The Silver Lining in Information Warfare

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Despite significant progress in the field of meteorology over the past six decades, military leaders, planners, strategists, and operators are failing to embrace its current capabilities. Advanced meteorological analysis highlights the difference between adversarial and friendly vulnerabilities—given capabilities, risk delimitations, and behavioral norms and anomalies—thereby determining the marginal advantage: the silver lining. The contemporary utility of meteorological analysis is as novel a capability as it is an offensive one.

Technological advances are bounded by decisionmakers' cognitive limitations of how to best use them. In near-peer conflict fought within the margins and where advantages are marginal, users' lack of knowledge will cost the United States and its Allies. For example many decisionmakers wrongly assume that weather's best, if not only utility is in its most perishable form, such as area forecasts, flight weather briefings (DD Form 175-1s), and three-day forecasts. Despite exceptional progress in the field these past 60 years, meteorology's use by military leadership, strategists, planners, and operators has failed to progress apace, relegating an evolved capability to dated functionality.

The redeeming factor is that although this mindset seems to be a postmodern norm, time and preparedness are relative in conflict. There are, however, no assurances that the United States or those friendly to it will be the first to acclimatize to weather operations in a true information warfare context. If information warfare is to advance, decisionmakers' preconceptions about the sophistication and utility of weather knowledge must evolve.[1]

Unlike time and preparedness, a constant in conflict is that terrestrial and space weather often exacerbate vulnerabilities across all domains with zero partiality to actors; moreover, weather drives behavior. Advanced meteorological (met) analysis delineates the difference between adversarial and friendly vulnerabilities—given capabilities, risk delimitations, and behavioral norms and anomalies—thereby determining the marginal advantage: the silver lining. The contemporary utility of met analysis is as novel a capability as it is an offensive one.

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1. US Air Force (USAF), *USAF Strategy for Information Warfare* (Washington DC: Headquarters USAF, July 8, 2022).

Seize, Signal, and Subsist

In the middle of difficulty lies opportunity.

John Archibald Wheeler[2]

Timing is everything in warfare. Advanced met analysis in Joint intelligence preparation of the operational environment (JIPOE), especially in informing the Joint targeting cycle, can impose costs, just as its absence can incur costs. Thus, met analysis represents a valuable yet underused tool in information warfare. For example, with pattern-of-life and risk analysis of activities correlated to winds and sea states, the Department of Defense could better estimate adversarial courses of action and detect anomalous behavior of enemy aircraft. Such information could inform defensive actions ahead of an attack, or better yet, could be leveraged to expend enemy resources and time.

In another example, advanced early warning radars and integrated air defense systems (IADS) with detection ranges beyond 150 nautical miles (nm), paired with missiles that reach similar distances, pose standoff and targeting challenges to the suppression of enemy air defenses aircraft.[3] But all-weather radar sensing technologies and aircraft are subject to corrosion—for example, sea spray and sand accelerate corrosion processes in the presence of abundant oxygen and humidity.[4]

On average, a diurnal sea breeze extends 50 nm inland in the middle latitudes and as much as 150 nm in the tropics.[5] Corrosion is in fact among the largest life-cycle component costs for weapons systems sustainability.[6] These costs include reduced sensor reliability, lifespan, maintenance and repair downtime, and replacement acquisition, ultimately decreasing combat readiness. Patterned sheltering or relocation of assets can be indicative of deliberate offset. Additionally, the downtime critical to preventative and corrective maintenance cannot be eliminated for fixed early warning radars and IADS. This is where there are exploitable windows of opportunity if factored into friendly decision calculi, specifically attrition strategy and tactics science.

Weather can drive initiative—the choice to take the offensive and make exigent threats—in the physical environment. Deliberate and dynamic targeting could exploit sheltering, relocation, and downtime by planning to attack when an opponent's counterair assets are either diminished

2. John Archibald Wheeler, "The Outsider," *Newsweek* 93, no. 11 (March 1979): 67.

3. "Worldwide Equipment Guide," OE Data Integration Network (ODIN), accessed May 15, 2023, https://odin.tradoc.army.mil/.

4. Multiple authors, "Corrosion Management Meeting Proceedings," NATO Science and Technology Organization, November 29, 2018, https://www.sto.nato.int; and Eric Herzberg et al., "Estimated Impact of Corrosion on Cost and Availability of DoD Weapon Systems," LMI, March 2019, https://www.dau.edu/ (full database).

5. Karolina Slamova et al., "Mapping Atmospheric Corrosion in Coastal Regions: Methods and Results," *Journal of Photonics for Energy* 2, no. 1 (June 2012), https://doi.org/.

6. Eric Herzberg and Rebecca Stroh, "The Impact of Corrosion on Cost and Availability of U.S. Department of Defense Weapon Systems," NATO Science and Technology Organization, November 29, 2018, https://www.sto.nato.int.

or delayed. Climatologically informed deliberate targeting is straightforward, albeit untapped. Still, training to such targeting can be alternatively effective if it elicits behavior changes, specifically if the target audience trades greater environmental exposure for quicker response times, attritting its fleet with compounding corrosion. Meteorologically-leveraged dynamic targeting offers the element of surprise—which is achieved through intellectual edge, not iron alone—and creates opportunities to seize the initiative and influence tempo.

Imposing costs involves compelling an opposing (red) force to cease belligerent behavior, because the costs of that behavior exceed accepted benefits and/or are counterproductive. Nevertheless, successful cost imposition can itself incur costs to the blue force as a result of unexercised alternatives. Additionally, it is not a technological or numerical disparity that determines winning outcomes, as the 1979 Sino-Vietnamese War and Russia's current war in Ukraine have demonstrated, but rather a timely so-called "wisdom differential" between actors. Wisdom is the use of knowledge—distilled from learned information—in a profound way. Classical theorist Alfred T. Mahan wrote that "in war, the defensive exists mainly [so] that the offensive may act more freely . . . [and] a coast fortress defends the nation to which it belongs chiefly by the fleet it shelters."[7] A wisdom differential, then, is when decisionmakers use knowledge better than their opponent, resulting in actions that are at once timely, relevant, and costly to the opponent.

Because environmental uncertainty is central to human activity, advanced met analysis must be included when blue forces are deciding how to impose costs on red force lines of communication (LOCs) and logistics. Red defenses—be it fleet, IADS, or other—are effective insomuch as they protect the means to threaten blue LOCs and logistics.[8] Yet, due to the epochal shift of information warfare that began in January 1995 with the formation of the first DoD information warfare executive board, the effectiveness of red defense is equally dependent upon its ability to protect its own LOCs and logistics.

Unifying Weather, Cyber, and Data Science in JIPOE—Data Prioritization

Refined domain awareness is a precondition for decision advantage, and it entails weather-leveraged predictive analytics (in mission management) and retrospective analysis of red force cognitive processes and behavior. Decision advantage in today's complex postmodern environment exists only when assisted by speeds beyond human capacity. One should assume going forward that command and control, physically and functionally, has been and continues to be under persistent disruption. Despite this, there is an overreliance on signals intelligence (SIGINT). But this also presents an opportunity to capitalize on the hardship that disruption causes if military requirements are viewed not just as tangible assets but also as available cognitive capabilities.

7. Jakub Grygiel, "Arming Our Allies: The Case for Offensive Capabilities," *Parameters* 45, no. 3 (Autumn 2015), https://press.armywarcollege.edu.

8. Grygiel.

SIGINT

More sensors and feeds paradoxically amount to an infinitesimal value because data volume exceeds processing power and goes unused, overlooked, or referenced and filed. For compounding SIGINT volume, variety, and velocity to be actionable, collection, dissemination, and analysis prioritization coupled with data acceleration—assisted by numerical modeling, automation, and artificial intelligence (AI)—is vital. Such prioritization and data acceleration are possible where chaos and game theories intersect, expertise that resides within Joint force weather, cyber, and data science specialties.

Signals intelligence sensors, platforms, and dissemination signals by and large are subject to weather; thus, economical mission management cannot be divorced from predictive analytics. Knowing what sensors, platforms, and frequencies can be used can lead to the better use of limited blue resources. Further, met analysis also informs on red SIGINT options, increasing blue's ability to predict red maneuver and platform availability. Useful interception of red LOCs is entwined with conserving blue LOCs for when and where they make the greatest contributions to combatant command theater strategy. For example, tasking SIGINT collection of adversary signal sources during specific terrestrial or space weather conditions could inform red force thresholds, capabilities, and alternate courses of actions, if any.

AI and Predictive Analytics

As deliberate plans approach their execution window, combined game-theory-based artificial intelligence and predictive analytics should drive dynamic retasking by first eliminating less useful data and then accelerating trend and anomaly discovery via algorithm. This allows planners to elevate operational and tactical situations post-analysis by prioritizing missions with higher collection usability and lower lost link rates, but this is in contravention of standing deliberate plans where weather is an afterthought in the targeting cycle.

Electromagnetic Spectrum

Accelerating electromagnetic spectrum (EMS) information integration to provide commanders "scalable options to control conflict escalation" necessitates first addressing scalable situational awareness.[9] Due to congressional limits, the Department of Defense cannot expand in size to meet increasing demands, so given big data and bandwidth challenges—EMS, throughput, human capital, and cognitive capacity—scalability must instead be addressed by modernizing dated internal processes.

9. Mark Esper, *Department of Defense (DoD) Electromagnetic Spectrum Superiority Strategy 2020* (Washington, DC: DoD, October 2020), https://media.defense.gov.

Improved Processes

Further, the convergence of weather with other information warfare components necessitates changes internal to the weather community. In order to scale processes, software solutions must be decentralized to formulate courses of action, thereby decreasing cognitive complexity. This will enable operational and tactical personnel to make quick decisions. Converging weather and intelligence capabilities begins with determining the impartial uncertainty—environmental (weather) conditions—but requires a departure from static times-series graphics and time-consuming manual PowerPoint and Excel production. Available automation expertise makes the latter virtually unnecessary, and the Air Force Weather Virtual Private Cloud makes decentralization possible. Nonetheless, static graphics and manual production linger because planners and operators, weather personnel and otherwise, have grown accustomed to it.

The manpower and time required to generate disruptive innovation, which would increase the United States' military competitiveness, is tied up in short-term repetitive tasks, focused on responsiveness at the cost of progress. Sustainable, expediting software must eliminate multiple touches by weather personnel, be available on demand (integrating automation and AI algorithms), and be intuitive. Further, valuable metrics that inform present insights and future strategies, as opposed to vanity metrics, should be considered from inception in the software development process.

All forces are subject to weather, so the question is not if but how red forces decide and behave in certain environmental conditions and what their limitations and risk tolerance are in training and operations. Differentiating between red and blue forces' cognitive processes and behaviors under similar environmental conditions and determining actionable opportunities begin with advanced met analysis of how environmental information or live conditions situationally influence forces. Retrospective met analysis is challenging in this respect, however, because meteorology is predominantly future-oriented, data archiving saps resources, and career field silos persist.[10]

Software-augmented analysis prioritization, near real-time analysis—essentially mission watch, and collocated integration of information-warfare-versed weather specialists within intelligence teams and other subunits—are ways to work around those challenges. Game theory is predicated on the assumption that decisions are interdependent. Data that would illuminate routine versus anomalous behavior patterns and wisdom differentials in operational art (and then better inform tactics, techniques, and procedures) lie not with one specialty but where weather and intelligence converge. Still, neither function can provide that knowledge at a speed of relevance without cyber capabilities, nor can they measure its value to draw insights for improvement without data science. The ability to act on such

10. John G. Grimes, *DoD Information Sharing Implementation Plan* (Washington, DC: Office of the Assistant Secretary of Defense for Networks and Information Integration/DoD Chief Information Officer, April 2009), https://dodcio.defense.gov/; and USAF, *Strategy for Information Warfare*.

knowledge is power. But to render its effects that frequently manifest in conventional ways into a cognitive outcome is profound.

Getting at the Will to Fight

Met analysis long reduced environmental uncertainty for blue forces, yet the capability, including the ability to anticipate warfighting challenges, remains underutilized in Joint intelligence preparation of the operational environment, and in plans and operations. Decisionmakers tend to fixate on destroying or neutralizing red capabilities and view diminishing will as the consequence rather than the aim, losing sight that the will to fight is fundamental to war.[11] Cutting-edge technologies are useless sans the will to employ them as casualties rise.[12] Effectiveness in conflict is highly dependent upon the ability to protect one's logistics, and an actor that cannot sustain critical logistics risks mortality rates that come at the costs of the combatant's and general population's will to fight.[13] One example of this is exemplified by the management of the blood supply during crises.

An estimated 25 percent of combat deaths between 2001 and 2011 in Iraq and Afghanistan were solely due to exsanguinating hemorrhage—the severe and rapid loss of blood—and yet, these were potentially preventable with the timely evacuation to a definitive care location.[14] Associated discussions of time tend to focus on the golden or resuscitative hour, within which medical intervention—often involving blood transfusions—is considered to offer the best chance of trauma survivability.[15] Yet crises sometimes coincide with inadequate blood supply and when direct blood transfusions are either impractical or insufficient. Blood supplies are protected under medical neutrality but not from the environment. Time and weather, in effect, can beget the endgame. Climate and weather predictions of adversarial blood supply chain effects could improve JIPOE.

There is a narrow margin for error in transporting and storing blood, a temperature-hypersensitive substance, lest its chemical composition is compromised, risking safe transfusion or wastage. First, the time of year—that is, seasonal ambient temperature fluctuations—combined with distribution equipment suitability can pose challenges to maintaining blood integrity, especially the greater the diurnal temperature variation. Although blood products can be stored frozen to extend shelf-life, thaw time for whole blood

11. Ben Connable et al., "Will to Fight: Returning to the Human Fundamentals of War," RB-10040-A (Santa Monica, CA: RAND Corporation, 2019), https://doi.org/.

12. Connable et al.

13. Russ S. Kotwal et al., "The Effect of a Golden Hour Policy on the Morbidity and Mortality of Combat Casualties," *JAMA Surgery* 151, no. 1 (January 2016), https://pubmed.ncbi.nlm.nih.gov.

14. Robert L. Mabry, "Challenges to Improving Combat Casualty Survivability on the Battlefield," *Joint Force Quarterly* 76 (January 2015), https://ndupress.ndu.edu/.

15. Leslie Waghorn, "New Research Shows Golden Hour Trauma Care Saves Lives on the Battlefield," Vital Record: News from Texas A&M Health, November 4, 2015, https://vitalrecord.tamhsc.edu.

or its components is typically prohibitive in emergencies, and refrigerated or room-temperature blood must be transfused within specific timeframes or discarded.[16]

Second, inclement weather at donation sites—locations which may dually serve civilian needs—can delay supply replenishment. Third, weather can delay transport timelines and, in extreme situations, jeopardize temperature-controlled storage when power outages extend beyond backup generator capacity. Casualties are tactical-level effects, but tactical support like blood supply readiness, or lack thereof, can give rise to results of strategic proportions. Enough past wars' lessons reinforce that outcomes are not decided in a contest of technologies but that of wills. As a human endeavor, war demonstrates there are limits to society's acceptance of compounding loss of human life.[17]

In conflict, all initiatives and responses come at a cost. Prudent calculi considers whether an objective's value outweighs the price of the encounter and the appropriate utility of available capabilities in vying for the initiative. Seizing, retaining, and exploiting the initiative are contingent upon thorough, advanced preparation.

Weather in Training

Knowledge is always fundamental to seizing, retaining, and exploiting the initiative. But prescient knowledge of environmental conditions, correlated with adversary inclinations, choices, and limitations creates an offensive paradox: opportunities to operate offensively in an unrestricted manner multiply in inclement weather. Further, the ability to disclose what an adversary cannot do presents a unique opportunity to degrade their military power projection. In the context of airpower, the conventional perspective of an offensive action is that an F-22A, F-35A, B-21, or other aircraft delivers the munitions. The dissident perspective of the same action is that opportune weather delivers the aircraft.

In a highly-contested battlespace between next-generation aircraft and sophisticated anti-access and area-denial capabilities, visual flight rules conditions are neither conducive to seizing the initiative nor guaranteed if the adversary commences the attack. It is better to err on the assumption that air superiority will be local and temporary at best. Increasing that probability necessitates exploiting time frames when freedom of action is exclusive, reversing what are deemed favorable, marginal, and unfavorable flying conditions. Like a rain-wrapped tornado, aircraft advancement might be detectable given existing technology, but it is more difficult for an adversary to react as effectively at the time.

Risk in warfare is a certainty, not a probability. Nonetheless, if the political object is the goal, and warfare a means to reach it, then the most significant risk is not losing an asset, battle, or even the war, but falling out of play to terms unfavorable for the United States and its Allies and partners.[18] It is a measured risk to train to and operate between and behind

16. Matthew Bradley et al., "Combat Casualty Care and Lessons Learned from the Past 100 Years of War," *Current Problems in Surgery* 54, no. 6 (June 2017), https://www.sciencedirect.com.

17. Connable et al., "Will to Fight."

18. Carl von Clausewitz, *On War*, eds. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1976), 87.

inclement weather rather than the way the Air Force does it now, in more stable environmental conditions. Such a hazardous posture is further complicated by the maturation of adversarial cyber and electromagnetic pulse capabilities, making communications delays and blackouts inevitable. Still, it is a posture that offers audacity, surprise, and a means to alter an operations tempo that will otherwise be rare in a future near-peer conflict.

Past high-intensity peer warfare preceded modern meteorology; thus, actors daringly played against the odds with a rudimentary understanding of weather. Today, prevalent norms are to avoid weather, so deviating and leveraging over 60 years of meteorological advances makes for calculated audacity.[19] The prerogative of surprise complements bold action; the unpredictability of time, place, and direction affords an adversary little to no physical and psychological respite. Within those moments of an adversary's unpreparedness and reactivity are opportunities to disrupt their operations tempo, interfering with their decision cycles while protecting one's own. But this depends on being more prepared. Risk acceptance in practice lends itself to risk transference to an adversary during a conflict.

Future conflicts will not involve pure high-intensity air combat but a hybrid approach with nonkinetic first strikes meant to affect information superiority well before any kinetic response, making it more consequential to recognize an unconventional offense. Although some actions may not bear doctrinal hallmarks, the purpose behind them is the better delineator. For example, consider a disinformation campaign exaggerating the severity of drought and the extant water shortages and food insecurity to trigger human displacement and instability within an adversary's borders. The action is intended as an offense play, but is unconventionally audacious, concentrated, surprising, and paced (tempo).

The purpose of any offense is to deny, degrade, disrupt, deceive, or destroy a target or target audience with real-world impacts to achieve broader military objectives. Leveraging coincidental timing of solar flares, geomagnetic storms, and damaging terrestrial storms for dayside operations is one example of influencing or annulling an adversary's decision calculus. Where satellite communications are nonviable or otherwise impaired and when high-frequency (3–30 MHz) beyond-line-of-site alternatives are disrupted, command-and-control options are limited to a period of minutes to days.[20]

Moreover, since high frequency is often the fallback for civilian emergencies, a state actor must prioritize its military and civilian needs and infrastructure recovery while encumbered by degraded communications. Another example is to leverage weather dictating the types of red forces employed and for which they are the least prepared, such as nonclimate-controlled aircraft at heights or ground components that prolong personnel exposure to the elements. Still, meteorological information flow is the proverbial double-edged sword of kinetic and nonkinetic wars, imperative to seizing any initiative militarily and, therefore, an early target.

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19. Eric Berger, "Modern Meteorology Was Born 60 Years Ago Today," Ars Technica, April 1, 2020, https://arstechnica.com.

20. Nathaniel Frissell et al., "High-Frequency Communications Response to Solar Activity in September 2017 As Observed by Amateur Radio Networks," *Space Weather* 17, no. 1 (January 2019), https://doi.org/.

Knowledge cuts through the fog of war, "the state of ignorance in which commanders frequently find themselves as regards the real strength and position, not only of their foes, but also of their friends."[21] Other national weather data availability will likely be sparse or unreliable preceding and in wartime, drastically affecting both sides' forecast accuracy. Yet the advantage will lie with whichever side possesses better modeling for and working weather knowledge of the contested region; specialists, not generalists, will be indispensable. Weather itself is inherently neutral and neutralizing, impartial to all actors, and ubiquitous to the point of being domainless. Still, it can be disarming in any battlespace of any time for those who use it effectively. The United States insists on the ability to inflict temporary or permanent effects at a time and place of its choosing, but for that to be true, there cannot be an exception for inclement weather.

Conclusion

The weapon of choice is knowledge. Military strength and position limits lie not in the physicalities of warfare but in cognitive biases. Environmental uncertainty is central to and a constant in human activity. Therefore, if any advantage is to be ascertained, much less exploited, in near-peer conflict, then military decisionmakers must break rigid preconceptions about the utility of weather. Defeat is often discussed as a cognitive outcome. Yet emphasis on tangible technological and numerical disparities obscures that the aim of any physical action is to influence perceptions and, thereby, attrit will. So, while conventional forms of attack may indirectly affect will, information warfare is the sole means of a direct attack on an adversary's will to fight.[22]

If the United States is to remain a global leader, particularly when key resources fall short, then its military must scale its cognitive approach. The determinants of military victory depend upon leadership, strategists, planners, and operators fully considering available capabilities, including accepting offensive paradoxes such as the concept that opportunities to operate unrestricted multiply in inclement weather. Every difficult situation offers an advantage; every cloud has a silver lining. The point is to make wise decisions at timely speeds. But this hinges on preparedness that takes time, and nothing can compensate for the loss of time. ✈

21. Lonsdale Hale, *The Fog of War* (London: Edward Stanford, 1896), XIX, 522.
22. J. Boone Bartholomees, "Theory of Victory," *Parameters* 38, no. 2 (Summer 2008), https://press.armywarcollege.edu.