and EM intrusion is intended to degrade adversary systems thus confusing or delaying actions of adversary operators.

**Exploitation**

*Exploitation is taking full advantage of any information that has come to hand for tactical, operational, or strategic purposes (JP 3-85).* In the context of EW, it entails using adversary EM radiation for friendly advantage. EM energy may provide tactical, operational, and strategic situational awareness of the EMOE, and is used to develop an EOB. Data transmissions produce EM energy for exploitation by signals intelligence provide targeting for EM or destructive attacks, and develop awareness of operational trends.

**Protection**

*Protection is the preservation of the effectiveness and survivability of mission-related military and nonmilitary personnel, equipment, facilities, information, and infrastructure deployed or located within or outside the boundaries of a given*
**Operational area** *(JP 3-85).* This includes ensuring that EW activities do not electromagnetically destroy or degrade friendly intelligence sensors; communications systems; positioning, navigation, and timing capabilities; and other EMS-dependent systems and capabilities. Protection is achieved by component hardening, EMCON, EMS management and deconfliction, and other means to counterattack and defeat adversary attempts to control the EMS.

**Destruction**

Destruction is to make the condition of a target so damaged that it can neither function as intended nor be restored to a usable condition *(JP 3-85).* When used in the EW context, destruction is the use of EA to eliminate targeted adversary personnel, facilities, or equipment. Target tracking radars and C2 nodes may be high value targets because their destruction seriously hampers an adversary's effectiveness. Destruction requires determining the exact location of the target. This location may be determined through the effective application of ES measures. Adversary EM systems can be destroyed by a variety of weapons and techniques ranging from bombardment with conventional munitions, high-speed antiradiation missiles, intense radiation, and high-energy particle beam overloading. Destruction of EM capabilities has the most sustained effects and may be the best means of denying adversary use of the EMS. The duration of the destructive effects depends on an adversary's reconstitution capability.
As with other applications of electromagnetic warfare (EW), airborne electromagnetic warfare considerations are split into the three divisions of electromagnetic attack (EA), electromagnetic warfare support (ES), and electromagnetic protection (EP). Specifically within the air domain, on a fundamental level of electromagnetic spectrum (EMS)-aided air warfare, an analogy of the adversary’s use of the EMS can be split into three categories: “swords,” “shields,” and “spies.” As a “sword,” the enemy uses the EMS via wireless communication, radars, or EMS-aided munitions, for offensive attacks to find, fix, track, target, engage, and assess action against friendly forces. Friendly EA, supported by ES (and other intelligence sources), aims to counter this. As a “shield,” the enemy utilizes counter-EMS systems such as radar, communication, and navigational jammers, to halt friendly freedom of maneuver in the EMS to complete an engagement. Friendly EP, supported by ES (and other intelligence sources), aims to counter this. Finally, as a “spy” the enemy uses the EMS via passive detection capabilities to detect and collect on friendly assets. Friendly EP, supported by ES (and other intelligence sources), also aims to counter this.

**Airborne Electromagnetic Attack**

Airborne EA aims to counter the enemy’s ability to use the EMS to attack friendly forces, and is split into two categories: offensive EA and defensive EA (commonly referred to as self-protection jamming). Offensive airborne EA capabilities, also referred to as “off-board EA” by protected entities, are generally employed by one air asset to protect other specific assets, or an entire strike package, depending on mission requirements. Defensive airborne EA, also referred to as “onboard EA,” by protected entities, or “electromagnetic countermeasures (ECM),” are generally employed by an air asset to protect the friendly assets. There may be instances where offensive EA can be used to protect friendly assets, or where defensive EA can be employed to support off-board assets, but planners and staffs should possess or request documentation that such employment can produce desired effects, before building plans that use EA in such a fashion.

**Airborne Offensive EA**

Historically, the Air Force supports the joint force requests for offensive airborne EA to
either protect surface forces or other air forces. In supporting ground or maritime forces, the aim of offensive EA in a supporting asset role, is to disrupt, deceive, degrade, destroy, or deny any adversary in a manner that benefits ongoing surface operations. This includes, but is not limited to communication equipment. There may be instances where offensive EA aircraft are the supported asset to affect targets in the land and maritime domains.

In addition to historical uses of airborne EA, the Air Force realizes the advantages of fighting as a truly multi-domain force. Airborne EA can also be used to provide effects in support of offensive and defensive counterspace operations. For instance, by attacking ground stations with EA, aircraft may negate an enemy’s ability to control their satellites and deliver space effects, to include enemy offensive counterspace attacks. Anti-radiation missiles passively hone in on radiation sources and may be used to strike ground-based space surveillance radars, missile warning radars, or satellite control stations. Successful counterspace operations will mitigate the enemy’s use of space capabilities to support their fielded forces in all domains.

In supporting joint forces in all domains, offensive airborne EA focuses on any EMS node or pathway that can be used by the adversary to engage friendly forces. This includes, but is not limited to, enemy communications and enemy radars. Examples of offensive airborne EA include:

 **Anti-Radiation Missiles (ARMs).** ARMs have sensors onboard the munition to passively home onto electromagnetic (EM) radiation of enemy systems, in order to affect them in a manner that is advantageous to friendly forces. Generally, ARMs cannot be employed in a manner that can “save” aircraft that are already being actively engaged; the inbound enemy munition will most likely impact the engaged aircraft prior to ARM impact, so effective utilization of ARMs requires proactive employment. For example, enemy knowledge of the presence of ARMs in the battlespace may serve as a deterrent.

 **Electromagnetic Intrusion.** EM intrusion is the intentional insertion of EM energy into transmission paths in any manner, with the objective of deceiving operators or causing confusion.

 **Electromagnetic Jamming.** EM jamming is the deliberate radiation, re-radiation, or reflection of EM energy for the purpose of preventing or reducing an enemy’s effective use of the EMS, with the intent of degrading or neutralizing the enemy’s combat capability. Specifically it is the intentional transmission of EM energy into a targeted RF receiver in order to prevent its proper function. Early Air Force efforts were primarily directed toward electromagnetically jamming hostile radars to hide the number and location of friendly aircraft and to degrade the accuracy of radar-controlled weapons. Currently, jamming enemy sensor systems, terrestrial and satellite communications links, and other devices that rely on the EMS can limit enemy access to information on friendly force movements and composition and cause confusion. Jamming can degrade the enemy’s decision-making and employment when applied against command and control (C2) systems. An adversary
heavily dependent on centralized control and execution for force employment presents an opportunity for EA.

**Air-launched decoys** are systems intended to deceive or disrupt enemy evaluation of the air domain. Air-launched decoys can re-radiate or jam enemy EMS emissions.

**Meaconing.** Meaconing consists of receiving radio beacon signals and rebroadcasting them on the same frequency to confuse navigation. The meaconing stations cause aircraft or surface stations to obtain inaccurate bearings.

**Electromagnetic pulse (EMP)** is a short pulse of rapidly changing electric and magnetic fields. This pulse can potentially interfere with the operation or electrical and electronic equipment or cause widespread damage to infrastructure. EMP is one of a nuclear device’s effects and depending on the altitude of detonation and the yield of a nuclear device, EMP’s effects can extend hundreds of kilometers from the blast site. EMP can also be delivered via non-nuclear means, producing temporary effects or system destruction. These effects can be delivered via conventional and non-conventional means. The portion of the EMS most vulnerable to EMP is the radio spectrum. Hardening of communications systems and planning for communication system protection is vital when EMP is likely. Finally, EMP is very powerful type of EM radiation, which may be employed as a weapon, from a strong electromagnetic pulse that can be produced by a nuclear explosion or generated conventionally to produce damaging current and voltage surges.

**Directed energy (DE) systems** are systems (e.g., lasers and radio frequency weapons, high-power microwaves (HPMs), EMP weapons that use DE [concentrated EM energy and atomic or subatomic particles]) to incapacitate, damage, or destroy enemy equipment, facilities, and/or personnel. Lasers are devices that emit light through a process of optical amplification based on the stimulated emission of EM radiation with sufficient energy to affect adversary systems, while radio frequency (RF) weapons employ EM radiation to damage equipment or harm personnel. HPMs are weapon systems utilizing high-power microwave RF. DE capabilities can be hosted in an offensive EA system as well as in a defensive EA and self-protection (DEA/SP) system.

**Airborne Defensive Electromagnetic Attack / Self-Protection**

Airborne DEA/SP activities use the EMS for self-protection of an aircraft. There may be DEA/SP capabilities that can provide survival benefits for other aircraft (e.g., chaff corridors or self-protection jammers that counter EMS-dependent systems in an overwhelming manner), but generally airborne DEA/SP equipment is developed to only provide protection of the host aircraft. Airborne DEA/SP may include radar warning receivers, jammers, chaff, flares, lasers, DE, towed decoys, and low-observable technologies. The desired effect is to counter enemy EMS-dependent equipment for friendly protection.

**Low observable technologies** increase assets’ ability to operate in the physical
domains by reducing the possibility of their detection and exploitation by adversaries through the EMS.

- **Chaff** are radar confusion reflectors, consisting of thin, narrow metallic strips of various lengths and frequency responses, which are used to reflect echoes for confusion purposes.

- **Flares** are infrared or ultraviolet generating sources ejected from aircraft to mislead infrared or ultraviolet-sensitive or -seeking targeting systems.

- **Directed energy weapons** are weapons or systems (e.g., laser turrets) that use directed energy to incapacitate, damage, or destroy enemy equipment, facilities, or personnel.

**Airborne Electromagnetic Warfare Support**

ES assets and capabilities collect, detect, intercept, identify, and locate sources of intentional and unintentional radiated EM energy. The purpose of airborne ES missions is to intercept, identify, and locate adversary electromagnetic and communication emissions to provide threat warning to friendly forces in all domains. The information gathered during ES operations is used for threat avoidance, EA, and targeting. ES platforms such as the RC-135V/W Rivet Joint and the EP-3E Aries II are tasked by an operational commander to provide combat support to friendly forces for an operationally-defined period. Supported mission areas include, but are not limited to, the following:

- **Joint Intelligence Preparation of the Operational Environment (JIPOE).** JIPOE is necessary to collect and correlate EMS reflections to build information on the target nation’s weapons systems and overall order of battle. ES operations should begin as early as possible to build an accurate tactical picture prior to any counterair, counterland, countersea, counterspace, or counter-EMS operations.

- **Counterair.** ES supports offensive and defensive operations to attain and maintain control of the air. Threats to air operations are identified through electromagnetic means and disseminated to C2 and strikers before adversary weapons can be employed. Suppression of enemy air defenses (SEAD) operations rely on the rapid location and dissemination of threat data to enable accurate and timely deployment of ARMs and other EA methods.

- **Counterland.** ES supports airpower operations against enemy land forces by monitoring enemy reactions and providing imminent threat warning (ITW) to friendly forces in close proximity. Airborne ES platforms responds to real-time requests for enemy information using tactical communication methods. This allows decision makers to make target determinations for air interdiction or engagement by tactical ground units.

- **Countersea.** Airborne ES is necessary to ensure awareness of the electromagnetic
environment (EME) in a wider collection area as opposed to a region-specific focus. In addition to threat warning and identification, airborne ES produces intelligence on enemy surface and subsurface vessels, maritime patrol, harbor tracking activity, and surface C2.

Counterspace. ES supports offensive and defensive operations to attain and maintain control of space. Threats to space operations may be identified through electromagnetic means and disseminated to C2 and strike assets before adversary weapons can be employed. Integrated employment of multi-domain capabilities through coordinated detection, identification, engagement, and assessment of enemy forces is necessary to defeat enemy attacks and protect friendly forces.

Combat Search and Rescue (CSAR). ES platforms support CSAR operations by collecting and passing information on enemy activity and status of isolated personnel (IP) as required to the Joint Personnel Recovery Center (JPDC), CSAR task force, and other relevant players. During execution, threat warning to rescue forces and identification of enemy activity near the IP is a vital requirement.

Non-Kinetic Operations. Operations that rely on actions designed to create effects without the direct use of destructive force are often referred to as “non-kinetic” operations. This can encompass much of EW, as well as information, space, cyberspace, and special technical operations. Making such operations effective often hinges upon airborne ES platforms’ ability to provide the most accurate data pertaining to enemy EM reflections. Employing effective EA techniques is not possible without accurate identification and characterization of the EME. A critical component of planning and executing effective non-kinetic actions is providing measures of effectiveness (MOE). MOEs are used to assess changes in system behavior or capability that are tied to measuring the attainment of an end state, achievement of an objective, or creation of a desired effect. Airborne ES is necessary for identifying information relevant to an MOE and disseminating it to the non-kinetic package commander for further analysis or action. Effective EA can also support ES operations by influencing enemy activity to achieve collection of desired EM information. However, consequence management must be considered when employing EA for ES operations so as not to encourage undesired reactions from the enemy. Having an airborne EA asset act as the airborne non-kinetic package commander may be beneficial in ensuring proper mission management and coordination with non-airborne assets.

There are several planning and execution factors that should be taken into account to employ effective airborne EA. Crews should plan orbits that best meet the requirements of the mission. Proximity to friendly forces is crucial to maintain two-way coordination, but proximity to enemy forces must enable freedom of movement without provoking engagement. Threats with long effective engagement ranges may prove consequential when calculating collection effectiveness from greater standoff distances. The ability to provide imminent threat warning (ITW) quickly and accurately depends on management of orbit placement as it pertains to sensor effectiveness. Effective ITW may warrant additional ES or EA platforms, airborne and non-airborne, in order to increase
opportunity for cross-cueing and cooperative geolocation. Dissemination methods (e.g., tactical reports (TACREPs), situation reports (SITREPs), ITW, combat advisory broadcasts) should be solidified during planning to guarantee rapid and accurate sharing of information. Finally, MOE can come from multiple ES sources in multiple domains. Careful planning is needed to task EM sensors at the right time and place to verify expected outcomes during operations. This is also true for counterland, counterair, countersea, counterspace, and counter-EMS operations when providing information on EM reflections to calculate battle damage indications.

- **Tactical Reports (TACREPs) / Situation Reports (SITREPs)** are situational updates and intelligence summaries that provide adversary-based signals intelligence (SIGINT) updates with location and identification amplification to support units in all domains prior to ingress.

- **Imminent Threat Warning (ITW)** is near real time threat reporting of SIGINT-derived intelligence to provide indications and warnings to friendly forces after ingress that are within, or transitioning to, adversarial threats.

- **Cooperative geolocation** is the real-time cross-cueing with assets across all domains to provide accelerated identification and location of adversary threats.

- **Utilizing EA to support ES (or Jam-to-Exploit)** is a planning-intensive operational capability to provide EA effects on specific adversary EMS capabilities, to drive the adversary to different assets that are more readily accessible to ES assets.

### Airborne Electromagnetic Protection

EP is a friendly EMS-dependent system’s mode of operation, or use of EMS or physical properties, to **preserve itself from adversary EW**, thereby allowing the system to continue operating. Ensuring EMS-dependent equipment is immune to environmental effects or other friendly EMS-dependent systems is also the goal of EP. **EP is not force protection.** The use of flare rejection logic on an infrared (IR) missile (i.e., allowing the IR missile to continue to function despite an adversary’s use of flares) is EP. The flare rejection technique ensures friendly use of the EMS to track the intended target despite the adversary's DEA/SP actions (i.e., the flare). Although defensive EA actions and EP both protect personnel, facilities, capabilities, and equipment, EP protects from the effects of EA (friendly or adversary) or EM interference, while DEA/SP is used primarily to protect against lethal attacks by denying adversary use of the EMS to target, guide, or trigger weapons.

Examples of EP include frequency agility, changing pulse repetition frequency, emission control (EMCON), and EM hardening (to include electromagnetic pulse hardening). Integration of EP and other security measures can prevent enemy detection, denial, disruption, deception, degradation, or destruction. Friendly force reliance on advanced technology demands comprehensive EP safeguards and considerations. Proper frequency management is a key element in preventing adverse effects (e.g., jamming friendly forces) from friendly actions. Much of the success of EP occurs during the
design and acquisition of equipment. EMCON is a passive application of EP.
Historically, militaries have viewed the "high ground" as essential to maintaining advantage in warfare. With rare exception, whichever force controlled the high ground gained superior ability to maneuver and maintain visibility of the operational environment to effectively “own the fight.” In that tradition, space assets orbiting high above our planet’s surface offer a superior position and an expansive view of the Earth. Space capabilities allow joint forces in all domains to cover more area with a smaller force. They provide indications and warnings of strategic, operational, and tactical threats; identify targets with precision without putting humans in harm’s way; synchronize communications worldwide; and increase effectiveness by making weapons highly accurate. Space capabilities also enable expeditionary operations with light and lethal forces forward and reachback stateside, and enable combat sorties worldwide to be flown stateside with unprecedented persistence.

Space operations are highly dependent on access to and freedom of maneuver within the electromagnetic spectrum (EMS). Achieving space superiority is of primary concern to Airmen as it enables the continuous provision and advantages of space-enabled capabilities to joint warfighting operations. Counterspace is the mission, like counterair, that integrates offensive and defensive operations to attain and maintain the desired control and protection in and through space. One of the methods used to conduct counterspace operations, ensuring the required access to and freedom of maneuver in the EMS, is electromagnetic warfare. Space EW may be used to suppress enemy command and control (C2), integrated air defense systems, and other significant military use to exploit the EMS. These assets must be flexible, agile, and responsive since they may be tasked to support operations using their capabilities to maneuver through a large range of the EMS. Due to the operational nature of space, assets may also support worldwide operations, which can drive competition between combatant commander requirements. Space EW considerations include persistence, regional effects, standoff ability, and no air escort required.
Planning Considerations

**Persistence.** EW assets targeting certain space-based receivers benefit from, exceptional dwell times, allowing extended operations. In many situations, EW assets targeting space-based receivers provide the most efficient and effective means to attain joint force objectives.

**Standoff.** EW capabilities targeting satellite receivers allow the possibility to affect terrestrial users from a greater distance than airborne EW assets can. This gives the warfighter an asymmetric advantage over the adversary and may result in friendly forces being less vulnerable to attack.

**Regional Effects and Implications.** Due to the nature of applying effects at the satellite, all users on the ground have the potential to be affected. Under certain circumstances this could cause affects across multiple areas of responsibilities. Integration of theater space requirements should consider both a global and theater perspective. Global integration is the responsibility of the Commander, US Strategic Command. Theater integration requires close coordination with the applicable theater **joint force commander** (JFC) and component commanders.

**Approval Authorities.** Space assets are used to fulfill single-theater, multiple-theater, or global national objectives. Thus, the command and control C2 structure for integrating space assets and forces should be robust enough to account for variations in operating areas. Broad planning considerations should be utilized when considering EW assets to ensure maximum operational flexibility. Planning should take into account the capabilities of Service, joint force components, and interagency, multinational, and commercial partners in all domains. During all phases of planning, the **commander, Air Force forces** (COMAFFOR) should coordinate with theater JFCs and joint force space component commander (JFSCC), in accordance with established support relationships. The JFSCC plans for simultaneous support to all theaters via the Combined Space Operations Center. Once priorities are established, the JFSCC should identify the action required to achieve the COMAFFOR’s objectives.

Assets from any domain may be used to conduct counterspace missions in support of joint operations in one or more geographic areas. These assets may be used to fulfill single-theater, multi-theater, or global objectives. Thus, the C2 structure established for integrating forces should be robust enough to account for these various operating areas. Employing assets to meet global or multiple theater requirements normally entails a C2 structure that bridges more than one theater and is capable of incorporating non-Department of Defense organizations. Additional detail on the C2 of space forces can be found in AFDP 3-14, *Counterspace Operations*. EW personnel support the COMAFFOR by accomplishing the following:

- Make recommendations on the proper employment of space EW planning and operational requirements.

- Develop a daily space EW battle rhythm that supports EW as well as general
planning and operations requirements.

- Accomplish specified and implied space EW tasks.
- Represent space EW within the information operations cell.
- Maintain current assessment of resources available for conducting space EW (to include number, type, and status of assets) and analyze what resources are necessary to accomplish operational objectives.
- Develop, coordinate, and integrate operations to achieve space EW effects, based on the JFC’s objectives.
- Predict effects of friendly and adversary space EW activity on joint and multinational operations.
- Assist in frequency management. This includes deconflicting frequency requirements and assignments.
- Coordinate and monitor space EW programming and reprogramming by identifying where EW reprogramming decisions and reprogramming actions affect operations.
- Conduct reachback to organizations supporting space EW operations.
- Provide liaison to other Service and functional components of joint and multinational forces for space EW issues.
- Function as the space EW integrator for counterspace operations.
- Coordinate space EW support for combat search and rescue.

**Command and Control.** Approval authorities for use of space EW capabilities can initially be at levels much higher than airborne EW capabilities. Due to the possible global nature of Space EW capabilities, control might not rest with a single combatant commander. Command relationship authorities should be clarified early on during operational planning.

**Effects Synchronization.** When operations planning is conducted, space EW effects should be synchronized with other EW platforms and kinetic operations as necessary. Space EW should be rarely utilized independently.

**Space Electromagnetic Attack (EA)**

EA may target enemy space systems by using EM energy, originating in any domain, to attack a link segment, to include uplink, downlink, and crosslink signals. Directed energy weapons, such as lasers, may also be used to provide a wide range of effects against on-orbit satellites, including heating, blinding optics, degradation, and destruction.
Under certain circumstances, lasers could also be effective against space launch vehicles while in flight.

**Space Electromagnetic Warfare Support (ES)**

Space ES responds to taskings to search for, intercept, identify, and locate sources of intentional and unintentional radiated electromagnetic energy for the purpose of threat recognition. Commanders, aircrews, and operators use space ES to provide near real time information to supplement information from other intelligence sources. Space ES information can be correlated with other intelligence, surveillance, and reconnaissance information to provide a more accurate picture of the EM operational environment and therefore a better understanding of the battlespace. This information can be developed into an electromagnetic order of battle for situational awareness and may be used to develop new countermeasures. The relationship between space ES and signals intelligence (SIGINT), which includes electromagnetic intelligence and communications intelligence, is close because they share common functions of search, interception, identification, location, and exploitation of EM radiation. The distinction lies in the type and use of information, and tasking authority. Space ES resources may be tasked by or under direct control of the JFSCC. The JFSCC may also request national SIGINT assets to provide space ES and may have direct operational control over tactical resources capable of providing space ES. In either case, space ES is distinguished by the fact that the JFSCC determines aspects of resource configuration required to provide space ES that meets immediate operational requirements. The passive nature of space ES allows it to be effectively employed during the entire range of military operations.

**Space Electromagnetic Protection (EP)**

EP of space capabilities includes the actions taken to protect personnel, facilities, and equipment from any effects of friendly or neutral EM interference, to counter enemy use of EW, as well as naturally occurring phenomena that negate friendly combat capability. Examples of EP specific to space capabilities include frequency agility, changing pulse repetition frequency, emission control, shutter control, and low observable technologies.
Employing cyberspace electromagnetic warfare (EW) capabilities within the electromagnetic spectrum (EMS) requires the ability to securely transmit, receive, store, and process information in near real time. The US’ state and non-state adversaries are equally aware of the significance of this technology and will use information-related capabilities (IRCs) to gain advantages in the information environment, just as they would use more traditional military technologies to gain advantages in other operational environments. Sophisticated adversaries leverage the EMS and cyberspace effects to create significant dilemmas for US and allied forces. Therefore, transformative efforts are needed to deal with an increasingly complicated threat. Vigilant timing, integration, coordination, and synchronization ensure collaborative efforts to prevent one theater of operations, or capability, from affecting others, and are intentional and supportive rather than collateral.

The information environment is the aggregate of individuals, organizations, and systems that collect, process, disseminate, or act on information. This environment consists of three interrelated dimensions, which continuously interact with individuals, organizations, and systems. These dimensions are the physical, informational, and cognitive (Joint Publication [JP] 3-13, Information Operations). The physical dimension is composed of command and control systems, key decision makers, and supporting infrastructure that enable individuals and organizations to create effects. The informational dimension specifies where and how information is collected, processed, stored, disseminated, and protected. The cognitive dimension encompasses the minds of those who transmit, receive, and respond to or act on information.

IRCs are the tools, techniques, or activities that affect any of the three dimensions of the information environment. The joint force employs IRCs to affect the information provided to or disseminated from the target audience (TA) in the physical and informational dimensions of the information environment to affect decision making.

Electromagnetic Warfare in Cyberspace Operations (CO)

All information-related mission areas increasingly depend on the EMS. The relational framework describes the application, integration, and synchronization of IRCs
to influence, disrupt, corrupt, or usurp the decision making of TAs to create a desired effect to support achievement of an objective. EW creates effects throughout the range of military operations and across all domains. Therefore, those planning and executing EW operations should be aware of the intent of other IRCs such as military deception, military information support operations, and operations security (OPSEC) to lessen the chance of compromise. While the primary focus of information operations (IO) is on the cognitive dimension of the information environment, EW's primary focus is to achieve objectives across the physical domains Cyberspace EW is responsible for securing and maintaining freedom of action in the EMS for joint and coalition forces while exploiting or denying it to adversaries. Airborne EW, space EW, and offensive CO capability and integration with other IRCs through IO is vital to ensure the capabilities complement rather than conflict with each other.

**Cyberspace Operations**

CO is the employment of cyberspace capabilities where the primary purpose is to achieve objectives in or through cyberspace. CO strive to achieve cyberspace superiority; defined as a degree of dominance in cyberspace by one force that permits the secure, reliable conduct of operations by that force and its related land, air, maritime, and space forces at a given time and place without prohibitive interference (JP 3-12, *Cyberspace Operations*).

Cyberspace operations require both wired and wireless links to transport information. Any wireless link requires access to the EMS and therefore requires coordination and synchronization between EW, Air Force information network operations, and US Cyber Command (USCYBERCOM) to maximize and achieve synergistic effects. For more on electromagnetic warfare’s role in cyberspace operations.

**Cyberspace Electromagnetic Warfare Missions**

Cyberspace is categorized into three missions: offensive cyberspace operations (OCO), defensive cyberspace operations (DCO), and Department of Defense information network (DODIN) operations.

**OCO** are cyberspace attacks, similar to electromagnetic attack (EA), which create noticeable effects in cyberspace, as well in the physical domains (i.e., deter, deny, disrupt, degrade, destroy, or manipulate enemy capabilities in cyberspace). OCO may exclusively target adversary cyberspace functions or create first-order effects in cyberspace to initiate carefully controlled cascading effects into the physical domains to affect weapon systems, C2 processes, logistics nodes, high-value targets, etc. Cyberspace attack, specifically those attacks conducted via the EMS and airborne and space EA, should be deconflicted to maximize the impact of each type of fires. Uncoordinated EA may significantly impact EMS-enabled cyberspace...
attack actions.

DCO are missions executed, similar to electromagnetic protection (EP), to defend the DODIN, or other cyberspace DOD cyberspace forces have been ordered to defend, from active threats in cyberspace (JP 3-12). Defensive cyberspace operations are conducted in response to specific threats, attacks, exploitations, or other effects of malicious cyberspace activity and leverage information from maneuver, intelligence collection, counterintelligence, law enforcement, and other sources as required. Components of DCO are internal defensive measures of the DODIN, which include pro-active and aggressive internal threat hunting countermeasures and responses; and response actions where cyber effects enabling activities are taken external to the defended network or portion of cyberspace without the permission of the owner of the affected system.

DODIN operations mission includes operational actions taken to secure, configure, operate, extend, maintain, and sustain DOD cyberspace and to create and preserve the confidentiality, availability, and integrity of the DODIN (JP 3-12).

Planning Integration, Synchronization, and Considerations

Cyberspace attacks via the EMS should be deconflicted with other EAs to optimize each type of fires. Depending on power levels, the geographic terrain and nature of the system targeted, unintended effects of EW operations may propagate outside of the local commander’s operating area. Planners should consider different coordination requirements for the various types of fires that depend upon the EMS. To minimize overlap, the primary responsibility for cyberspace attack coordination begins with the COMAFFOR’s appointed cyberspace coordinators and planners. Planning is subsequently coordinated between USCYBERCOM and the joint force. This resides with the applicable joint force headquarters and USCYBERCOM in coordination with the combatant command CO staff.

Air Force forces conducting OCO do so under the authority of combatant commands and USCYBERCOM. Cyberspace target planning may require extended time, extended approval time, synchronization, and deconfliction.

Cyberspace Authorities

Cyberspace forces normally conduct operations under the authority of Title 10, U.S.C., Armed Forces or Title 50, U.S.C., War and National Defense. The authorities invoked differ depending on the type of operation conducted. The rules for operating under these varying titles are different. Authorities to act against adversaries are included in the execute order or operation order for a specific operation. If aggressive defensive responses or counter-offensive operations are authorized, authorities should be clearly defined and understood. Cyberspace forces belonging to the Air National

**Cyberspace Operations Command and Control**

USCYBERCOM, as the coordinating authority for CO, plans, coordinates, integrates, synchronizes, and conducts activities to direct the security, operations, and defense of the DODIN, preparing to, and when directed, conducting military CO external to the DODIN in support of national objectives. USCYBERCOM will assign CO integrated planning element representatives to the combatant commander for the synchronization and deconfliction of cyberspace operations.

The director of cyberspace forces (DC4) team synchronizes and coordinates full spectrum CO in support of the [commander, Air Force forces](https://www.af.mil) (COMAFFOR). The DC4 normally ensures all cyberspace planning, execution, and assessment are integrated into the warfighting lines of operations across all domains for the COMAFFOR. Coordination is required to integrate multi-domain operations with the air operations center’s [Non-kinetic Operations Coordination Cell (NKOCC)](https://www.whitehouse.gov). Together, both the NKOCC and DC4 teams address non-kinetic integration. For more information on the NKOCC and integration of non-kinetic actions (including IO, space, cyberspace and EW), see [Air Force Tactics, Techniques, and Procedures 3-3.AOC, Air Operations Center, chapter eight](https://www.airforce.mil).

**Intelligence, Surveillance, and Reconnaissance (ISR) in Cyberspace**

CO requires all-sourced cyberspace-focused ISR, including digital network analysis to air force cyberspace operators. This support is generally characterized within five cyberspace-focused ISR areas: current intelligence and reporting, indications and warnings, threat attribution and characterization, intelligence preparation of the operational environment, and computer network exploitation.
Electromagnetic Spectrum Operations (EMSO) require a solid foundation from which to launch operations in the electromagnetic spectrum (EMS). To achieve successful operations spanning the range of military operations (ROMO) in the EMS, continued investments in numerous mission areas are made during peace and wartime. Cementing the base of joint EMS capability is a dedication to the education and training of the whole force and the staffing of a dedicated professional force fluent in EMS operations. A joint electromagnetic warfare (EW) strategy is driven by persistent national and combatant command (CCMD)-derived intelligence to monitor our adversaries and understand their use of the EMS. Coordination within the Department of Defense (DOD) and across the Air Force will ensure streamlined and responsive acquisitions processes and resource allocations under a unified effort. Lastly, a dedication to testing and programming or reprogramming efforts ensure the Air Force is postured to best sense, protect, and respond effectively to any threat in the EMS.

A thorough knowledge of adversary capabilities derived from near real time (NRT) information is a critical enabler of successful military operations, focused for the operational commander, as well as baseline operational, scientific, and technical intelligence information gathered over time. Accurate intelligence is needed to gauge the intent of an adversary, and this intelligence should be transmitted to the users in a timely manner. Intelligence, surveillance, and reconnaissance (ISR) is a critical force multiplier when applying lethal as well as nonlethal effects of electromagnetic warfare, and cyberspace warfare.

Under Secretary of Defense for Intelligence (USD-I) serves as the principle staff assistant to the Secretary of Defense (SecDef) and Deputy SecDef regarding intelligence support to the DOD and exercises the SecDef’s authority, direction, and control over combat support agencies (CSAs). These include the National Security Agency (NSA) / Central Security Service (CSS), Defense Intelligence Agency, National Geospatial Intelligence Agency, and the National Reconnaissance Office. These CSAs
are required to support DOD activities. There are many types of support these agencies provide the DOD and specifically to EW. These include foundational intelligence, technology support, signals intelligence (SIGINT), cryptologic support, foreign military orders of battle (to include electromagnetic order of battle), global intelligence analysis through open source intelligence, integration of foreign partner intelligence capability, access to denied areas, and the planning and execution of military operations.

The Service intelligence organizations provide intelligence support for DOD missions related to military systems, equipment, training, and national intelligence activities. The Deputy Chief of Staff of the Air Force for Intelligence, Surveillance, Reconnaissance, and Cyber Effects Operations (AF/A2) is responsible for policy, formulation, planning, evaluation, oversight, and leadership of Air Force global integrated intelligence, surveillance, and reconnaissance (GIISR) capabilities, which support and feed EW, specifically **EW support** (ES). The 25th Air Force (25 AF), a subordinate to Air Combat Command (ACC), is responsible for executing AF/A2s GIISR responsibilities. ACC and 25 AF organizes, trains, equips, and presents assigned forces and integrates their all-source intelligence capabilities within the Air Force, combatant commands (CCMDs), and CSAs.

Additionally, ACC, via 25 AF, is responsible for prioritizing and acquiring capabilities to support the CCMDs and their priority EW and EMSO effects. As adversaries continue to advance their capabilities to including complex signals and cognitive/artificial intelligence capabilities, a strong link between EW capabilities and their intelligence support activities is necessary to maintain the advantage in a contested battlespace.

**Intelligence, Surveillance, and Reconnaissance Support**

Accurate and timely ISR is the foundation for effective EW planning and employment. ISR supports EW through several functions. First, constant analysis by various scientific and technical centers guards against hostile technical surprise. Second, **indications and warning** centers provide tactical, operational, and strategic warning to friendly forces. Third, ISR continually monitors threat systems to support programming and reprogramming of all systems. Fourth, intelligence supports mission planning.

**Signals Intelligence** (SIGINT) is a category of intelligence comprising either individually or in combination with all communications intelligence, electromagnetic intelligence and foreign instrumentation SIGINT, however transmitted. SIGINT collection and dissemination are highly dependent on the EMS. SIGINT provides the basis for characterizing the electromagnetic environment (EME) to include those frequencies associated with radio, radar, infrared equipment, and **directed energy** systems. Intelligence preparation of the operational environment analysts evaluate how the EME will affect military operations in a specific operational area (OA) and

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25 Note that 25 AF is in the process of reorganizing and combining with 24th Air Force (Air Forces Cyber), which is also subordinate to ACC. The full implications of this change have yet to be determined.
collaborate with intelligence planners to deliver tailored EMS operations mission support products

**Electromagnetic Warfare Support** refers to the division of EW involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate or localize sources of intentional and unintentional EM radiation for the purpose of immediate threat recognition, targeting, planning, and conduct of future operations. ES is closely related to, but separate from, SIGINT, based primarily on the intent for which the data or information is to be used. The Non-kinetic Operations Coordination Cell in the air operations center synchronizes and integrates the planning and operational use of ES sensors, assets, and processes within a specific OA should be integrated and synchronized to reduce uncertainties concerning the adversary, environment, time, and terrain. ES data can be used to produce SIGINT, provide targeting for electromagnetic attack or other fires, and produce measurement and SIGINT.

**ES and SIGINT.** ES and SIGINT are differentiated by purpose, scope, and context. ES assets are tasked by operational commanders to search for, intercept, identify, and locate sources of intentional or unintentional EM radiation. In contrast, SIGINT assets are tasked by Director, NSA (Chief, CSS), or by an operational commander under SIGINT operational tasking authority delegated by the Director, NSA. The purpose of ES tasking is immediate threat recognition, planning, and conduct of future operations, and other tactical actions such as threat avoidance, targeting, and homing. ES is intended to respond to an immediate operational requirement. ES and SIGINT operations often share the same or similar assets and resources and may be tasked to simultaneously collect information that meets both requirements. For example, data collected for intelligence purposes can meet immediate operational requirements, just as data collected for ES purposes can be processed by the intelligence community (IC) for further exploitation after the operational commander’s ES requirements are met. For further information on the SIGINT and ES relationship, see Joint Publication (JP), 3-85, *Joint Electromagnetic Spectrum Operations*, and Chairman of the Joint Chiefs of Staff Instruction 3210.03C, *Joint Electronic Warfare Policy*, for a more in-depth discussion of the relationship and distinction between ES and SIGINT.

**Sensitive reconnaissance operations** support constant analysis by various scientific and technical centers, which guards against hostile technical surprise. While preventing surprise, intelligence guides EW strategy and critical technology research and acquisition decisions. Constant analysis establishes and maintains comprehensive support databases as well as examination of scientific and technical intelligence and general military intelligence capabilities. Clearly defined intelligence requirements are necessary to ensure resulting intelligence information meets the needs of EW planners and decision makers are not overloaded with excessive or meaningless data.
**Indications and warnings**-capable assets, executing the ES role provide tactical and operational threat warning to joint and coalition forces.

ISR continually monitors threat systems to support reprogramming of all systems.

ISR-derived intelligence supports mission planning in the tasking cycle.

ISR provides NRT measures of effectiveness and measures of performance data to assessors for effective electromagnetic battle management.

Specifically, ISR supports EW by providing technical threat descriptions and tailored threat environment descriptions. EW planning requires parametric and employment data, modeling and simulation tools, and mission planning tools to prioritize targets and defense tasks. ISR assets are required to support both offensive and defensive EW planning. To be of value, these assets should provide timely intelligence and be responsive to the commander's needs. Intelligence support includes establishing and maintaining comprehensive support databases as well as looking at scientific and technical intelligence and general military intelligence capabilities. Clearly defined intelligence requirements are necessary to ensure resulting intelligence information meets the needs of EW planners and decision makers are not overloaded with excessive or meaningless data.

**Electromagnetic Warfare Wings**

The Air Force has numerous ISR wings that provide EMSO support with EA platforms and ISR-enabled ES platforms, which deploy in support of geographic combatant commands. Currently, the 55th Wing provides both ES ISR and electromagnetic attack (EA) assets, while the 480th ISR and 70th ISR Wings provide global distributed and reach-back ISR capabilities. The 70th ISR Wing works closely with the NSA/CSS, leveraging the net-centric capabilities of a world-wide cryptologic enterprise. The 480th ISR Wing capabilities include national cryptologic, information technology, cyberspace ISR, tactical analysis, joint force air component commander support, and SIGINT integration. Finally, the 363d ISR Wing provides targeting-related intelligence to air component forces, to include non-kinetic targeting support. All of these wings and support activities are vital to EW and EMS operations, and are foundational capabilities that allow the CCDR to bring EW and EMSO to bear in the battlespace.

Additionally, integration of organizations and forces that conduct EW and ISR is crucial to effectively integrate an EW and EMS operations plan. Efforts should be taken to ensure priority EA targets and collection requirements are integrated and not just deconflicted. Designing a purposeful plan that maximizes the spectrum is critical to gaining and maintaining the desired degree of EMS control. At the strategic and operational levels, some EW and EMS capabilities may need to be coordinated with the...
NSA and other IC organizations to ensure that an assessment of intelligence gain or loss is accomplished, and the effects are incorporated into the combatant commander’s strategy.

**Education and Training Support**

Today’s Airmen are digital natives, fluently using information technologies and smart devices throughout every aspect of their lives. A common understanding of how the spectrum is utilized and how the Air Force conducts operations throughout the EMS should be paired with this personal digital fluency across the force to produce synergistic battlespace effects.

Beyond a baseline knowledge and lexicon in the force, the Deputy Chief of Staff of the Air Force for Operations (AF/A3) ensures EW professionals receive focused training at initial, operational, and senior staff levels. While initial training is required to operate at the tactical level, operational and senior staff education builds integration and strategic knowledge sets that contribute to the joint EMSO campaign. With the continued cat-and-mouse nature of EW spiraling ever faster in the 21st Century, deliberate developmental education is critical for EW professionals. Deliberate education enables our professionals to maintain their own knowledge base while developing a strategy to counter future threats.

To best train for warfare in the EMS, simulator-based training is essential for Airmen. Simulators allow Airmen to train in a congested and contested EMS environment while not exposing sensitive capabilities to our adversaries.

**Functional Coordination and Synchronization**

Proper coordination of the Air Force EW and EMSO mission ensures that unity of effort is achieved in all organize, train, and equip (OT&E) decisions, which is accomplished by Headquarters Air Force Electronic Warfare Division (AF/A5RE). To properly align its efforts, the DOD established the **Electronic Warfare Executive Committee (EW EXCOM)**. EW EXCOM serves as the senior executive focal point for the DOD’s EW enterprise in all capability and capacity decisions. Aligned under the EXCOM’s priorities, the Air Force ensures that it coordinates manning, training, and acquisition decisions. For example, in radar warning receiver (RWR) acquisitions, EW system requirements and procurements could be standardized to ensure that fewer and more capable RWRs are implemented. This improves upon the current model whereby each major weapon system program procures their own RWR, suffering higher cost and implementation times as well as slower reprogramming due to the numerous models currently fielded.

**Basic Research Support**

Air Force Research Lab (AFRL) is responsible for discovery, development, and integration of warfighting technology. Basic and applied research enables future capabilities in the Air Force. Basic research is required to enable future concepts such
as cognitive EA and adaptable waveforms. The research that is done in AFRL feeds into the CCMD requirements process as well as ACC’s and Air Force Space Command’s (AFSPC’s) organize, train, and equip responsibility. By ensuring that research advances are shared across functional communities, the Air Force can more confidently ensure that major developments do not allow strategic surprise and place the Air Force at a disadvantage in a near-peer conflict. While these functions occur across the Air Force, direct connections and integration should occur for EW and EMSO just the same.

**Weapons and Tactics Program Support**

The weapons and tactics program includes the tactics improvement proposal (TIP)-to-test process in which the combat Air Force (CAF) identifies tactics, techniques, and procedures (TTPs) across the Air Force which need testing. This process takes existing capability and tests the utility of using that existing capability in a new way. The TIP-to-test process feeds directly into the CAF test priority list (TPL) and those tests are approved by the major command (MAJCOM) commander for test. The test results are published and incorporated into the 3-1 series of Air Force TTPs. EW and EMSO capabilities are a part of the TIP-to-test process as any other weapon system or mission design series.

**Operational Testing Support**

The Air Force performs developmental testing and operational testing for all weapon systems. The 53rd Wing is responsible for operational testing and evaluation for the combat air forces. Testing is conducted for EW and EMSO capabilities within the 53d Electronic Warfare Group (EWG). In addition to testing an EW or EMSO weapon against a certain threat, the 53rd Test and Evaluation Group (TEG) also considers electromagnetic interference (EMI) and interoperability with other blue force weapon systems. Considering EMI and interoperability across the range of EW and all EMSO, to include weapons such as air-to-air missiles, air-to-ground weapons, and other systems, is critical to successful integration in the battlespace. It is critical when testing weapons that EMSO considerations are accounted for in those TIPs and test plans. If a weapon requires the use of the EMS, then an element of that test should include EMSO. **Specifically the EP features of the weapon or system being tested should be accounted for in all test plans.** Contested, degraded, and operationally limited impacts by the adversary should also be considered. Currently, the 53rd Wing also conducts COMBAT SHIELD exercises that test the actual EW effectiveness of CAF units’ equipment. Further, the Joint Electromagnetic Preparedness for Advanced Combat capabilities are used to simulate “red” (enemy) EW forces, to assist in development of tactics.

**Modeling, Simulation, and Analysis (MS&A) Support**

Effective and representative MS&A is critical to understanding the impact that EW and
EMSO activities have in the battlespace. The Air Force should ensure that capabilities like Advanced Framework for Simulation, Integration and Modeling (AFSIM), and other simulation capabilities, are able to replicate accurately the adversary’s environment and that EW and EMSO capabilities are represented to the highest fidelity. Without access to every adversary capability for testing, MS&A is the one way that EW and EMSO capabilities can be tested and validated. Specifically MS&A beyond a 1v1 scenario (a single "blue" weapon vs a single "red" weapon) is a requirement. The ability to understand second-order effects, electromagnetic interference (EMI), and how EW and EMSO capabilities integrate with other weapon systems should be incorporated into MS&A. The impact of not fully modeling and simulating EW and EMSO capabilities is that effects in the EMS may be negated or have reduced effectiveness unknowingly. A synchronized plan, including all EW and EMSO capabilities, focused on critical nodes and targets based on intelligence is necessary to maintain high standards and readiness.

**Requirements Support**

Combatant command EW and EMSO requirements for operation plans are identified and communicated to component MAJCOMs and fulfilled by Air Staff and the major commands (e.g., Air Combat Command, Air Force Space Command, and Air Force Global Strike Command). Periodic CCMD review and updates are required to ensure adversary capability changes and TTPs are incorporated throughout every level of acquisition and planning process. Specific EW and EMSO requirements are routed through Joint Urgent Operational Need (JUON) and Urgent Operational Need (UON) statements. However, JUONs and UONs should not be the “requirements process.” The requirements process is an iterative and strategic outlook that stays ahead of the adversary and works to identify and build EW and EMSO capability required to execute future operations.

EW and EMSO requirements do not always have to be hardware or new systems. With an open architecture and software standards, requirements may be as simple as a software or application change. In the future, flexibility within EW and EMSO will be enabled by standards that allow for a streamlined requirements process. Clear communication between the joint level, the CCMD, typically the CMD EWO and Spectrum Operations, to the component MAJCOM and to Air Staff enables efficient and effective planning.

**Acquisition Support**

“Our decades long acquisition upgrades cannot counter the global proliferation of threats” (DOD Electronic Warfare Strategy, 2017). The intelligence process is critical to the acquisition process. As new targets are identified and complex targets continue to evolve, the acquisition process should be flexible and agile in order to maintain pace with the adversary. In order to maintain pace, EW and EMSO requirements must include standards and a common open architecture. The commercial world has outpaced the DOD in many areas and technology interoperability being one area that directly impacts EW and spectrum operations. Adversaries have access to more
capability and technology than ever before, at low cost. The need to rapidly detect, design build, and field capability has reached a revisit rate far faster than any other time in history. The approach taken in the Air Force EW and EMSO acquisition process should incorporate lessons learned from history, but also look to the future, more closely aligning the Air Force’s doctrinal functions that enable required combat capability. A common example is the Android operating system (OS). Developers can create applications for the Android OS and they will be compatible and executable. The value of this is that it reduces development time and cost, while increasing capability. The process that allows this to occur is a user need (the requirement), foundational information about the capability (the intelligence), and a set of standards and procurement vehicles that enable rapid acquisition of capability.

Doctrinally these functions exist in the DOD and Air Force; however, they should be synchronized to enable cost effective and relevant EW and EMSO capabilities.

**Logistics Support**

Readiness and sustainability of electromagnetic assets are directly related to the quality of logistics planning. EW logistics programs should be in balance with modernization efforts and the operating capability each category of resources provides. Emphasis should be on total effectiveness to maximize EW capabilities.

**Operational Mission Data File Programming and Reprogramming Support**

Operational mission data programming and reprogramming takes advantage of the Electronic Warfare Integrated Reprogramming (EWIR) process defined in Air Force Instruction (AFI) 10-703, *Electronic Warfare (EW) Integrated Reprogramming*. The EWIR process uses a suite of software-definable tools that enables aircrew survivability and mission success while operating in an environment characterized by friendly, neutral, and hostile threat systems that use the EMS. EWIR provides a capability to characterize the EM emissions of hostile and other systems, analyze and model their impact on operations, and incorporate these characteristics to enable rapid detection, accurate identification and appropriate response within the EM spectrum. The 53 EWG is the Operational Reprogramming Center for the CAF, Combat Search and Rescue, and selected foreign military sales-supported aircraft. For more information on EWIR, see AFI 10-703.

53 EWG provides operational mission data production though the use of the Specialized Electromagnetic Combat Tools and Reprogramming Environment (SPECTRE) enterprise. SPECTRE is a suite of software definable tools to support the automation, centralization and standardization of all 53 EWG reprogramming activities for the CAF in accordance with AFI 10-703. This process should continue to be agile and adaptive to ensure the DOD maintains advantage within the EMS as the Air Force consolidates and modernizes the EW reprogramming enterprise.
SPECTRE Model-Based Systems Engineering Environment

SPECTRE provides a full web-based collaborative environment where mission data can be developed and tested in a model-based systems engineering environment (MBSE) (see figure, “SPECTRE Model-Based Systems Engineering Environment) will enable the operational reprogramming center to meet associated timelines to meet the warfighter needs.

SPECTRE is designed to allow machine-to-machine transfer of intelligence data and programming information into mission data generator tools. SPECTRE has modules to support all current CAF platforms and has the organic capability to expand into emerging Air Force and joint force airborne operational mission data software reprogramming needs. (See figure, “SPECTRE Process”.

KEY:
AFMC – Air Force Materiel Command
APP – Application
OFP – Operational flight program
ORG – Organization
To meet emerging capabilities, a single Air Force Multidomain Operational Reprogramming Center is responsible for programming and reprogramming EMS and EW systems, and providing sensor engineering for all Air Force and joint platforms. To enable an advantage or achieve localized superiority within the EMS, we should integrate concepts such as artificial intelligence, human-in-the-loop machine learning, and software-centric EW capabilities into Air Force operational mission data production to meet the warfighters’ air tasking order timelines. In the near term, software centric EW will require experts to develop, test, and characterize machine algorithms to take advantage of a decade’s worth of radio frequency data. The Air Force should move toward agile, software definable capabilities in which new mission data will enable greater capability through software interfaces, as well as develop new programming schemes for emerging space systems that should be thoroughly integrated into the current construct.

Integrating cross-platform data will increase efficiencies not previously encountered by enabling more rapid and agile MD updates. Taking advantage of the systems-of-systems concept is the vehicle through which the capability will emerge. We will continue to build and adapt the SPECTRE open and common architecture to allow transparent system-of-systems integration to enable greater efficiencies.
The figure, “Mission Data File Process” shows the six-step process that all mission data files undergo. This process ensures the most up-to-date intelligence data is incorporated into the output along with a complete verification and validation in a simulated environment. The commander, Air Force forces’ A3 staff should work with MAJCOM wing’s weapons shops to collect EW programming and reprogramming requirements. Based on the current timeline, the urgency of the warfighters’ need will drive the routine, urgent, or emergency (yearly, 72 hours, 24 hours) binning of the request. However, by increasing our technological capability, the Air Force’s timeline to program and reprogram new mission data updates and releases will be significantly reduced.
Organizing for Electromagnetic Warfare Operations

Last Updated: 30 July 2019

Electromagnetic warfare (EW) forces are task organized on the doctrinal tenet of centralized control and decentralized execution. Air Force EW is normally controlled at the component level and executed at the lowest level providing responsiveness to the commander, Air Force forces (COMAFFOR). Appropriate expertise should be available at all levels of command and control (C2) where EW coordination, planning, and execution occur.

When required, the COMAFFOR may form a Non-kinetic Operations Coordination Cell (NKOCC) within the air operations center (AOC). The NKOCC plans, manages, and assesses air and space component EW operations and ensures effective coordination and synchronization with other joint force components. The NKOCC is responsible for ensuring control and access to the electromagnetic spectrum (EMS) through coordination of electromagnetic attack (EA), electromagnetic warfare support (ES) and electromagnetic protection (EP). Synchronization and integration of EW activities occurs through electromagnetic battle management (EMBM) to enable freedom of action. See JP 3-85 for more information.

The NKOCC is normally organized into plans and operations divisions led by experienced electromagnetic warfare officers. EW uses EM energy and directed energy (DE) to control the EMS and create effects contributing to the accomplishment of the joint force commander’s (JFC’s) objectives. EW may be associated with a variety of mission types that include but are not limited to counterair; counterland; counterspace; cyberspace operations; information operations (IO); and intelligence, surveillance, and reconnaissance (ISR). Therefore, to promote unity of effort and prevent electromagnetic (EM) fratricide, the NKOCC should integrate across all AOC divisions.

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28 For more on EW organization and processes within the Air Operations Center see Joint Publication (JP) 3-85, Joint Electromagnetic Spectrum Operations; and Air Force Tactics, Techniques, and Procedures 3-3.AOC, Air Operations Center.
EW and COMAFFOR Headquarters Organization

The COMAFFOR headquarters is usually comprised of normal staff directorates, A-1 through A-6, as well as a special staff. The core of the EW function is located in the A-3 operations staff. Most EW functions have close ties to IO. The IO cell works with the NKOCC to integrate fully with the A-staff. The EW personnel should provide these functions:

- **Intelligence, Surveillance, and Reconnaissance (A-2)**
  - Provide to the ISR staff the A-2 related EW objectives, intent, and plans.
  - Coordinate ISR support to EW operations from JFCs’ fusion centers, Air Force major command ISR staffs, theater intelligence agencies, national intelligence agencies, and coalition ISR sources.

- **Operations (A-3)**
  - Organize the operational EW aspects of the headquarters staff.
  - Coordinate operational EW issues with the JFC and component staffs. Typical issues include:
    - Rules of engagement for EW air component forces.
    - Develop EW requirements for air tasking order and airspace control order.
  - Identify essential elements of information (EEI) to A-2.
  - Apprise the ISR team chief of EW capabilities and limitations of all components and the potential effects on operations.
  - Assist ISR team chief with ISR support requirements to EW operations of subordinate units.
  - Develop and coordinate the EW plan and integrate it into the IO plan that accomplishes the JFC’s objectives.
  - Identify Service-specific EW training requirements and coordinate joint training with other components.
  - Advise COMAFFOR on concepts of EW employment, force planning, and management of EW resources for which he has [operational control](#) or [tactical control](#), or has established [supported or supporting relationships](#).
Plans (A-5)

 Coordinate operational EW issues with the JFC and component staffs. Typical issues include:

- Assist in unit beddown requirements for EW forces.
- Requirements for additional EW forces and capabilities.
- Requirements for force protection.

Identify EEI to A-2.

Identify Service-specific EW training requirements and coordinate joint training with other components.

Provide information on the number and location of all EW assets.

Communications and Information (A-6)

 Coordinate for the A-3 to ensure that frequency allocations and assignments meet technical parameters under host-nation agreements.

Deconflict frequencies and coordinate the joint restricted frequency list with the JFC staff’s J-6.

Provide communications-electromagnetics operating instructions for air and space component forces.

Plan, coordinate, and monitor EW related communications security procedures and assets.

Joint and Multinational Operations

EW is an integral part of joint and multinational operations. Planning and execution of multinational force (MNF) EW is made more difficult because of security issues, different cryptographic equipment, differences in the level of training of involved forces, and language barriers. An increasing dependence on the EMS requires close coordination among all joint force and MNFs, in addition to other organizations that may be impacted, like civil air traffic control facilities and civil defense activities.

Joint force and Service component EW capabilities are employed in supported and supporting roles. For example, Air Force ES capabilities may be employed to identify and locate a surface-to-air threat which subsequently may be targeted and engaged by Army surface-to-surface fires as a suppression of enemy air defense mission, in order to establish a degree of control of the air for close air support. To promote the
effectiveness of joint EW actions, air component EW personnel should be familiar with JFC and other Service or functional component EW organizations, and be prepared to directly coordinate.
The size of the combatant commander’s (CCDR’s) staff, the mission(s) the joint force is tasked to accomplish, and the time allocated to accomplish the mission(s) are just some of the factors that affect the organization of the staff. This section discusses nominal requirements, organizations, and staff functions to plan and execute electromagnetic (EM) spectrum (EMS) operations (EMSO) in joint operations. A brief introduction on how the CCDR is organized to plan and execute EMSO is included in order to provide background on how the commander, Air Force forces (COMAFFOR), who is normally also the joint force air component commander or the joint force space component commander, interacts with the joint force commander (JFC) and Non-kinetic Operations Coordination Cell (NKOCC).

**Responsibilities**

It is the responsibility of the COMAFFOR to establish and promulgate command-specific policy and guidance for EMSO planning and execution. This can be divided among multiple directorates of the NKOCC based on long-, mid-, and near-term functionality and availability of trained EMSO personnel. Processes and directives (e.g., joint restricted frequency list [JRFL] process, the joint communication-electromagnetics operating instructions [JCEOI], software defined radio waveform implementation and sharing) should also be determined as necessary for operations specific to the area of responsibility. All aspects of EMSO should be coordinated closely with JFCs and their components.

The NKOCC works within the air operations center (AOC) to convey across the force and up the chain of command the COMAFFOR’s plan for achieving control of the EMS within Air Force operations. The NKOCC is responsible for integrated non-kinetic effects planning, coordination, synchronization, deconfliction, and assessment in the AOC. The NKOCC team is the COMAFFOR’s non-kinetic capabilities integrator. Additionally, it establishes prioritized EMS-user requirements and frequency authorization throughout the AOC for transmission in the EMS and provides them to the joint electromagnetic spectrum operations center (JEMSOC).
Electromagnetic Spectrum Control Authority (EMSCA)

EMS control is the coordinated execution of EMSO with lethal and nonlethal operations that enable freedom of action in the EM operational environment (EMOE). The COMAFFOR should designate an EMSCA to assume overall responsibility for EMSO. The EMSCA will have primary staff responsibility for planning, coordinating, monitoring, assessing, and prioritizing execution of EMSO. The EMSCA directs the planning, developing, and publishing of the EMS control plan (EMSCP) and EMS control order (EMSCO), as well as conducting EM battle management (EMBM). The EMSCA establishes procedural EMS control methods based on the military operation and level of conflict. Authority for directing and ordering of specific EMS operations in, around (posturing), and through the EMS for the purposes of achieving control of the EMS resides with the COMAFFOR or as delegated. The EMSCA plans these EMSO, and tasks NKOCC, through the EMSCP and EMSCO, who incorporate them in their respective plans and orders. EMSCA should ensure EMSO orders and plans are coordinated with the JEMSOC to ensure synergistic effects and deconfliction of the EMS with other Services and functions.

**EMSCA Responsibilities.** The EMSCA provides centralized direction through the EMSCP and EMSCO, supplemented by EMS coordination measures, all coupled with an EMBM system. The EMSCA normally coordinates with component EMSO cells prior to commencement of operations to integrate and coordinate all component EMS-use requirements. The EMSCA does not have the authority to approve or disapprove combat operations. That authority is vested only in operational commanders. The EMSCA assumes responsibility for EMBM in the designated joint operations area (JOA). Subject to the authority and approval of the COMAFFOR, the broad responsibilities of the EMSCA include:

- Prioritize, integrate, synchronize, direct, and deconflict the use of the EMS.
- Develop broad policies and procedures for EMS control and for the coordination required among all joint EMS users.
- Establish EMBM that provides for integration of AOC and other affected joint constraints and requirements.
- Promulgate EMSO policies and procedures via the COMAFFOR-approved EMSCP.
- **Authorize Joint Electromagnetic Energy Transmission.** While no authorization is required to receive EM energy, EMSCA authorization is required to transmit EM energy. The NKOCC prepares the orders that authorize joint forces to transmit EM energy. The two authorities for transmitting EM energy are:
  - Electromagnetic Attack Control Authority (EACA). EACA is the authority
to conduct **electromagnetic attack** (EA) in the JOA. EACA can either be retained by the EMSCA or executed by the EMSCA’s designated representative. Routine execution of EACA responsibilities is normally delegated to the NKOCC director and may be temporarily delegated to components for the purpose of local or tactical mission refinement and interference remediation. EACA responsibilities include:

- Participating in EMS coordination measures development (e.g., the joint restricted frequencies list [JRFL]).
- Ensuring compliance with the approved EMS coordination measures.
- Gaining and maintaining situational awareness of all EA-capable systems and related operational parameters in the JOA.
- Resolving EMSO prioritization recommendation issues.
- Coordinating introduction of new EMS-dependent systems in the JOA.
- Coordinating with components on EA requirements.
- Developing, coordinating, updating, and promulgating EACA guidance and directives (e.g., instructions, rules of engagement [ROE], EMSCP, EMSCO, special instructions).
- Monitoring and assessing joint force EA activity for EACA compliance and determining corrective action when necessary.

**Frequency Assignment Authority.** This is the authority to transmit EM energy (other than for EA) in the JOA. Frequency assignment authority can either be retained by the COMAFFOR or assigned to the COMAFFOR’s designated representative. Routine frequency assignment authority responsibilities are normally delegated to the NKOCC director and may be delegated to components for the purpose of local or tactical mission refinement and flexibility. Frequency assignment authority responsibilities include:

- Participating in EMS coordination measures development (e.g., JRFL).
- Ensuring compliance with the approved EMS coordination measures.
- Gaining and maintaining situational awareness of all EM energy (other than for EA) in the JOA.
- Resolving EMSO prioritization recommendation issues.

AFDP.
Coordinating introduction of new EMS-dependent systems in the JOA.

Coordinating with components on EM transmission (other than for EA) requirements.

Monitoring joint force EM transmission (other than for EA) activity for frequency compliance and determining corrective action when necessary.

The COMAFFOR establishes a standing NKOCC to support joint planning, coordination, and control of the EMS for assigned forces. The COMAFFOR establishes a command policy on how the EMS is used in his or her functional area as appropriate, obtains EMS clearance (or approval) from host nations (through existing coordination procedures), and authorizes EMS use by assigned military forces to execute designated missions. The COMAFFOR conveys to his or her subordinates how to conceptualize achieving the desired degree of EMS control within the JOA through the respective concept of operations (CONOPS). Part of this planning includes development and approval of an operational approach, mission statement, commander’s planning guidance, commander’s intent, commander’s critical information requirements, and CONOPS, at a minimum.

It is the responsibility of the COMAFFOR to establish and promulgate command specific policy and guidance for EMSO planning and execution.

COMAFFOR duties include establishing a standing EMSO organizational structure (to include a NKOCC) and the procedures to support planning and operations. Specific actions should be taken to:

- Ensure all plans address EMSO coordination among forces operating in the EMOE to enable data exchange, eliminate duplication of effort, achieve mutual support, and minimize friendly EM interference (EMI).

- Ensure plans address any necessary augmentation of the NKOCC to support EMSO.

- Resolve EMS user prioritization issues not resolved at a lower level.

- Maintain close contact with appropriate foreign military forces and civil administrations to ensure that mutual EMS support is considered in combined planning, operations, training, and exercises.

- Function as controlling authority for the JCEOI in the EMSCO.

- Function as controlling authority for EMS policy.
Ensure procedures and policies are in place for the safeguarding, use and transfer of reprogrammable EMS-dependent system waveforms.

Establish policy and guidance for EMS coordination measures (e.g., JRFL).

Other Functional and Service Component Commanders

Responsibilities include:

- Establish an EMSO element to coordinate with the NKOCC on functional or Service component EMSO operational plans.
- Prioritize, consolidate, validate, and report component EMS-use requirements to the NKOCC.
- Receive reports, identify, and attempt to resolve component-specific EMI.
- Make recommendations for best force contributions and utilization to gain and maintain control of the EMS within the JOA.

Electromagnetic Spectrum (EMS) Users

The responsibilities are to:

- Provide the NKOCC prioritized EMS use requirements through their EMSO element. Inputs will include receive-only systems to ensure prioritization and integration with joint force EM transmissions (e.g., sensing, communications, EA).
- Obtain frequency authorization through their EMSO element for each transmission in the EMS. EA users must ensure compliance with applicable EACA processes and ROE.
- Operate systems in accordance with parameters authorized by the frequency assignment process (e.g., frequency, bandwidth, power, waveform).
- Ensure EMS-dependent equipment is properly maintained to preclude unintentional violation of authorized EMS-use parameters.
- Make recommendations for best force contributions and utilization to gain and maintain control of the EMS within the JOA.
- Use Air Force spectrum interference resolution (AFSIR) procedures to report adverse EMS effects on operations.
The employment of electromagnetic warfare (EW) capabilities to affect an adversary can provide significant advantages. EW objectives and effects should be clearly established, support overall national and military objectives, and include identifiable indicators of success.

The commander, Air Force forces (COMAFFOR) exploits the capabilities of airpower operations through a cohesive joint air operations plan (JAOP) and tasking cycle. The COMAFFOR should clearly define EW objectives and effects, and ensure that assets supporting these are properly employed and integrated throughout operations.

Air component centralized planning for EW normally occurs at the air operations center (AOC). The AOC formulates plans and coordinates air component EW activities based on the joint force commander’s (JFC’s) guidance. It receives, assembles, analyzes, processes, and disseminates all source intelligence required for EW planning. EW planners are responsible for ensuring that freedom of action is gained and maintained within the electromagnetic spectrum (EMS). To accomplish this, EW planners should participate in all phases of the joint planning process for air and the joint air tasking cycle.

Employing electromagnetic attack (EA), electromagnetic warfare support (ES), and electromagnetic protection (EP), EW creates effects throughout the operational environment to include all domains. The cross-domain implications of EW operations require centralized planning and decentralized execution. For joint operations, EW planners should coordinate EW efforts at the JFC level in order to minimize unintended

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33 See Air Force Tactics, Techniques, and Procedures (AFTTP) 3-3.AOC, Air Operations Center, and AFTTP 3-3.IPE, Integrated Planning and Employment, for additional information on AOC EW planning and organization.
EW planning requires a broad understanding of adversary and friendly capabilities and tactics. Employment of EW assets should be closely integrated into the commander's overall planning effort. This planning requires a multidiscipline approach with expertise from functional mission areas to include but not be limited to: air, space, ground, intelligence, logistics, weather, and information / cyberspace.

EW planning responsibilities include:

- Provide EW coordination and planning expertise to the COMAFFOR.
- Integrate EW capabilities into theater campaign and contingency planning.
- Prepare EW inputs for operation plans and orders.
- Develop and recommend EW task to support the COMAFFOR’s course of action.
- Plan, coordinate, and assess EA requirements.
- Identify EW shortfalls and provide advice on requests for forces and joint urgent operational needs statements.
- Develop an EW strategy and an operations plan that state how the COMAFFOR plans to exploit EW capabilities to support the JFC’s objectives.
- Integrate EW capabilities into the joint tasking cycles.
- Make EW air apportionment recommendations.
- Prioritize EW effects and targets based on the COMAFFOR’s objectives and available assets.
- Identify requirements for intelligence, surveillance, and reconnaissance (ISR) support operations, including assistance to the AOC ISR division in planning the collection and dissemination of ES information.
- Represent EW within the information operations (IO) cell to formulate and recommend to the joint targeting coordination board targets to support the campaign or operations plan.34
- Coordinate the EW portion of the special instructions (SPINS) and rules of engagement (ROE).
- Plan, coordinate, integrate, and deconflict EW in current and future operations,

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34 See Air Force Tactics, Techniques, and Procedures (AFTTP) 3-3.AOC, Air Operations Center, and AFTTP 3-3.IPE, Integrated Planning and Employment, for additional information on AOC EW planning and organization.
taking in consideration lethal and nonlethal capabilities (e.g., IO, cyberspace, space, special operations, and special technical operations) within the joint operations area or theater.

- Coordinate EW support requests from other Service and functional components according to the JFC’s priorities.
- Monitor and adapt execution of EW plans in current operations.
- Provide oversight and coordination of EW measures of effectiveness.
- Respond to subordinate unit requests for enemy EW sites’ operational status, availability of friendly EW support as required and tasked by the air tasking order (ATO) or joint space tasking order.
- Develop a joint EW strategy.
- Task, plan, coordinate, and allocate the joint EW capabilities and forces made available to the COMAFFOR by direction of the JFC.
- Perform assessment of joint EW operations at the operational and tactical levels.
- Provide integrated EA, ES, and EP for the JFC.
  - Identify COMAFFOR requirements.
  - Integrate and synchronize use of airpower assets.
  - Task ES assets to satisfy JFC requirements.
- Function as the electromagnetic warfare control authority (EWCA), as directed by the JFC.

**EW Mission Integration**

Since EW activity may create effects throughout the entire EMS, EW planning should include comprehensive EMS management to integrate safely with other EMS aspects of joint and multinational operations. EW can cause effects beyond the intended primary target(s) or effect(s) and, therefore, should be integrated with other military and IO core elements in accordance with the law of war and applicable ROE to achieve the overall objectives and negate or mitigate undesired indirect effects.

Since information systems are increasingly networked and as EW power capacity
increases, with the potential for disrupting or damaging even closed electromagnetic systems, the requirement to integrate, synchronize, and deconflict EW with other elements of friendly operations has become even more critical than in the past. EW personnel should be aware of direct effects and plan for indirect effects when accomplishing “traditional” EW activity, as well as planning and implementing EW activity to integrate with other IO and cyberspace elements to achieve the commander’s objectives.

EW jammers vary in effective range, power, and modulation. Electromagnetic radiation can be aimed and focused, but do not stop at definitive geographic boundaries or discrete altitudes. Therefore, EMS (frequency) interface deconfliction procedures, like employment of the joint restricted frequency list (JRFL) are necessary to minimize interference and degradation of friendly efforts.
Electromagnetic warfare (EW) planning is seldom used by itself when planning coordinated attacks. Electromagnetic attack (EA) is used in coordination with space and cyberspace capabilities, and as a delivery mechanism for specific information operations (IO). Preplanning, timing and synchronization, and near real time assessments are critical for ensuring successful operations.

**Planning**

Offensive EA planning begins with intelligence-based targeting derived from the commanders’ intent. EW planners should be familiar with the target set and tactical problem and be a part of the initial planning team and target development teams to assess the threats and develop requirements. Planning should be conducted as part of the Joint Planning Process (JPP), accomplished as part of campaign planning or contingency planning. For more on the JPP see Joint Publication (JP) 5-0, Joint Planning, Chapter 5.

In many cases air operations centers’ (AOC’s) electromagnetic warfare cells have been folded into the larger non-kinetic construct, executing as part of a Non-kinetic Operations Coordination Cell (NKOCC) or information operations (IO) team, where many functions of EMSO are resident in these teams.

**General Planning Considerations**

The joint planning process for air (JPPA) is the desired method to enable the best usage of EA to support and enable kinetic and non-kinetic operations. When planning effects based operations, an AOC’s strategy division leads the target effects team development of a strike plan. In this planning process, EW experts require support from the intelligence, surveillance, reconnaissance division (ISRD) and the A-6 to assess the adversaries’ use of the EMS and understand where friendly operations in the spectrum
reside. The joint restricted frequencies list (JRFL) will need to be validated with national agencies in order to determine what adversary spectrum is valid for targeting. During this process of selecting and pairing capabilities the synchronization of air, space, cyberspace, and other operations will begin to come together into an operation plan (OPLAN) in order to deliver effects that influence the enemy to operate in a manner that will enable the joint force to achieve their objectives. The need for EW spans across all airpower operations leveraging EA, electromagnetic warfare support (ES), and electromagnetic protection (EP) in different forms as specified earlier. The detail required for this planning should be specific enough to drive valid requests for forces; examples of this include jamming pods to include specific bands used by Navy EA-18G, MALD-J, EC-130H COMPASS CALL, airborne signals intelligence (SIGINT), cyberspace, the Counter-Communications System, and EC-130J COMMANDO SOLO.

**General Planning: EMS Inputs and Outputs**

EW planners in concert with the greater non-kinetic planning effort, develop collection requirements in coordination with the AOC’s ISRD to determine measures of performance (MOPs) and measures of effectiveness (MOEs) to provide near real time feedback of ongoing operations as this may impact the acceptable level of risk. The best planning practices simultaneously develop non-kinetic and intelligence objectives to support each other, and to maximize intelligence collection aiding in developing effective MOEs and MOPs before the execution of operations. Intelligence gain or loss discussions between EW planners and the ISRD should occur to assess that the plans in place support intelligence building when required and shift as appropriate to
maximize the protection of those in harm’s way.

During the EMSO planning process, EW experts should to adhere to guidance and rules of engagement (ROE) or request changes when required. EW planners will need to develop direction through special instructions (SPINS) development to support theater campaign plans to provide forces with clear ROE and direction for execution of the planned missions. Furthermore, EW planners should ensure the air tasking order (ATO) tasks the correct airborne assets at the required times to ensure appropriate airspace is coordinated through the airspace control order (ACO) development.

Adversaries may possess capabilities that can degrade positioning, navigation, and timing and communications systems, which will require EW planners to work with command and control (C2) planners to ensure communications requirements and support are in place to provide adequate C2 and maneuver within the spectrum.

At the conclusion of the planning process, training requirements for supporting crews (space, cyberspace, and airborne) should be developed and communicated from the commander, Air Force forces (COMAFFOR) to the joint force commander (JFC), then down to the supporting commands. If there are any material deficiencies or capabilities requirements that are determined during the planning process as crucial to the success of the mission, this should also be communicated from the COMAFFOR to the JFC for inclusion into urgent operational need processes as appropriate.

Steady-State EMS Operations

To enable effective steady-state operations planning, joint planning should be completed regularly to ensure the organization is poised to support normal operation plan (OPLAN) development or respond to a crisis event.

With EMS operations absorbed into the non-kinetic team construct, EW members should ensure the following functions are fulfilled:

- JRFLs regularly updated and coordinated across the Services.
- EW strategy is written to support OPLANs.
- EW SPINS are supportive of OPLANs.
- Related communications security and emission control (EMCON) guidance is reviewed.
- The status of EW assets in theater are ascertained.
- Beddown requirements are facilitated.
Contingency Planning

In times of crisis, planning processes follow the same methods working from intelligence-derived targeting looking outward. The significant differences in the planning process are that the timeline is reduced; planners are unlikely to request additional forces not already in theater; and ACO, ATO, joint space tasking order, and SPINS changes not co-located could prove challenging to communicate and approve. EMS inputs and outputs to contingency planning are illustrated in the figure, “Contingency Planning: EMS Inputs and Outputs.”

Additionally, not having a current JRFL in place could hamper operations or, at worst, impede friendly capability. Authorities and permissions should be clearly defined or this could hinder employment.
Electromagnetic Spectrum Operations Planning

JFCs centralize EMSO planning under the designated EMS control authority (EMSCA), EW control authority, or jamming control authority and decentralize execution to ensure EMSO unity of effort while maintaining tactical flexibility. Viewed holistically, EMSO across all functions and domains are often complex and interwoven. This requires detailed integration and synchronization to avoid friendly fire and achieve the desired degree of EMS control. The complex EM operational environment (EMOE) that the joint force may experience makes this integration more difficult. EMSO planning provides the basis for the prioritization, integration, and synchronization of Air Force EMS activities between the staff functions (primarily A-2, A-3, and A-6), other components, and multinational partners. As all joint functions are heavily dependent on the EMS, EMSO should be a key planning consideration across all phases of military operations. The Non-kinetic Operations Coordination Cell (NKOCC) is the lead staff element for EMSO planning.

The commander’s guidance and estimate form the basis for determining joint force objectives. During mission analysis, EMSO planners develop a staff estimate which forms the basis for an EMS control strategy. The EMSO staff estimate is used during course of action (COA) development and analysis to determine EMS supportability. When a COA is chosen, it becomes the basis to develop the EMSO annex which outlines EMSO missions, priorities, policies, processes, and procedures across all phases of the operation. The joint force components develop component EMSO plans and submit them to the joint electromagnetic spectrum operations center (JEMSOC) for integration into the overall EMSO appendix. During planning and execution, the NKOCC consolidates component EMSO plans and attendant requirements, prioritizes, integrates, and synchronizes them, and produces an EMS control plan (EMSCP) to provide to the JEMSOC. An updated EMSCP begins the EMSO execution cycle resulting in an EMS control order (EMSCO) directing joint force EMS use. For information on joint planning, refer to JP 5-0, Joint Planning, and Chairman of the Joint Chiefs of Staff (CJCS) Manual 3130.01A, Campaign Planning Procedures and Responsibilities. For more information on EW planning, see JP 3-85, Joint Electromagnetic Spectrum Warfare, Air Force Tactics, Techniques, and Procedures (AFTTP) 3-3.AOC, Air Operations Center, and AFTTP 3-3.IPE, Integrated Planning and Employment.

**EMSO Staff Estimate.** A primary product of mission analysis, planners use staff estimates to prepare evaluation request messages to solicit COA input from subordinate units and subsequently develop preliminary COAs. The EMSCA uses the commander’s mission, commander’s estimate and objectives, commander’s intent, concept of operations, and the components’ inputs to develop COAs. The JEMSO staff estimate informs the commander, staff, and subordinate commands how JEMSO supports mission accomplishment and COA development and selection. During COA development and selection, EMSO planners fully develop their estimate, providing an EMS analysis of the COAs, as well as recommendations on which COAs are JEMSO supportable. Planners should identify critical shortfalls or obstacles that impact mission accomplishment. The JEMSO staff estimate should
be continually updated based on changes in the situation. For information on staff estimates, refer to JP 5-0.

EMS Superiority Strategy. An EMS superiority strategy outlines how the COMAFFOR will execute the JFC’s guidance to achieve EMS superiority. This strategy ensures joint forces achieve the advantage in the EMS that permits the conduct of operations at a given time and place without prohibitive interference, while affecting an adversary’s ability to do the same. The strategy is comprised of the mission analysis and mission statement portions of the JEMSO staff estimate and is usually located in the EMSO section of the OPLAN, concept plan, or operation order. It outlines the key missions and tasks the joint force components carry out to achieve EMS superiority and establishes the basic relationships between the exploit, attack, protect, and manage activities the joint force will accomplish. The strategy identifies key EMS users, both functionally, such as air, space, and cyberspace operations, as well as organizationally, such as multinational partners. It provides the framework for detailed JEMSO planning. Key elements of the EMS superiority strategy include:

EMS missions that forces are expected to perform. This includes such activities as mitigating an adversary’s ability to contest friendly force operations through the EMS, degrading or denying the adversary from maneuvering in the EMS to support their operations, optimizing friendly force EMS use, coordinating through the frequency management office the necessary joint force EMS-use authorities with host nation (HN) and relevant adjacent nations according to treaties and international agreements.

Assumptions (e.g., HN EMS-use authorizations).

Key considerations based on the expected EMOE.

Anticipated scale of operations and the number and type of friendly forces (to include multinational partners).

Establishment of EMSO organizations.

Relationships between EMS organizations both internal and external to the joint force.

Define and Characterize the EMOE.

The situation analysis portion of the JEMSO staff estimate is where the EMOE is initially defined and characterized, forming the foundation for the EMSO aspects of COA development, analysis, and selection. NKOCC planners should provide a mechanism to periodically characterize the EMOE to ensure relevant EMS-systems and activities
Characterizing the EMOE is an iterative process that employs many of the tasks and methodologies associated with joint intelligence preparation of the operational environment (JIPOE). An EMOE tends to be dynamic, requiring the associated databases and analyses be updated periodically, often on a very short timeline. The physics of the EMS dictate that the military usefulness and properties of a given set of frequencies may vary periodically based on environmental factors outside of JFC control. JEMSO planners should not only allow for changes in both neutral and adversary operations in the EMS but need to consider potential naturally occurring EMOE changes as well.

EMOE information should be current, accurate, and accessible to authorized users. JEMSO planners should designate primary EMOE data sources to facilitate this. This source designation should be accompanied by information on the organization(s) responsible for maintaining the data sources, the associated processes and timelines for source population, requirements for access (user clearances and timelines), and the processes for dealing with data source conflicts.

Meteorological and Oceanographic (METOC) Data. JEMSO planners should include the effects of atmospherics and space weather on both the EMOE as well as friendly and adversary EMS-dependent systems. The various types of atmospheric conditions and phenomena can positively or negatively affect these systems. For example, atmospheric temperature inversions can increase the propagation of radio transmissions; high humidity and rainy climates are detrimental to infrared systems; and ionospheric scintillation can adversely affect the Global Positioning System (GPS) satellites. Some atmospheric effects are well known and are categorized by season and location. Planners should consult with the combatant command’s METOC officer to determine the type of support available for their operation.

Determine Friendly EMS-Use Requirements.

The Air Force supports joint operations by employing EMS-dependent systems across almost all functions and activities. Components identify the EMS-dependent systems they will employ in the joint operations area (JOA), describing their capabilities and associated EMS-use requirements, and registering them with the NKOCC. The NKOCC then coordinates with the JEMSOCC to establish the process to solicit, compile, and process joint EMS-use requirements. The resultant data is used to inform the EMS superiority strategy, characterize the EMOE, determine COA EMSO supportability, and build the EMSCP and EMSCO which authorizes component EM transmissions.
EMSO planners at all echelons and components should account for any special classification requirements and communicate them to the JFC’s JEMSO staff to ensure proper clearances and “need to know” are established. Proliferating network-enabled joint warfighting capabilities have increased the number of EMS-dependent links between previously autonomous capabilities. JEMSO planners should review EMS-use requirements submissions to ensure that cross-capability and cross-functional EMS links have been properly captured.

The EMSCA issues guidance to the joint force staff elements, components, and supporting agencies on how to request JEMSO support for EMS-dependent systems that operate under their control within the joint force’s JOA. The guidance includes requirements for all EMS-dependent systems, including those that are receive-only. The message requires units to submit their EMS-use requirements to the NKOCC, who then validates as passes to the JEMSOC. The EMSCA guidance typically includes the following:

- Joint force JEMSO policy and guidance.
- Security classification guidance.
- Procedures for submitting EMS-use requests to support EMS-dependent equipment or request non-organic JEMSO support, including lead times and request format.
- **Electromagnetic battle management** (EMBM) guidance and processes.
- Master net list requirements collection process, including the need for identifying nets requiring call signs, call words, and possible frequency sharing.
- EMS coordination measure (e.g., JRFL) submission procedures, including lead times and restrictions.
- Air Force spectrum interference resolution (AFSIR) reporting requirements and routing procedures.

**EMSO Appendix.**

Once a COA is chosen, the AOC develops the EMSO appendix within the operations annex for the COMAFFOR’s approval. The EMSO appendix establishes procedures for EMBM system use in the operational area and includes EMS coordination measures, specifying procedures and ROE for joint force EMS use. In order to provide effective operational procedures, the EMSO appendix should be integrated across all portions of the COMAFFOR’s orders.
The JEMSO appendix considers procedures and interfaces with the international or national frequency control authorities and systems necessary to effectively support EMSO, augmenting forces, and COMAFFOR objectives. Consequently, the JEMSO appendix should be preplanned to the highest degree possible and maintained in a basic, understandable format.

The EMSO appendix should be coordinated with HN representatives, if appropriate and feasible.

Planning factors to be addressed when developing the EMSO appendix include familiarity with the basic OPLAN or OPORD; knowledge of both HN and multinational considerations; consideration of lessons learned; an understanding of the operational and mission variables; familiarity with the capabilities and procedures of EMS control and military and civil Federal Communications Commission-equivalent agencies; and the general locations of friendly, neutral, and enemy forces.

The EMSO appendix supports transitions across the range of military operations. Such transitions may occur during a period of increasing or decreasing tensions, or suddenly without warning. The EMSO appendix should support all phases of an operation with flexibility to respond to current requirements.

Policy and ROE. EMSO activities frequently involve a unique set of complex issues. There are Department of Defense (DOD) directives and instructions, the law of war, and ROE that may affect them. Laws, rules, policies, and guidelines become especially critical during peacetime operations when international and domestic laws, treaty provisions, and agreements (e.g., status of forces agreements) may affect EMSO planning and execution. Commanders should seek legal review during all phases of EMSO planning and execution, to include development of theater ROE. While ROE should be considered during the planning process, it should not inhibit developing a plan that employs available capabilities to their maximum potential. If, during the planning process, an ROE-induced restriction is identified, planners should work with staff legal advisors to clarify the ROE or develop supplemental ROE applicable to EMSO. EMS policy and ROE requirements are promulgated though the EMSCP and EMSCO as they become effective.

Prioritization. COMAFFOR EMS-use prioritization guidance is a key planning factor used by the NKOCC to rank EMS-use requests in congested EMOEs and by the components to rank assigned tasks, and pass to the JEMSOC. The NKOCC regularly reviews the JFC’s priorities, solicits component inputs, and recommends EMS-use prioritization changes to the JFC.

EMSO-Use Requests. EMS-use requests represent joint force requirements for conducting operations in the EMS in support of their assigned missions and tasks. To be properly prioritized and integrated, they include the following
information:

- The activity to be conducted in the EMS (sense, communicate, attack).
- The purpose of the activity.
- The relative priority of the activity.
- The platform or system conducting the activity.
- Missions supported by the activity.
- Required EMS-use parameters (e.g., time, location, frequencies, power, waveform).

**EMS Coordination Measures.** EMS coordination measures are rules, mechanisms, and directions governed by joint doctrine and defined in the EMSO appendix. These measures direct maneuver within the EMS in specified dimensions (e.g., space, time, frequency, power, waveform). The EMSO appendix specifies EMS coordination measures (e.g., JRFL) to be used in the JOA and how these measures will be distributed and implemented. During execution, the EMSCP should provide guidance on what EMS coordination measures will be activated in the EMSCO. EMSO elements establish EMS coordination measures to accomplish one or more functions during specific time windows and geographical areas:

- Establish reserved EMS bands for specific EMS activities.
- Restrict the actions of some EMS users.
- Create EMS bands in which units can use EMS-dependent systems with minimal risk of EMI.
- Require EMS users to accomplish specific actions.

**JRFL.** The JRFL is an EMS coordination measure that operational, intelligence, and support elements use to identify the level of protection desired for various networks and frequencies. The JRFL is a time, frequency, and geographically oriented listing of functions, nets, and frequencies requiring protection from friendly EM transmissions and is limited to the minimum number of frequencies necessary for friendly forces to accomplish joint force objectives. Although the JRFL is the primary coordination method, it may be necessary to coordinate the protection of intelligence collection frequencies via the immediate joint EMS-use request process to meet the time-sensitive needs of collection activities. The JRFL is developed prior to initiating joint force operations and is continually modified during operations.
EMBM-Related Capabilities. The systems and tools that facilitate EMBM and provide EMSO-related planning capabilities. EMBM guidance establishes which capabilities and related databases will be used and how they should exchange data using approved DOD architectures for vertical and horizontal interoperability. This interoperability facilitates timely and routine EMSO data exchanges. This exchange may be conducted in either non-real time or near real time (NRT) via common, secure, jam-resistant radios and data links. The ability to exchange NRT data (such as targeting information) to enhance situational awareness and combat coordination between various force elements is a critical combat requirement. EMBM guidance should include:

- Type or version of EMSO planning tools used.
- Secure connectivity to components.
- Availability of C2 networks.
- Compatible data exchange format and processes.
- EMS coordination processes (e.g., frequency assignment, EM targeting, EMI resolution).
- Interfaces to national and intelligence databases.
- Interfaces to battlefield sensors.

EM Signature Control. EMSO planners determine adversary EMS capabilities and potential impacts on EMSO to establish the necessary level of emission control (EMCON) signature control includes:

- Assessing adversary electromagnetic warfare support (ES) and signals intelligence (SIGINT) capabilities against friendly forces.
- Planning and implementing appropriate EMCON measures by task and phase.
- Providing EMCON guidance and direction to components.
- Nominating adversary ES and SIGINT systems for targeting.

Electromagnetic Warfare. The EMSO appendix EW section outlines the EW requirements for achieving EMS superiority. Specific planning actions include:
Reviewing EMS superiority strategy.

Identifying the purpose and intent of performing EW, the immediate desired effects, and enabling conditions for authorizing EW.

Determining the status of EW capability of available forces relative to adversary capability and determining if sufficient assets are available to perform the identified EW tasks. Draft requests for support if in-place assets are insufficient.

Considering friendly EMS use with respect to the anticipated operations, tactical threat expected, and EMI possibilities. Once identified, these requirements should be entered into the JRFL under appropriate categories (e.g., TABOO frequencies).

Identifying measures to deny operations security indicators to adversary passive EM sensors.

Establishing and updating appropriate EMS coordination measures (e.g., JRFL TABOO).

Determining the processes necessary to eliminate or mitigate EM interference (EMI) from EW activity with other JEMSO.

Identifying the EMS-related commander’s critical information requirements (CCIRs). These CCIRs should be included in the intelligence annex (normally annex B) of the OPLAN or OPORD to facilitate timely and comprehensive ES.

Coordinating and establishing procedures to ensure fulfillment of EW planning tasks.

Reviewing ROE and applicable legal factors to determine the authorities needed or the restrictions, if any, that apply to EW operations.

Identifying EM target element categories in order to guide collections priorities and support EM target element development.

Analyzing the vulnerabilities of friendly force EMS-dependent systems, determining the ability of the adversary to exploit those vulnerabilities, and evaluating the resulting mission impact.

Analyzing the vulnerabilities of adversary EMS-dependent systems and networks, determining the ability of friendly forces to exploit those vulnerabilities, and evaluating the resulting mission impact.

Navigation Warfare (NAVWAR). Due to the dual civil and military nature of
GPS, global navigation satellite system (GNSS), and other PNT services, potential impacts from NAVWAR efforts on non-military users and the civil and commercial critical infrastructure must be thoroughly analyzed during COA development and may need to be coordinated with HN EMS authorities. NAVWAR considers the impact of adversary GPS jammers on friendly force systems, provides guidance on the type of GPS receivers needed to support mission execution, aids in determining the quantity and types of GPS-aided munitions required to execute a COA, and recommends GPS jammers as targets.

**Interoperability.** Interoperability is essential in order to use EMSO effectively as an element of joint military power. EMSO planners must know and integrate the EMS-dependent capabilities in theater and how they will interact during execution to minimize EMS conflicts and enhance EW effectiveness.

All EMSO are subject to the EMSCP and the EMSCO. The EMSCP and EMSCO provide direction to prioritize, integrate, coordinate, direct, and deconflict all joint force EMS-use within the JOA. (Note: This does not imply any level of command authority over EMS assets or their self-defense [defensive EA] capabilities.)

**EMSCP.** The EMSO appendix (approved by the commander as part of the operations annex) provides overarching guidance for the control of the EMS. The NKOCC issues an EMSCP at the beginning of the EMSO execution cycle containing updated EMSO guidance for that cycle.

**EMSCO.** The EMSCO is an order that provides the details of the approved EMS-use requests, EMS control procedures, and EMS coordination measures for a given time period. Joint forces unable to comply with EMS coordination measures, specified transmission authorization, or ROE, are not authorized to transmit EM energy in the JOA. The EMSCO defines and establishes the portions of the EMS for military operations as approved by the JFC. It notifies all agencies of the effective time of activation and the composite structure of the EMS to be used. The EMSCO may include coordination measures such as JRFL. Timely EMSCO change alerts and promulgation of EMSCO changes to all EMS users, to include multinational forces, is essential to avoid friendly EMI and unintended engagements against civil and neutral receivers, and to increase operational effectiveness.

**Specified Transmission Authorization.** Certain regions of the EMS may require finer control of joint force EMS transmissions than EMS coordination measures provide for a variety of reasons (e.g., excessive congestion, potential collateral effects). The EMSCO will identify and publish specified transmission authorizations.

**EMSCO Development.** The EMSCO is normally published and distributed daily and contains coordination measures, procedural control instructions, and the portions of the EMS required to implement the
EMSCP. The EMSCO activates and deactivates control measures. Procedures to develop and update the EMSCO are included in the EMSCP. Normally, component commanders consolidate, prioritize, deconflict, and forward their EMS-use requests to the EMSCA by a specified time for further consolidation with other inputs. Guidance should be given, depending on the level and the number of forces in the OA, on what other information should be included (e.g., EMS and other coordination measures). The EMSCA is responsible for EMS control for the entire OA, but may delegate specific authority for EMS control to the component commanders through EMSCP guidelines. The JFC may also elect to task the component commanders to generate EMSCO annexes for their assigned sectors. Regardless, the JEMSOC is tasked with providing continuity along sector boundaries and ensuring integration of each sector authority’s EMSCO within the EMSCP guidelines.

Communications-Electronics Operating Instructions (CEOI). The CEOI is the portion of the EMSCO which provides the commander the voice and data network EMS-use authorizations necessary to support operations. It contains the technical characteristics of communications networks. The CEOI consists of the following subsections: directory of radio nets or units and their associated frequencies, call signs, call words, and network identifications listed by time period, supplemental procedures for electromagnetic, visual, and verbal interactions, such as sign and countersigns, smoke and pyrotechnics and suffix and expanders. It is usually further subdivided into different sections, or layers (e.g., joint layer, components, corps, fleet, wing). Additionally, the CEOI provides procedures for conducting electromagnetic, visual, and verbal communications methods (e.g., sign or countersign, smoke or pyrotechnics, suffix and expanders) to supplement or enhance radio communications.

For information on joint CEOI, refer to CJCS Instruction 3320.03, Joint Communications, Electronics Operating Instructions.
The employment of electromagnetic warfare (EW) capabilities is vital throughout all phases of an operation. During shaping and deterrence phases, electromagnetic warfare support (ES) assets contribute to the overall understanding of the operational environment. A commander may employ EW to implement favorable joint intelligence preparation of the operational environment without prematurely crossing the threshold to conflict. The potential to employ nondestructive and nonlethal capabilities make EW assets vital to the preparation of the operational environment and mission analysis.

Using all aspects of EW, air, space, and cyberspace forces may set the conditions for combat, and prosecute the attack once combat is underway. The ability to achieve an objective through nondestructive means may allow a more rapid transition from seizing the initiative and dominate phases to support operations in a stabilization phase.

From stabilization to enabling civil authority, EW can foster restorative operations by offering options such as force protection through ES to
monitor subversive elements, electromagnetic attack (EA) to counter radio-controlled improvised explosive devices (RCIEDs), or broadcasting messages supporting military information support operations (MISO) and civil defense to assist civil authorities.

**EW Support to the Commander, Air Force Forces (COMAFFOR)**

The **COMAFFOR** provides unity of command and unity of effort for Air Force EW operations. The COMAFFOR normally exercises operational control over assigned and attached Air Force EW forces. EW personnel support the COMAFFOR by accomplishing the following:

- Make recommendations on the proper employment of EW capabilities and forces.
- Develop a daily EW battle rhythm that supports EW planning and operations requirements.
- Accomplish specified and implied EW tasks.
- Represent EW within the Non-kinetic Operations Coordination Cell.
- Maintain current assessment of the EW resources available (to include number, type, and status of EW assets) and analyze what resources are necessary to accomplish operational objectives.
- Develop, coordinate, and integrate operations to achieve EW effects based on the joint force commander’s (JFC’s) objectives.
- Predict effects of friendly and enemy EW activity on joint and multinational operations.
- Plan, coordinate, execute, and assess electromagnetic protection (EP) (e.g., frequency management, emission control, EW programming and reprogramming).
- Assist in frequency management. This includes deconflicting frequency requirements and assignments.
- Coordinate and monitor EW programming and reprogramming by identifying where EW reprogramming decisions and reprogramming actions affect operations.
- Conduct reachback to organizations supporting air component EW operations.
- Provide EW liaison to other Service and functional components of joint and multinational forces.
Prepare an EW estimate of the situation to support the JFC’s estimate.

Function as the EW integrator for counterair and counterspace operations, strategic attack, offensive counter-cyberspace operations, the overall air interdiction effort, space support, and theater airborne reconnaissance and surveillance.

Coordinate EW support for combat search and rescue.

Provide EMS database and communications network support.

Conduct joint EW training of components for joint force components, in joint operations planning for which the COMAFFOR has or may be assigned primary responsibility, or for which the air component's facilities and capabilities are suitable.

**EW Employment Considerations**

In contested environments, the density and potential lethality of the adversary air defense systems may challenge mission effectiveness and the survivability of friendly forces. At the tactical level, mission planning tries to strike the appropriate balance between mission accomplishment and risks. Thorough planning at the operational level gives tactical commanders the proper tools to allow them to strike that balance. The decision to employ EW should be based not only on overall joint campaign or operation objectives, but also on the risks of possible adversary responses and other potential effects on the campaign or operation. A properly constructed operation that includes EW enhances the probability of mission effectiveness and survival of friendly forces.

The application of EW can prevent an adversary’s use of the EMS for employment of improvised explosive devices (IEDs), specifically RCIEDs. Employing EA, EW can deny or degrade the adversary’s ability to use the EMS to detonate IEDs. EW can also enable
friendly use the EMS to pre-detonate RCIEDs at a time of our choosing. Similarly, EW can disrupt adversary communications by disrupting an adversary's ability to use the EMS, interfering with their ability to react to friendly activity in a timely manner. Recent increases in power supply capacities in EW systems (especially directed energy systems) provide capabilities for disruption or damage to many physical targets. This provides additional options in lethal or destructive attack and may enable friendly forces while causing significantly less collateral damage. New EM systems can target humans with both lethal and nonlethal effects, in some cases with debilitating but non-damaging effects.

Commanders should seek legal review during EW planning and execution, to include development of theater rules of engagement. See Joint Publication 3-85, Joint Electromagnetic Spectrum Operations for more detailed discussion of important legal and policy considerations that should be taken into account for EW employment.
Electromagnetic spectrum operations (EMSO) are conducted according to the same plan, prepare, execute, and assess cycle as other aspects of joint operations and are all subject to the electromagnetic spectrum (EMS) control plan (EMSCP) and the EMS control order (EMSCO). The EMSCP and EMSCO provide direction to prioritize, integrate, coordinate, direct, and deconflict all joint force EMS use within the joint operating area (JOA). (Note: This does not imply any level of command authority over EMS assets.) While EMSO are centrally planned to ensure unity of effort, they are decentrally executed to permit maximum tactical flexibility in a highly dynamic electromagnetic operational environment (EMOE). All EMS transmissions operate under procedural control. The EMS control authority (EMSCA) does not positively identify, track, and direct joint force EMS transmissions (i.e., positive EMS control). The EMSCP provides component EMSO planners with the EMS-use prioritization scheme.

**Execution**

**Concept of Control.** The supported joint force commander (JFC) designates an EMSCA to authorize joint force EMS use. EMSCA is normally delegated to the Air Force air operations center’s (AOC’s) Non-kinetic Operations Coordination Cell (NKOCC) director. The EMSCA approves the EMSCO which the NKOCC will publish and provide timely updates.

**Battle Rhythm.** The AOC establishes the battle rhythm for NKOCC planning and operations. This battle rhythm is based on the phase of operation, pace of operations, nature of the EMOE (i.e., how dynamic it is), and battle rhythms of related operations (e.g., orders cycle, air operations cycle, intelligence cycle). It includes the required participation in cross-functional staff organizations associated with EMSO planning and execution. The NKOCC will participate in key AOC battle rhythm processes throughout the entire EMSO cycle, to ensure effective and efficient production, dissemination and execution of each assigned EMSCO.

**Issue EMSCP.** The NKOCC begins the EMSO operations cycle by issuing an updated EMSCP to the components. The EMSCP includes:

- Commander’s EMSO-related guidance.
 deixis Updated EMS superiority objectives.
 deixis EMOE boundary changes.
 deixis Rules of engagement (ROE) changes.

Joint intelligence preparation of the operational environment (JIPOE) information (e.g., red and gray electromagnetic (EM) order of battle updates, EMS-related meteorological and oceanographic data).

EMS-use prioritization changes.

Electromagnetic attack control authority (EACA) and Federal Aviation Administration (FAA) delegation.

EMS coordination measure activation and deactivation.

Friendly EM order of battle changes.

Projected EMS-use allotment changes.

EMS-use tasking changes.
 deixis Branch and sequel execution.
 deixis New operations.
 deixis EMS-use associated with joint targeting coordination board-approved EMS-related target elements.

**Update Component EMSO Plans.** The EMSO plan are updated based on the EMSCP. The NKOCC conducts sufficiently detailed EMSO planning to identify changes in their EMS requirements along with any EMSO shortfalls and generate prioritized EMS-use requests, which are passed to the joint electromagnetic spectrum operations center (JEMSOC).

**EMS-Use Request.** Components submit EMS-use requests to the NKOCC to obtain authorization to transmit EM energy or reserve EMS frequencies and bands for sensing. The EMSCO lists all authorized joint EMS use including EMS-authorization delegation. EMS-use requests are not necessary for units operating equipment in accordance with established EMS coordination measures.

**Non-Organic EMS Support.** Components needing to conduct EMSO but lacking required organic capabilities or EMS-use allocations may submit EMS-use requests to the NKOCC for prioritization and approval. The EMSCO lists prioritized approved EMS-use requests along with the tasked components. The EMSCO lists the detailed
EMSO activity associated with a given EMS-use request.

**Prepare EMSO Plan.** The NKOCC consolidates, prioritizes, integrates, and synchronizes the EMSO plan and attendant EMS-use requests to produce an integrated EMSO plan, to pass to the JEMSOC. It conducts EM policy and engineering analyses on the EMSO plan to ensure compliance and feasibility. The NKOCC director briefs the EMSCA on the EMSO plan and its impact on Air Force and joint operations.

**Generate and Distribute EMSCO.** When the EMSCA approves the EMSO plan, the NKOCC generates and distributes the EMSCO. The EMSCO contains the following information:

- EMSCO period objectives.
- EMOE boundary changes.
- Rules of engagement ROE.
- EMS-use prioritization.
- EACA and FAA delegation.
- EMS band allotments (including EM parametric restrictions).
- Specific transmission authorizations.
  - Joint communication-electromagnetics operating instructions.
  - Other as required.
- Active EMS coordination measures.
  - Joint restricted frequency list.
  - Other as required.
- EMSO support activities.
  - **EM battle management** (EMBM) reporting procedures.
  - EW reprogramming considerations.

**Conduct Detailed EMSO Execution Planning.** If delegated authority for specific portions of the EMOE, the Air Force conducts the necessary EMSO prioritization, integration, and synchronization and contribute to orders and fragmentary orders (FRAGORDs) as required. EMSO orders and FRAGORDs should be forwarded to the NKOCC who distributes them across the commander, Air Force forces staff for
situational awareness.

Monitor and Direct JEMSO. During the period an EMSCO is active, the NKOCC should monitor execution and direct changes in EMSO prioritization and tasking based on A-3 direction and inputs using EMBM processes. The NKOCC distributes these changes via FRAGORD across the force for situational awareness. Key processes include the immediate support process and the Air Force spectrum interference resolution (AFSIR) process.

Immediate EMSO Requests. EMS-use requests that arise after the JEMSO planning cycle cutoff time should be submitted directly to the NKOCC. The NKOCC conducts an abbreviated staff coordination and analysis cycle to determine request priority and feasibility. The NKOCC should immediately distribute approved requests across the force via FRAGORD through EMBM processes for situational awareness, notifying impacted units directly.

AFSIR. The NKOCC assists the force with EM interference (EMI) incidents that cannot be resolved or mitigated at a lower level. If the NKOCC cannot resolve or mitigate the EMI, it will determine if force EMS-use or tasking need to be reprioritized and if so, staff resultant immediate EMS-use and EMS-support requests as required.

Role of Air Force EMSO across the Joint Functions

Joint functions are related capabilities and activities grouped together to help JFCs integrate, synchronize, and direct joint operations.

Command and control (C2). For C2 of forces, commanders are highly dependent on the EMS, especially the radio, microwave, and optical frequency bands. These bands are increasingly congested by civil and commercial use, and can be potentially contested by adversaries. The JEMSOC deconflicts joint force communications from civil, commercial, or enemy use, prioritizes and synchronizes communications across components, and protects joint force communications from enemy electromagnetic attack (EA). EMSO and cyberspace operations (CO) mission areas integrate closely to enable assured C2 of assigned and attached forces. Assured C2 requires gaining and maintaining the desired degree of control of the EMS during all phases of military operations.

Intelligence. Understanding the operational environment is fundamental to joint operations. EMS-dependent sensors, both active (e.g., synthetic aperture radars) and passive (e.g., radio scanners, infrared cameras), provide much of the information necessary for joint intelligence preparation of the operational environment. By prioritizing, integrating, and synchronizing joint EMS-use, EMSO enhances intelligence activities with assured sensor C2, data dissemination, and
optimized target collection. EMSO deconflicts joint force sensors from civil, commercial, or enemy use, prioritizes and integrates them with other EMSO (e.g., communications, fires), and protects them from enemy EA.

**Fires.** EMSO are critical enablers in supporting fires and are themselves (as EA) a type of fires. EA capabilities can produce a full range of scalable effects including disruption, deception, denial, degradation, and destruction. Many fires systems have EMS-dependent targeting sensors; positioning, navigation, and timing requirements; seekers; and C2 datalinks. The NKOCC coordinates with the JEMSOC to deconflict these systems from civil, commercial, or adversary EMS use, prioritizes and integrates them with other JEMSO (e.g., communications, sensing), and protects them from enemy EMSO. JEMSO, especially the EW mission area, and CO mission areas integrate closely to produce synergistic effects on targets. As a type of fires, EA is capable of creating either lethal or nonlethal effects on a target, while electromagnetic warfare support (ES) and signals intelligence provide targeting and weaponeering information for EA as well as other forms of fires.

**Movement and Maneuver.** As a physical space, joint forces can maneuver in the EMOE to achieve a position of advantage over an enemy. Joint forces can employ EA to occupy key frequency bands for channeling or denying enemy EMS use to enable lethal and nonlethal effects against that enemy. EMSO provides maneuver forces assured access to the C2, intelligence, fires, protection, and sustainment functions necessary for effective combined arms operations.

**Protection.** EMSO protects friendly forces through defensive EA, ES, and electromagnetic protection (EP). Defensive EA (e.g., counter-radio controlled improvised explosive device [IED] systems, aircraft survivability systems) denies enemy sensing and targeting systems the information necessary to attack joint forces, while ES systems (e.g., radar warning receivers) provide indications and warning of enemy attacks. Directed energy systems are employed to deny or destroy attacking munitions while built-in EP features provide inherent protection against enemy EA. EP and joint spectrum interference resolution processes identify, minimize and mitigate the enemy EA and EMI experienced by joint forces. EMSO also deconflicts joint force combat identification systems from civil, commercial, or enemy use, prioritizes and integrates them with other EMSO (e.g., communications, fires), and protects them from enemy EA.

**Sustainment.** EMSO deconflicts joint force logistics communications from civil, commercial, or enemy use, prioritizes and synchronizes communications across components, and protects joint force communications from enemy EA. JEMSO supported sustainment activities ensure freedom of action, extend operational reach, and prolong combat endurance.
**Assessment**

At the end of an EMSCO cycle, the NKOCC collates feedback and assesses EMSO using the measures of effectiveness and measures of performance established during planning in the EMSO appendix and observed during the EMSCO period. All data will then be provided to the JEMSOC.

**EMSO Assessment Data Uses**

**EMSO Effectiveness/Shortfalls.** The NKOCC uses the assessment information to update the EMSCA on EMSO effectiveness, process efficiency, capability shortfalls, and recommended EMSCP changes. All data will then be provided to the JEMSOC.

**Lessons Learned.** The NKOCC develops lessons learned for dissemination to the components as well as the relevant joint and Service organizations. Lessons learned can be used for current operations, but also form the basis for future planning. EMSO observations are reported into the Joint Lessons Learned Information System. This website can be found at [https://www.jllis.mil](https://www.jllis.mil) or [http://www.jllis.smil.mil](http://www.jllis.smil.mil).

For further information on lessons learned, see CJCSI 3150.25, *Joint Lessons Learned Program*.

**Intelligence Updates.** Assessment data is a key element for updating intelligence support to EMSO. Assessment data ensures timely EMSO activity feedback is distributed across the joint force. It is also used to update automated correlation and analysis algorithms increasing accuracy, reducing ambiguity, and enhancing situational awareness, effectiveness, and efficiency.

**EW Reprogramming.** EW reprogramming maintains and enhances the effectiveness of EW and target sensing system (TSS) equipment in a rapidly evolving, congested, and contested EMOE. EMOE changes may be the result of deliberate actions on the part of friendly, adversary, or third parties, or may be brought about by EMI or other inadvertent phenomena. EW reprogramming includes changes to self-defense systems, offensive weapons systems, ES, and intelligence collection systems. The reprogramming of EW and TSS equipment is the responsibility of each Service or organization through its respective EW reprogramming support programs. Air Force reprogramming efforts should include coordination from the joint commander’s JEMSO staff to ensure those reprogramming requirements are identified, processed, deconflicted, and implemented in a timely manner by all affected friendly forces.

**Software Reprogrammable EMS-Dependent System Waveforms.** There is a need to provide software control of a variety of modulation techniques, wide-band or narrow-band modulation, communications security functions, and waveform requirements of current and evolving standards over a broad frequency range. The purpose of a software defined radio policy updates is to maintain or enhance the effectiveness of automated communications equipment in a rapidly evolving, congested, and contested
EMOE. EMOE changes may be the result of deliberate actions on the part of friendly, adversary, or third parties, or may be brought about by EMI or other inadvertent phenomena.