

Lunar Roads and Connectivity: Infrastructure, Governance, and Resource Politics Beyond Earth

Caitlin Ahrens¹, Bohumil Doboš²

¹University of Maryland, College Park, MD 20742

²Charles University, Prague, Czech Republic

This paper explores the strategic importance of roads on the Moon as a foundational element of future lunar infrastructure, focusing on their implications for geopolitical influence, resource management, and international collaboration. Drawing on the concept of connectography, we argue that roads on the Moon will serve not only practical purposes but also strategic functions: enabling resource access, facilitating territorial soft power, and anchoring multinational management. Within the legal and ethical frameworks of space treaties, like the Outer Space Treaty, we examine how lunar roads could evolve from utilitarian pathways into instruments of cooperation or conflict. Finally, we assess how road networks could contribute to sustainable lunar development.

Isaiah Bowman's *The New World: A Century of American Geography on the World Stage*

Douglas Batson¹

¹National Geospatial-Intelligence Agency (Retired)

We last saw Dr. Bowman (portrayed by Douglas Batson at the 13th ICMG in Italy), who, as Director of the American Geographical Society, prepared American geographers and area specialists of The Inquiry for the 1919 Paris Peace Conference. Undaunted by 1920s isolationism, Bowman forcefully marshaled both the talents and tenets of geography toward global peace and multilateralism. His masterful book, *The New World: Problems in Political Geography*, introduced an increasingly complex geopolitical world to two generations of readers (as late as 1942, 2000 copies were distributed in U.S. Army camps).

In 1921, Dr. Bowman became a director of the nascent Council on Foreign Relations (CFR), founded in New York City to inform unversed policymakers and businessmen on the workings of international relations. Study groups launched to research political geography matters also began to publish books and articles. For over a century, CFR's *Foreign Affairs* magazine remains a leading forum for discussions of U.S. foreign policy and global affairs.

Federated Cloud/Edge “Big Earth Data” Analytics for Multi-Domain GEOINT

Peter Baumann^{1,2}

¹Constructor University, ²rasdaman GmbH

Modern ISR as well as tactical missions have to "operate off the same map" and "get the right data at the right time, in the right format". GEOINT today operates in space/time “datacubes” of 2-D imagery, 3-D x/y/t image timeseries and 4-D x/y/z/t MetOc, among others. In multi-domain, heterogeneous coalition setups, additionally disparate heterogeneous data need to be integrated with moving and fixed data sources and consumers in realtime, with clients ranging from human analysts to automated effectors. AI plays an increasing role, while at the same time not always providing the accuracy required for the kill chain.

Interestingly, for such “Big Data problems” the technology built for Big Data wrangling rarely is used: databases. We present dual-use architecture employing a database approach to distributed management and analytics of massive spatio-temporal Big Earth Data. The rasdaman (“raster data manager”) technology, which is in operational use in USA, Europe, and Asia, combines several critical capabilities relevant for GEOINT / ISR:

- Multi-domain distributed information fusion for realtime GEOINT/ISR, based on semantic-rich low/zero-coding space/time datacubes;
- Location-transparent federation with cloud/edge integration (orbit proven);
- AI-Cubes, which make AI simpler, safer, and faster, including multi-model management as well as server-side sanity checks and AI accuracy estimation for queries received;
- Full interoperability (reference implementation), enabling a wide spectrum of 3rd party clients;
- "Define and forget" automated datacube maintenance;
- Security-by-design, configurable down to single pixel level.

The NATO Space Center of Excellence has selected rasdaman into its *Space Asset Register* and *Emerging and Disruptive Technologies Register*. In our talk we discuss these capabilities, based on results from NATO projects and live demos.

Coastal geomorphology as an operational variable: harbour morphology and the outcomes of Italian underwater raids in the Mediterranean (1940–1943)

Aldino Bondesan^{1,2}

¹Department of Historical and Geographical Sciences, and the Ancient World (DiSSGeA), University of Padua,
Via del Santo 26, 35123 Padua, Italy

²Department of Military Geography, Faculty of Military Science, University of Stellenbosch, South Africa,
(research fellow)

This study develops a transferable military-geoscience framework to explain why some Mediterranean ports proved more vulnerable than others to underwater sabotage during World War II. We compiled a georeferenced catalogue of Italian naval special-operations attacks and attempts (1940–1943) involving SLC human-torpedoes (*siluro a lenta corsa*), Gamma assault swimmers (combat divers employing limpet mines), explosive motorboats (MTM), and torpedo motorboats (MTS/MTSM), recording target classes, mooring configurations, outcomes (loss, constructive total loss, or damage), and documented defensive responses. For each attacked port we constructed a standardized geo-oceanographic port profile integrating (i) coastal setting and artificial-shoreline geometry; (ii) bathymetry, gradients, and seabed substrate; (iii) tidal range and harbour-exchange constraints; (iv) wind forcing and sea-state windows; and (v) passive and active defences (booms, nets, patrol patterns, and diver inspection). Morphological baselines were reconstructed from historical hydrographic charts and wartime harbour plans by digitizing soundings to generate a historical digital bathymetric model; modern gridded bathymetry was used to supply regional context. Event-scale metocean conditions were parameterized from reanalysis products to yield comparable 48–72 h indices of wind directionality, gustiness, and pressure tendency across case studies. We applied the workflow to Alexandria (GA3) and the Gibraltar–Algeciras system (BG4, BG6, BG7) as primary exemplars, with Suda Bay and Algiers as supplementary controls. Results highlight recurring physical commonalities: sheltered basins concentrate high-value targets yet amplify the importance of entrance geometry and boom management;

strong strait-driven currents and local circulation patterns complicate swimmer and SLC navigation while simultaneously constraining optimal search spacing and timing; and anchorage fields in semi-protected bays reduce infrastructure-related constraints yet shift vulnerability toward patrol intensity and diver-based inspection capacity. The framework links geomorphology and operational oceanography to both attack planning and defence evolution, offering a replicable method for historical analysis and for contemporary port-vulnerability assessment against subsurface threats.

Terrain as force multiplier: geomorphological constraints and defensive outcomes at Naqb Rala (El

Alamein, 23rd October 1942)

Aldino Bondesan^{1,2}, Maria Petriccione¹

¹Department of Historical and Geographical Sciences, and the Ancient World (DiSSGeA), University of Padua,

Via del Santo 26, 35123 Padua, Italy

²Department of Military Geography, Faculty of Military Science, University of Stellenbosch, South Africa,

(research fellow)

The Naqb Rala plateau occupies a position of paramount strategic importance, marking the southernmost anchor of the El Alamein line at the junction between the desert escarpment and the impassable Qattara Depression. During the decisive offensive of October 1942, this sector constituted the hinge of the entire Axis front; a collapse at this point would have permitted the British Eighth Army to bypass the primary defensive belts and strike the rear of Panzer Army Africa. Within the broader framework of General Montgomery's Operation Lightfoot, General Horrocks's XIII Corps mounted a large-scale assault aimed at breaking through this southern flank. The southernmost objective was assigned to General Pierre Koenig's 1st Free French Brigade, which committed elite units of the 13th Foreign Legion Demi-Brigade supported by massed British artillery and armored columns.

Opposing this mechanized force was the V Folgore Parachute Battalion under the command of Lieutenant Colonel Giuseppe Izzo. A commander with a pronounced aptitude for topographical analysis, Izzo recognized that his depleted battalion could not sustain a conventional linear defense against so marked a material disparity. He undertook a meticulous study of the local geomorphology and identified a critical vulnerability: a southwestern ramp that afforded a natural, unmined approach from the depression floor to the plateau surface. Although the French commander, Colonel Amilakvari, intended to exploit this concealed topographical feature to outflank the Italian positions, Izzo anticipated the maneuver and incorporated the terrain itself into a deliberate tactical trap.

The ensuing engagement demonstrated the degree to which micro-topographical features can govern the outcome of battle when correctly integrated with adaptive tactics. Izzo deliberately left the ramp lightly defended so as to draw the Legionnaires into a prearranged killing ground on the plateau. He emplaced his limited anti-tank assets and a purpose-built mobile reserve to deliver converging fire toward the crest of the ramp rather than outward across the open desert, thereby neutralizing the French armored support and compelling their elite infantry into a disorganized withdrawal under concentrated enfilade. The maintenance of the Southern front at Naqb Rala demonstrates that the stability of the sector resulted from a technical application of tactical intelligence which utilized the physical constraints of the landscape to mitigate decisive material superiority.

Environmental Targeting in the Russian Invasion of Ukraine.

M.H. Bulmer^{1,2}

¹ Roedown Research, Davidsonville, Maryland, 21035; ² Department of Earth Sciences, University College London; Gower Place, London WC1E 6BS

The On 6 Jun, 2023 Ukraine (UKR) accused Russian Federation Armed Forces (RFAF) of blowing up the Nova Kakhovka dam and hydroelectric power station on the Dniepro River in an area controlled by Moscow for more than a year. RUS Defence Minister Sergei Shoigu charged that UKR destroyed the dam to prevent potential Russian attacks in the Kherson region after what he alleged was a failed Ukrainian counteroffensive. Ukrainian President Volodymyr Zelenskyy called it “the largest man-made environmental disaster in Europe in decades.” U.N. Secretary-General Antonio Guterres, ahead of an emergency Security Council called it “another devastating consequence of the Russian invasion of Ukraine.”

UKR has terrain that favour to Hydroelectric power generation (HEP). The Dnieper Hydroelectric Station (or DniproHES) near Zaporizhzhia, built between 1927 and 1932 had an output of 558 MW. It was destroyed during WWII by retreating Soviets, and rebuilt in 1948 with an output of 750 MW. RFAF have demonstrated their use of infra targeting to gain, maintain and project power and influence within UKR and internationally. At operational and tactical levels, the destruction of dams has been common in warfare and in contemporary conflicts has been used to help achieve military objectives in Afghanistan, Iraq and Syria.

The source of the Dniepro river is in the Valdai Hills, Smolensk, Russia. It flows through Belarus and UKR to the Black Sea. It is approximately 2,200 km long, with a drainage basin of 504,000 km². The river forms part of the defensive lines for both UKAF and RFAF. The Kakhovka Reservoir was created in 1956, when the Kakhovka Hydroelectric Power Plant was built at Nova Kakhovka. The reservoir covers 2,155 km² in the Kherson, Zaporizhzhia, and Dnipropetrovsk Oblasts. It is 240 km long, up to 23 km wide with a pre-dam failure water depth from 3 to 26 m and averages 8.4 m. The total water volume of 18.2 km³ was used for HEPs, the Krasnoznamianka Irrigation System, the Kakhovka Irrigation System, the 5.7 GW Zaporizhzhia NPP,

freshwater fish farms, the North Crimean Canal and the Dniepro–Kryvyi Rih Canal. The reservoir submerged previously un-navigable rapids enabling a deep-water route from the Black Sea to Kyiv.

Threats to UKR include loss of HEP generation and high cost of dam replacement, interruption, damage and destruction of infra by flooding, need for evacuation of civilians in flood prone areas, and loss of navigation along the Dniepro, and movement of contaminants plus UXO in the flood water and sediments. If the dam was intentionally breached then RFAF has been able to target energy infrastructure to deny and destroy physical elements. Where they maintained ISTAR ability they targeted UKR attempts to respond to flood. The sustained flood event and resulting impact likely impacted UAF planning of amphibious and river crossing operations in the Dniepro estuary and river in the short term. If RUS or international community obtains and verifies evidence that UKR was responsible for the dam breach through active physical means then this will likely result in a loss of confidence in, and support for the GoU. If UKR or international community can obtain and verify evidence that RFAF was responsible for the dam breach through inadequate maintenance, inappropriate operation or deliberate means then this constitutes a potential war crime.

The Formation of a Militarized Frontier: Territorial Inscription along the Armenia–Azerbaijan Border after the Second Karabakh War (2020–2024)

Emanuele Cassano^{1*}, Maria Petriccione¹, Francesco Ferrarese¹, Aldino Bondesan^{1,2}

¹ University of Padova, DiSSGeA – Department of Historical and Geographical Sciences and the Ancient World, Geography Section, Palazzo Wollemborg, Via del Santo 26, 35123 Padua, Italy

² University of Stellenbosch, Department of Military Geography, Faculty of Military Science, Stellenbosch, South Africa

The 2020 Second Karabakh War profoundly reshaped the geopolitical configuration of the South Caucasus, shifting the Armenia–Azerbaijan confrontation from the former Nagorno-Karabakh enclave to their international borderlands. Since the ceasefire, both states have engaged in an accelerated militarization of this frontier, transforming it into a dense corridor of fortifications and surveillance.

This study investigates the spatial and temporal dynamics of that process between 2020 and 2024 through a geographic information system (GIS) framework integrating high-resolution satellite imagery, digital cartography, and spatial statistics. A multitemporal dataset was built from ESRI World Imagery WaybackTM and Google Earth Pro archives, complemented by official Russian Ministry of Defense maps. Military infrastructures, posts, trenches, and fortified roads, were digitized and analyzed using density and nearest-neighbor models to quantify their growth and spatial organization.

Results reveal an overall increase of more than 1,600 % in point installations and 1,900 % in linear features within four years, concentrated along key transit axes and high-ground sectors that command strategic visibility. Beyond its empirical findings, the research contributes to the theoretical debate on militarized landscapes by linking quantitative spatial evidence with the political geography of post-war border formation.

The study demonstrates how open geospatial data can document the persistence of conflict through infrastructure, offering a replicable model for monitoring other border zones undergoing remilitarization.

Ultimately, the analysis highlights the role of GIS as a critical tool to expose the territorial logic of security and

the material inscription of power within the post-Soviet frontier.

**The Use of Geology to Locate an 1863 Civil War Union Picket Site Along the
Rappahannock River, Central Virginia**

Thomas C. Chidsey, Jr.¹, and Stephen E. Chidsey²

¹Emeritus, Utah Geological Survey, Sandy, Utah 84094, USA

²Hanover County Public Works Department (Retired), Ashland, Virginia 23005, USA

Our great grandfather, Charles F. Chidsey, was a private in the 129th Regiment, Pennsylvania Volunteers of the Union Army during the Civil War. After their disastrous defeat at the Battle of Fredericksburg in central Virginia, December 1862, the Union Army went into Winter Quarters around the nearby the town of Falmouth along the Rappahannock River. The encampment was ringed with pickets to observe enemy troop movements and patrols. In a letter home dated April 9, 1863, Charles described his shelter and surrounding area while serving as a picket above the river west of Falmouth.

Far up on the mountain side we espied, what seemed to be a cave, and for this point we started determined to make our abode...Over our heads projected a flat rock forming a sort of awning...

Far down the valley we could extend our gaze, taking in all the numerous camps...

We used a combination of geologic and topographic maps, Google Earth images, and field work, to locate this site. The view east down the Rappahannock can only be observed near the present-day Interstate 95 bridge before the river makes a sharp loop southwest. In this region (the eastern Piedmont Province), the bedrock consists of the faulted Neoproterozoic to Lower Paleozoic Po River Metamorphic Suite.

Sites along the steep, wooded and densely vegetated slopes above the river, between the bridge and Falmouth, revealed only clay-rich soil with one significant exception. Just east of the bridge we found Po River outcrops that formed alcoves and crags, which were a remarkable match to the “cave” and rocks described by Charles. Furthermore, we discovered weathered rifle pits at the ridgetop. These factors lead us to conclude this was the site where Charles and his comrades took shelter while on picket duty in 1863.

From Battlefields to Brownfields: Field Trips as Experiential Learning in Critical Military Geography

Justin Cook¹

¹United States Air Force Academy, Colorado Springs, CO

In the pedagogical tradition of military geography, the field trip has long been synonymous with the “staff ride”—an exercise in terrain analysis and historical reconstruction designed to teach tactical decision-making. While the value of traditional military geography remains high for the warfighter, the emergence of critical military geography necessitates a broader approach to experiential learning. This paper explores the pedagogical value of field trips that move beyond the battlefield to engage with the material and discursive ways militarism shapes everyday landscapes, environments, and social relations.

Using Geo 491: Capstone Seminar in Military Geography at the U.S. Air Force Academy as a case study, this paper argues that field trips are essential for transitioning students from a “geography for the military” perspective to a “geography of the military” perspective. I discuss the design of a field trip to the Rocky Mountain Arsenal (RMA) in Colorado, a site that encapsulates the transition from a 17,000-acre chemical weapons manufacturing hub to a National Wildlife Refuge and EPA Superfund site.

The RMA serves as a critical “staff ride” where students analyze the military’s role as a maker of places. By observing the juxtaposition of shortgrass prairie and bison herds against permanent hazardous waste landfills and groundwater treatment facilities, students confront the “toxic-to-tonic” discourse and the long-term environmental legacies of the Cold War. This experiential approach allows future military officers to critically assess the military operating environment not just as a space for operations, but as a site of environmental justice, public health concerns, and political memory. By comparing the pedagogical outcomes of traditional battlefield tours with critical site visits, this paper demonstrates how field-based inquiry fosters a more nuanced geographic perspective essential for geography students.

Operationalising quantum sensing for subsurface spatial intelligence

Drew Craig¹

¹Headquarters, Allied Rapid Reaction Corps, British Army, United Kingdom

Where present, 90% of subsurface data is outdated or incomplete. In many areas it doesn't exist at all. This uncertainty creates major risk across infrastructure, defence and energy. As a result, decisions are being made with incomplete data.

Gravity is universal, inescapable, and impossible to mask. Quantum gravitometry sensors treat it as a truth signal and can detect voids or masses by passively comparing tiny differences in space.

Applications in defence and security are predominantly focused on the detection and mapping of subterranean systems. Such systems could be hardened bunkers, underground civilian infrastructure in the urban operating environment, or cross border tunnels. There are also applications in navigation, most notably in GPS denied environments, and the indirect link to the detection of defence associated critical minerals.

Delta.g, a spatial intelligence company, combining expertise in quantum physics, engineering, software development, and business strategy, is the only commercial organisation globally to have developed a rugged, non-expert operable, terrain agnostic, vertically integrated Sensor and Data platform.

Detecting vessel loading operations at richards bay coal terminal using multi-metric iceye spotlight sar analysis

Du Toit L.M¹

¹Department of Military Geography, Division of Defence Science & Technology, Faculty of Military Science,
Stellenbosch University

This paper presents a proof-of-concept methodology for detecting vessel loading operations at Richards Bay Coal Terminal (RBCT), South Africa, using time-series Synthetic Aperture Radar (SAR) imagery. Six ICEYE Spotlight X-band (VV polarisation, ~1 m resolution) images acquired during March 2020 were analysed to classify loading status across occupied berths based on temporal changes in backscatter intensity and texture.

The detection principle exploits the physical relationship between cargo loading, increasing vessel draught, and measurable reductions in SAR backscatter: as a vessel's freeboard decreases under load, less metallic hull is exposed above the waterline, producing a quantifiable decrease in both mean backscatter intensity (σ^0_{mean}) and spatial heterogeneity (σ^0_{std}). A multi-metric classification framework - requiring concurrent decreases in both metrics exceeding 2 dB - achieved 75% loading detection accuracy across eight occupied berth observations, with zero false unloading detections consistent with RBCT's export-only operational profile. The multi-metric approach outperformed single-metric classification by 25 -37 percentage points, demonstrating that textural corroboration substantially reduces false positives.

Results are validated through operational and physical consistency arguments, and the methodology demonstrates the potential of commercial SAR constellations for passive, all-weather monitoring of strategic port infrastructure.

**A unique representation of military architecture in Roman Syria – An extramural defence complex at
Hippos of the Decapolis**

Michael Eisenberg¹, Arleta Kowalewska²

¹ The Zinman Institute of Archaeology, and the School of Archaeology and Maritime Civilizations, University of
Haifa

² The Zinman Institute of Archaeology

Hippos (Sussita) was founded as a polis in the Hellenistic period on a hilltop east of the Sea of Galilee, naturally detached from its surroundings and enjoying near-perfect natural defences. Only on its southeastern side does a topographic saddle connect the hill to the surrounding ridges; consequently, this saddle became the city's principal access route throughout all periods of its existence. A defensive ditch cut across the center and entire width of the saddle, forming a barrier between the "Saddle Necropolis" and the city itself, serves as a unique example in Roman Syria.

An extensive extramural complex made of basalt ashlar was constructed along the ditch during the Roman period (early 2nd century CE). The complex was recently excavated and includes a ditch, a monumental western gate with a fountain next to it, a smaller eastern gate along the main axis, and fortification walls connecting the gates and the artificially cut local stone serving as part of the city's outworks.

The purpose of this gate complex—whether primarily monumental or defensive—will be discussed in the lecture, together with a proposed reconstruction. In addition, the plan of the ditch will be presented and considered in light of regional poliorcetic practices.

A Spatial Assessment of Axis Amphibious and Airborne Options during the Planned Invasion of Malta in 1942

Gianluca Giorgio Falzon¹, Maria Petriccione², Aldino Bondesan^{2,3}

¹Department of History, Faculty of Arts, University of Malta, Msida MSD2080, Malta

²Department of Historical, Geographical Sciences, and the Ancient World (DiSSGeA), University of Padua, Via del Santo 26, 35123 Padua, Italy

³Department of Military Geography, Faculty of Military Science, University of Stellenbosch, South Africa

Present-day historiography suggests, somewhat more implicitly than earlier work, that, in the context of the British conduct of the war in the Mediterranean, the overall strategic influence of Malta as an operational asset was considerable. Recent counterfactual statements by key historians suggest that a successful Axis invasion of the island would, realistically, have prolonged the war in the Mediterranean by some twelve months. Yet while Malta's offensive capabilities and overall defensive conduct have been treated at some length, local British schemes concerning defence against invasion and fortress security have never been seriously discussed. Thanks to a composite documentary record and a multidisciplinary approach, a study of an assault on the Maltese Islands shortly following the Axis victory at the Battle of Gazala (21 June 1942) can be attempted by examining what operational factors and terrain morphology can infer about the outcome of the airborne and seaborne assault phases of *Operazione C3* within the first 48 hours along the Famagosta sector. The analytical framework combines archival research with geospatial methods to reconstruct the operational constraints facing Axis commanders. A geomorphological assessment of the southern Maltese coastline identifies and ranks sectors suitable for seaborne landings, considering coastal gradient, beach morphology, and natural obstacles. Cost-distance analysis, computed within a GIS environment on terrain derivatives, quantifies the likely rate of inland advance from the beachhead toward strategic objectives under mid-1942 conditions. Viewshed modelling, constructed from known British defensive emplacements, defines zones of observation and dead ground that would have shaped engagement conditions during both

the landing and penetration phases. These spatial analyses enable a more rigorous appraisal of the operational feasibility of *Operazione C3*, moving beyond the speculative dimensions characterising existing literature, and demonstrate how terrain analysis and GIS-based modelling can reframe longstanding questions in military history within a reproducible and spatially explicit framework.

The Fortifications of New York Harbor

Francis A. Galgano¹

¹Department of Geography and the Environment, Villanova University, Villanova, Pennsylvania 19085

New York City's harbor's fortifications were essential to the security of a young United States, protecting a vital port, controlling key maritime approaches, and deterring potential foreign naval threats during the nation's formative years. This study examines the military geography of New York City Harbor and the evolution of its fortification system from the colonial period through the twentieth century. Emphasizing the interplay between physical geography and defensive strategy, the analysis explores how natural features shaped the placement, orientation, and design of key fortifications. Particular attention is given to how these sites created an integrated defense and controlled critical maritime approaches to Manhattan and the Hudson River. The study situates these installations within broader technological and strategic transitions, tracing the shift from early masonry fortifications to reinforced concrete batteries, disappearing guns, and eventually anti-aircraft defenses in response to evolving naval and aerial threats. Drawing on historical maps, geospatial analysis, and archival military records, the research evaluates how successive defensive systems adapted to advancements in weaponry and changing geopolitical conditions. The findings underscore the enduring significance of terrain, hydrography, and urban proximity in shaping defensive landscapes. Ultimately, the study demonstrates how New York Harbor functioned not only as a commercial hub but also as a strategically vital defensive gateway to the United States.

Characterization of the shallow structure of fog using categorical machine learning models.

Pedro P. M. Guerreiro^{1,2} and Paula Gonçalves^{1,2}

¹Portuguese Air Force Academy Research Center, 2715-021 Pêro Pinheiro, Portugal

²Military University Institute, Rua de Pedrouços, 1449-027, Lisboa, Portugal

This study addresses the characterization of the shallow structure of fog through the application of categorical machine learning models, with a focus on operational implications for aviation visibility. Aerodrome visibility is primarily defined by horizontal meteorological visibility and Runway Visual Range (RVR), the latter representing the distance over which a pilot can discern runway markings or lights under specific observational conditions. Given the critical role of RVR in determining approach minima during low-visibility landings, accurate estimation and interpretation of visibility parameters are essential for aviation safety.

In operational contexts, pilots frequently rely on Converted Meteorological Visibility (CMV), which translates near-surface horizontal visibility into an equivalent RVR value. However, this conversion is influenced by multiple atmospheric and environmental factors, including extinction coefficient, background luminance, and runway lighting intensity, which are not fully captured by conventional methods. To address this limitation, the present study explores the use of decision-tree-based ensemble models to classify fog into distinct categories based on a comprehensive set of preconditioning features.

The proposed approach enables the identification of fog types with unique microphysical and optical characteristics, each associated with a representative RVR distribution. The resulting classification reveals that certain fog categories systematically correspond to reduced visibility conditions, with RVR values frequently falling below the 550-meter threshold required for low visibility operations. This highlights the importance of fog-type-specific analysis in improving situational awareness.

Furthermore, a climatological assessment of the classified fog types is conducted, allowing for the development of an RVR-based operational impact diagram. This tool provides a practical framework for

anticipating visibility constraints and supports decision-making processes in airport operations under adverse weather conditions. Overall, the integration of categorical machine learning models offers a robust methodology for enhancing the understanding and prediction of fog-related visibility impacts in aviation environments.

Using open source vector GIS datasets to prevent inadvertent war crimes

Peter L. Guth¹

¹Professor Emeritus, Annapolis MD, USA

The 21st century has witnessed disturbing trends in military actions, with parties to conflicts justifying force to conquer territory, appropriate resources, or change regimes; using artificial intelligence (AI) or mass surveillance to select missile and drone targets; claiming civilians are enemy combatants; practicing indiscriminate bombing; failing to protect civilians caught up in military operations; failing to discipline combatants or pardoning members convicted by their own courts; justifying targeting civilian infrastructure with unverified claims of dual military usage; or viewing legal constraints on military operations as unworthy of the profession of arms. The combined effect of these trends has moved actions that might be considered war crimes into mainstream military practice for some of the largest militaries.

The second half of the 20th century had seen a general consensus that warfare had legal constraints, and that there should be limits in military operations. Protected targets could be grouped into several categories. The most protected would be diplomatic facilities from third party nations, schools, hospitals, religious structures, and world heritage states. A second tier would be infrastructure like power plants, dams, and desalination plants. When targets are selected by AI, using outdated intelligence, or justifying mass collateral damage for supposedly valid objectives, military operations risk straying into the realm of war crimes.

Open-source unclassified vector GIS datasets provide the opportunity to put a human in to loop to verify targets before execution and avoid embarrassing mistakes. Existing databases include the National Geospatial Intelligence Agency national gazetteers, Open Street Map, and the official World Heritage site. None of these are complete, but a concentrated effort by an international body aiming to avoid war and promote peace could encourage inclusion in these databases of those facilities that should not be targets for civilized, professional military forces. We need international agreement on the limits of warfare, and a final

check with a human in to loop to sign off on proposed targets using open-source data bases and imagery like that in Google Earth would benefit military professionals.

The Beaches of WWII Eighty Years Later – Metallic Sediment as a Legacy of Warfare

**Samuel M. Hudson¹, Olivia J. Tatum, Julie Robinson, Brad Taylor, Sydney Crockett, Kassandra Ramirez,
Dallin Laycock, Erin Pemberton, Glen Burrige, Austin Toner, Cassidy Grover**

¹Brigham Young University, Provo, UT 84602

Amphibious assaults were a key feature of World War II, from Operation Overlord in Normandy to numerous invasions across the Pacific Theater. Initial naval bombardment, intense ground combat, and prolonged military occupation of these coastlines resulted in the emplacement of substantial quantities of anthropogenic metal within modern coastal environments. Detailed sampling and sediment analysis across all five landing zones of Normandy and the beaches of Saipan show that this metallic signal is widespread in the shallow marine environment, with magnetic, sand-sized grains common in both settings. The distribution of this metallic sediment differs between Saipan and Normandy, as does the geomorphology of these coastlines.

Over 500 samples were collected along the Normandy coast as part of this study. All samples show evidence of anthropogenic metal across the breadth of the beach and at depths exceeding one meter below the surface, with an average concentration of 0.4 wt.% and only a few samples containing concentrations above 1 wt.%. Longshore currents, wave reworking, and beach modification have muted the anthropogenic signal of the assault along the Normandy coastline, but sedimentological evidence for the conflict is ubiquitous. An additional 110 samples were collected along several transects on the eastern shore of Saipan. While metals were common, they were concentrated around remaining war detritus (up to 11 wt.%) and were much more diffuse across the carbonate shelf. Sediment samples collected immediately proximal to two tanks, one ship, and an airplane still present in the shallow marine environment suggest that these objects remain important contributors of anthropogenic metals. The highly localized nature of this signal, however, suggests that frequent storms and high sedimentation rates overwhelm this signal within tens of meters of these remaining artifacts, in contrast to what is observed at Normandy.

**Tree Failure Risk Along Roadways During Severe Weather: A Literature Review to Inform Risk
Assessment at Military Installations**

B. Kyle Hunt¹

¹Department of Geography and Earth Sciences, United States Military Academy, West Point, NY, 10996

Across the United States, severe weather events are a significant risk to infrastructure, especially roads. High winds and heavy precipitation from severe thunderstorms can weaken trees and increase the frequency of trees falling along roadways. These events regularly result in road closures, delaying or disrupting travel and producing additional hazards. This literature review synthesizes research from meteorology, urban forestry, and infrastructure risk to identify the critical factors that contribute to tree failure along roadways during severe weather events, such as wind speed and soil and tree factors. The review will also assess the multidisciplinary methods used to study tree fall risk. The findings of this review provide a foundation for future research on the severe weather-related risks to roadways at West Point, with wider application to other United States military installations.

The Geographic Eye of War: Military Geographic Intelligence from the Second World War to the Age of Open-Source Surveillance

Ömer Emre Kuşcu¹

¹PhD Student, University of Illinois at Urbana-Champaign

Geographic intelligence has always been warfare's hidden weapon. The ability to collect, interpret, and act upon geographic information has proven as decisive as firepower or manpower, yet the tools and actors producing it have undergone a profound transformation. This paper traces that transformation from the systematic cartographic intelligence of the Second World War to the democratized open-source geospatial analysis of the 21st century, arguing that while instruments have changed beyond recognition, the strategic primacy of geographic knowledge remains constant.

The paper examines the Wehrmacht's *Militärgeographie* apparatus, focusing on the Mil-Geo series: geographic intelligence documents produced for theaters across Europe, North Africa, and the Soviet Union. Integrating terrain, hydrography, climate, infrastructure, and human geography into actionable intelligence, these publications represent one of history's most comprehensive institutionalized applications of military geography. Analyzing the structure and doctrinal function of the Heft series offers an original contribution to how geographic knowledge was systematically militarized at the institutional level, a dimension underexplored in existing literature.

The paper then turns to meteorological geographic intelligence through Operation Overlord. The SHAEF meteorological team's identification of the favorable weather window on June 5, 1944, and Eisenhower's decision to launch, stands as the one of the most consequential geographic intelligence assessments in military history. Counterposed against the German failure to anticipate the same window, this case illustrates that geographic intelligence is not merely data collection, but interpretive capacity and institutional trust.

Finally, the paper addresses the contemporary revolution brought about by satellite imagery, OSINT, and

civic geospatial analysis. In the Russia-Ukraine War, Bellingcat, Planet Labs, and Maxar Technologies have produced real-time geographic assessments previously exclusive to state intelligence agencies, signaling a structural shift: military geographic intelligence is no longer the monopoly of armies. Synthesized through a neo-classical military geography framework, the paper concludes that geographic intelligence is not a relic of pre-digital warfare but an increasingly critical and contested domain of modern conflict.

Testing McColl in the Reg: A Theoretical and Autoethnographic Approach to Insurgent Territoriality in Southern Afghanistan

David Leydet¹

¹Department of Geography and Earth Sciences, United States Military Academy, West Point, NY, 10996

McColl's 1969 paper, "The Insurgent State", discusses the various stages of insurgency and the development of the insurgent state. It argues that the core insurgent base should have seven specific geographic attributes, including political instability, proximity to border regions, economic self-sufficiency, favorable terrain, and being situated near important objectives (McColl, 1969). McColl's theory is based on the revolutions in places like China, Cuba, Vietnam, and Malaysia in the 20th century. In this paper, we test this framework in Southern Afghanistan, with a primary focus on the Spin Boldak district between 2009 and 2010. Utilizing a qualitative approach, this study assesses McColl's framework using the environmental matrix (Galgano and Palka, 2011) and autoethnographic observations from the author's operational experiences. By mapping the lived experiences against structured frameworks, we examine how Spin Boldak's environmental and cultural contexts influenced insurgent territoriality and control. We find that, despite evolutions in technology and tactics, McColl's framework on insurgency remains a relevant and important tool for examining and understanding insurgent territoriality.

UAS Photogrammetric Mapping of U.S. Army Garrison – Kwajalein Atoll

Mr. Duncan MacIntosh¹, LTC David Stamps¹, Dr. Matthew O'Banion¹, CPT Victoria Gramlich¹, CW4

Mitchel Dascent¹

¹U. S. Military Academy (USMA), Geospatial Science Program, Department of Geography and Environmental Engineering, West Point, NY 10996

Small unmanned aircraft systems (sUAS) have dramatically changed the ways in which landscapes are able to be surveyed and mapped. By employing commercial off the shelf (COTS) sUAS platforms and payloads, this project explores the effectiveness of commercial airborne photogrammetric methodologies to adequately survey and digitally represent challenging landscapes and installation infrastructure. sUAS technologies provide unique opportunities in a military geospatial environment to allow a greater understanding of terrain in complex environments to better predict and model security and longevity of assets remotely. Through a partnership with NGA Foundation GEOINT and the USACE Army Geospatial Center, this study assesses the geometric accuracy and data quality of sUAS-derived photogrammetric data collected on the U.S. Army Garrison - Kwajalein Atoll in the Marshall Islands. The assessment employs co-collected terrestrial lidar as reference and ground truth to evaluate the suitability of sUAS photogrammetric surveys for the identification of features that would impede or enable crewed helicopter landing sites as well as ingress and egress mobility concerns. Additionally, this work presents a qualitative comparison between the two following photogrammetric reconstruction software: Pix4Dmapper and Skyline.

Mapping Mutiny: A Spatiotemporal Study the 1826 West Point Eggnog Riot

Jon C. Malinowski, Ph.D.¹

¹Department of Geography and Earth Sciences, United States Military Academy, West Point, NY, 10996

The 1826 “Eggnog Riot” is an infamous and rare example of mass student disobedience at the United States Military Academy. A number of West Point cadets, many intoxicated, attacked officers and destroyed property. To date, the drunken Christmas event has received little scholarly attention. A 1979 book based on historical records contains fictionalized passages which hamper its use for analysis. This paper presents a reconstruction of the event by applying AI-driven analysis techniques to a new transcription of the original 1827 West Point Court of Inquiry. By synthesizing traditional archival research with spatiotemporal analysis using generative AI, this study maps the progression of the disturbance, offering new insights into the breakdown of discipline and the landscape of cadet rebellion.

Mapping UXO Risk across two world wars: a multi-criteria spatial analysis in the Venetian Prealps (NE Italy)

Leonardo Mora^{1,2*}, Maria Petriccione¹, Aldino Bondesan^{1,3}

¹Department of Historical, Geographical Sciences, and the Ancient World (DiSSGeA), University of Padua, Via del Santo 26, 35123 Padua, Italy

²Dipartimento di Studi Umanistici, University of Ca' Foscari, Palazzo Malcanton Marcorà, Dorsoduro 3484
30123 Venezia, Venezia, Italy

³Department of Military Geography, Faculty of Military Science, University of Stellenbosch, South Africa
(Research fellow)

The discovery of unexploded ordnance (UXO) during excavation and construction activities poses significant risks to public safety. UXO includes mines, bombs, shells, and other explosive remnants of war, primarily dating to WWI and WWII. Since 2012, Italian law has required that bomb risk be addressed as part of preliminary workplace safety assessments. However, while the regulatory framework mandates qualitative screening to evaluate the likelihood of UXO presence, it does not provide a detailed or standardized methodology for spatial risk analysis. Similar regulatory approaches exist across Europe, particularly for WWII ordnance, yet they often lack integrated procedures capable of addressing areas affected by both world wars. In particular, no established methodology systematically combines historical documentation from both conflicts, records of UXO discoveries over recent decades, and current data on land-use exposure and vulnerability. Although UXO has been widely studied from historical and technical perspectives, spatially explicit risk assessments remain limited.

This study addresses this gap through a spatial risk analysis of Cismon del Grappa (northeastern Italy), a strategically significant area in the Venetian Prealps that was heavily bombed during both conflicts. The primary objective is to produce bomb risk maps that integrate hazard, exposure, and vulnerability data. Hazard mapping was carried out using a Historical GIS approach, building a geodatabase of risk-relevant features derived from military cartography, aerial photography, and georeferenced archival sources. These

data were combined with present-day exposure and vulnerability indicators within a Multi-Criteria Decision Analysis (MCDA) framework. Using Weighted Linear Combination, each variable was assigned a relative weight and aggregated to produce ordinal maps (1–10 scale) representing hazard, vulnerability × exposure, and overall risk. The results demonstrate that risk mapping integrating geohistorical data and spatial analysis methods serves as a practical decision-support tool for land-use planning and construction management, enabling targeted safety measures and more efficient resource allocation.

Terrain in 1916

Paul Nathanail¹

¹Nottingham Trent University, Nottingham, United Kingdom

The year 1916 saw the start of the Battle of the Somme, the German assault at Verdun, the debacle at Kut, Mesopotamia, the Trentino Offensive in Italy, Brusilov Offensive in Ukraine, the Arab revolt at Hejaz and terrorist damage to the Statue of Liberty, New York.

Terrain – and the adversaries understanding of and ability to exploit it - played a role in the execution and outcome of each of these events. A look back after 110 years shows how much our understanding of ground has come.

Through contemporary evidence and modern-day data, our ability to understand and predict then and today will be compared and contrasted.

From Dive-Bombers to Drones: Geospatial Modelling of Cultural Property Risk in Urban Aerial Warfare, 1945–2025

Maria Petriccione¹

¹Department of Historical, Geographical Sciences, and the Ancient World (DiSSGeA), University of Padua, Via del Santo 26, 35123 Padua, Italy

The assumed linear relationship between weapon precision and cultural heritage protection in urban warfare, greater accuracy yielding lower collateral damage, is challenged through a comparative geospatial analysis spanning eight decades of aerial conflict, from Operation Bowler over Venice (1945) to contemporary drone warfare in Aleppo, Odesa, and Shushi (Nagorno-Karabakh).

Operation Bowler, conducted by Allied forces on 21 March 1945, exemplifies deliberate tactical restraint aimed at neutralising military infrastructure while preserving Venice's cultural heritage. A multi-source historical GIS was developed using georeferenced aerial reconnaissance photographs (1944–1945) and cultural property databases. Two probabilistic risk scenarios were modelled: a counterfactual based on the Circular Error Probable (CEP) of high-altitude conventional bombing (>300 m), and an operational scenario reflecting the lower CEP (<60 m) of dive-bombing. Results demonstrate that the tactical choice eliminated the city's most significant monuments from the risk zone, an outcome attributable to deliberate operational planning, not chance.

This quantitative "risk avoided" model is then applied to three contemporary conflicts. In Aleppo (2012–2016), UNOSAT analysis documented damage to 518 heritage structures within the UNESCO World Heritage perimeter. In Odesa (2022–2025), over 25 architectural monuments were damaged in a single July 2023 strike. In Shushi (2020), the Ghazanchetsots Cathedral was struck twice with guided munitions, impact points less than two metres apart, precision deliberately employed against cultural property.

The juxtaposition reveals what this paper terms the "precision paradox": contemporary weapon systems offer CEP values orders of magnitude smaller than in 1945, yet heritage destruction has not diminished.

Geospatial evidence supports the thesis that accuracy is a necessary but insufficient condition for heritage protection; the decisive variable is the integration of cultural property considerations into targeting doctrine. The "risk avoided" model provides a reproducible, GIS-based framework for both historical assessment and forward-looking risk analysis in an increasingly urbanised battlespace.

Clausewitz and the spatial perspective: a grammar for military geography

Joel Radunzel¹

¹Department of Geography and Earth Sciences, United States Military Academy, West Point, NY, 10996

Military geography has long struggled to connect with the broader field of political geography, often criticized for its atheoretical, positivist approach (Woodward 2005 & 2014, Rech *et al* 2015). In response, defenders cite its lineage of theorists and practical importance for students in military contexts (Lohman & Fuhrman 2019). This paper argues that traditional military geography must better use the language and grammar of the broader geographic discipline to define the unique ways in which the subfield approaches the spatial study of war (Farish 2015, O'Lear 2010 & 2020, Woodward *et al* 2020). Specifically, a more explicit engagement with the spatial concepts of scale, landscape, place, and space will help the subdiscipline better identify its own inherent strengths, as well as areas for innovation and growth. This paper uses discourse analysis of spatial language present in written U.S. and NATO military doctrine to highlight how military forces envision and engage with these core geographic concepts. Uniting these threads, the paper argues that a more critically self-aware traditional military geography will be better able to provide jumping off points for engagement with critical military geography as well as adjacent fields such as critical geopolitics, warfare ecology, and militarized landscape research.

Underground Warfare 2.0: The October 7th War and Beyond

Prof. Daphné Richemond-Barak¹

¹Lauder School of Government, Diplomacy and Strategy Reichman University

The war waged between Israel and Hamas since the October 7, 2023, attack marks a turning point in the evolution of subterranean warfare. I conceptualize this shift as the advent of *Underground Warfare 2.0* – a phase in which the underground is no longer ancillary to surface operations but has been fully integrated into, and elevated to advance, the strategic aims of war.

Comparative analysis from Gaza, Lebanon, Yemen, Syria, and Ukraine reveal that geology shapes – rather than deters – the militarization of the underground. The analysis departs from the traditional assumption that hard terrain, water, or dense urban environments constitute inherent barriers to subterranean warfare. Instead, it demonstrates that once actors identify a strategic advantage in going underground, geological conditions influence the depth, layout, and features of tunnels, but do not prevent the use of the subterranean environment. Over time, belligerents seek to maximize and protect the considerable investment of human and financial resources required by subterranean warfare.

In Gaza, Hamas built the most extensive and sophisticated subterranean system ever used in war, combining geological adaptation with urban infrastructure and energy access to sustain command-and-control and weapon supply under sustained military pressure. Similar trends can be seen in Hezbollah's deep underground facilities in Lebanon, the Houthis' hardened sites in Yemen, and the use of industrial and improvised subterranean spaces in Ukraine to prolong resistance.

I advance three broader claims. *First*, military geoscience helps explain how subterranean warfare is optimized and sustained across environments – not whether it occurs. *Second*, advances in detection and precision-strike technologies have failed to deter underground warfare and have instead accelerated the construction of deeper, more complex, more robust, and more strategically integrated subsurface systems. *Third*, the maturation and diffusion of subterranean practices blur the boundaries between land warfare and

the subterranean domain, with significant implications for doctrine, force protection, and the role of the surface. I conclude by showing why future conflicts – particularly those marked by technological asymmetry – are likely to be shaped and prolonged by an increasingly strategic use of the underground.

The return of the defensive function of borders: theoretical reflection and empirical analysis of the border-hardening process

Martin Riegl¹

¹Global Political Studies Program, Charles University, Prague, Czech Republic

February 2022 redefined the strategic environment, heralding the return of the defensive function of borders, which had long been considered obsolete due to technological developments. Nevertheless, a return to heightened state-on-state competition and conventional war in Europe is accompanied by the emergence of projects such as the Great Wall of Ukraine, East Shield, the Baltic Defense Line, and the Drone Wall. These massive military projects not only reflect the deteriorating strategic environment but also the changing geopolitical landscape. Building border barriers is by no means a new trend; already in 2016, the Washington Post published a multimedia investigation titled "New Age of Walls," but the War in Ukraine brings a qualitative change to the process of border-hardening. Since 2016, the world has witnessed an acceleration in the construction of border barriers, driven by fears of insecurity. Border management regimes have reflected shifting global paradigms and the dynamics of the geostrategic environment for more than a century, not only in Europe but worldwide. Periods of trade liberalization and an emphasis on cross-border flows and cooperation alternate with periods characterized by control over territorial space and the adoption of restrictive policies, enforcement mechanisms, and physical border demarcation. However, theoretical reflection on the practice of constructing border barriers and on the introduction of the geopolitical theory of teichopolitics has emerged only in the 21st century. The following text introduces a new dataset on border barriers and analyzes how this process reflects perceptions of geopolitical threats across different regions of the world. In light of the deteriorating strategic environment, including renewed debates over territoriality and strategic autonomy, the question of the EU's role as a geopolitical actor has regained analytical relevance. These debates have been closely connected to contested understandings of territory and its defence. Against this background, the EU's response to two distinct yet structurally different types of threats – state and non-state.

Using GIS and publicly available data to determine coercion into marine wildlife poaching and piracy on the West Coast of South Africa

Peter Schmitz¹, Hennie Smit¹

¹Department of Geography, University of South Africa, Florida Science Campus, Florida, South Africa

This abstract is based on a paper published in Advances in Cartography and GIScience of the International Cartographic Association, 1, 2019, titled *"Using GIS and cartography as part of the whole-of-society approach to determine coercion into marine wildlife poaching and piracy,"* and on a presentation at the ICMG 2024 conference. The presentation will examine the profiling of coastal communities along the South African West Coast to identify potential targets for coercion into piracy and marine wildlife crime within a whole-of-society approach. The criteria and data are based on publicly and privately available sources for profiling. The criteria range from access to motorised boats, history of illegal, unregulated and unreported fishing activities, poverty and unemployment, proximity to marine reserves, anecdotal data and information from knowledgeable persons, and levels of education. The criteria for piracy are based on articles and reports on the causes of piracy along the Somali and Cameroonian coasts. The Western Cape coastal towns near Cape Town have been reanalysed using anecdotal and more recent socio-economic data, as well as information from knowledgeable persons. From the analysis and available information in the public domain, these coastal towns have been used by criminal syndicates to smuggle drugs mainly from South America, owing to minimal law enforcement at these small harbours. Furthermore, given the current socio-economic conditions at these locations and the presence of criminal syndicates, the probability of piracy and extortion targeting local fishing fleets and aquaculture is higher than it was in 2019. These findings have military implications, as piracy ultimately requires a holistic solution that may necessitate military involvement.

Assessing military impacts on the environment: a geoscientific and operational framework

Hennie Smit¹, Ivan Henrico²

¹Department of Geography, University of South Africa

²Department of Military Geography, South African Military Academy, South Africa

The environmental impacts of military activities have been extensively researched and are generally well understood. These impacts encompass both predominantly negative consequences and, to some extent, unintentional positive outcomes. Scholars and military practitioners widely agree on the importance of mitigating these negative effects. However, there exists a research gap in fully assessing the diverse environmental effects associated with different military activities. This can be attributed to insufficient long-term data, a lack of systematic analyses, and the absence of standardised indicators. This gap includes an in-depth examination of the types of impacts occurring during various military operations, their duration, the necessary mitigation/enhancement measures, the ease of implementation, and the desired end state after successful mitigation and enhancement. This chapter addresses the research hiatus by presenting a comprehensive framework that encapsulates the environmental effects of armed forces' activities, fostering further debate and research in this area. The framework consists of a comparison of seven types of military activities and their associated impacts on the environment and serves as a valuable tool to guide military organisations in adopting more environmentally friendly practices within their operations. By facilitating a deeper understanding of the nuanced environmental consequences of military activities, this framework contributes to informed decision-making and promotes sustainable approaches in military operations. The study's findings encourage heightened consideration of environmental factors and the adoption of responsible strategies in military endeavours, aiming to create a positive impact on both the environment and mission effectiveness. Through category-specific mitigation measures, the military can achieve improved mission success, reduce environmental footprints, and ensure better working conditions for soldiers and affected populations. As military operations continue to play a significant role globally, it is

essential to prioritise environmental responsibility to safeguard ecosystems, biodiversity, and human well-being.

Assessing the impact of the publications of the International Association for Military Geosciences: a literature review

HAP Smit

¹Department of Geography, University of South Africa

Studying the publication record of a researcher or organization can reveal valuable insight into the themes of investigation, the impact and reach of the work of such an individual researcher or organization.

Furthermore, literature reviews can assess the reaching of the stated aims of an organization or the lack thereof.

The International Association for Military Geosciences (IAMG) was founded at a conference held in Aviemore, Scotland, in 2011. Colonel (Dr) Edward PF (Ted) Rose was elected as the first honorary President of the new society. According to the website of the IAMG, Military geosciences, as they are understood by the Association, comprise “all disciplines that are interested in military activities within a geological, geographical or, more generally, spatial context, of which those listed below are but a few examples: Engineering Geology; Hydrogeology; Geospatial Sciences; Terrain Analysis; Archaeology; Historical Geography; Geomorphology; Environmental Science; Geophysics; Climatology and Cognate disciplines.” These “areas of interest” to military geoscientists should be reflected in the publications emanating from the conferences organised under the auspices of the IAMG.

A decade and a half later, we can look back on six successful conferences, with 9 publications emanating from these conferences. A total of 82 book chapters or journal articles were produced. These book chapters/articles reflect the research endeavours of the members of the IAMG and should align broadly with the stated aims of the Association.

A comprehensive literature review of the publications emanating from the Conferences held under the auspices of the IAMG over the last 15 years will attempt to identify the themes of investigation, the reach and

impact and the scope of the work of the IAMG during this period.

From COIN to Climate Security: Adapting the U.S. Army ADT Model for Low-Elevation Atoll Environments

Alexander K. Stewart¹, Gregg Nakano²

¹Department of Geology, St. Lawrence University, Canton, NY 13617

²Kwajalein Atoll Local Government

Agriculture Development Teams (ADTs), developed by the U.S. Army and Army National Guard in 2008, were small, interdisciplinary units of soldier-experts that integrated civilian professional skills with military operational capacity in Afghanistan's counterinsurgency environment. These teams worked alongside local communities to assess conditions, identify priorities, and support Afghan-led, U.S.-funded agribusiness projects designed for long-term viability rather than charity. They drew on bottom-up engagement, flexible structures, and governance coordination, integrating social dynamics with rigorous analysis of hydrology, terrain, and infrastructure under severe constraints while improving agricultural systems and dietary diversity. This feasibility-focused, governance-aligned logic is transferable beyond its origins. Low-elevation atolls in the central Pacific now confront converging pressures, including sea-level rise, coastal flooding, freshwater degradation, extreme population density, limited land, and restricted local food production, within a region of growing strategic competition. Kwajalein Atoll in the Republic of the Marshall Islands illustrates these dynamics through the contrast within a single lagoon system between the U.S.-administered Kwajalein Island and adjacent Ebeye, among the most densely populated places in the world, where infrastructure and governance disparities intensify constraints on freshwater availability and quality, storage capacity, and access to fresh food, shaping adaptation options. Engagement with the Kwajalein Atoll Local Government underscores that viable pathways must reflect community-defined priorities and align with existing systems, governance capacity, and expectations rather than external prescriptions. In this setting, U.S. Army-supported, non-prescriptive collaboration on physical conditions and built systems functions as science diplomacy, enabling locally selected pathways while reinforcing bilateral relationships and regional

stability. A Coastal ADT framework for low-elevation atolls extends this model through feasibility-oriented evaluation and governance-aligned collaboration, offering a structured approach to distinguish climate drivers from infrastructure-related vulnerabilities while integrating social dynamics and local food systems into adaptation decisions.

From 360 Degree to 3D: How Acknowledging the Ubiquitous History of the Subterranean in Warfare Can Help Geoscientists and the Operational Force

Jacob Stoil¹

¹U.S. Army Strategic Research and Assessment Department

A survey of the history of warfare suggests that the use of the subterranean environment is almost omnipresent. While not an aspect of every conflict or military activity, it appears across the full range of military operations, in a myriad of different environments. Yet, for a military planner today, most national doctrine, if it exists, offers little practical guidance for usefully understanding the environment. This is partly because the existing literature on the environment tends to focus on a few famous case studies or in-depth studies of a single case that are not practitioner-focused. The question of responsibility for the space further exacerbates the problem. Although a maneuver commander will ultimately hold responsibility for the subterranean area, many countries leave its conceptualization to special operations forces, engineers, or geoscientists. Recognizing the ubiquity of the subterranean in war will help the force acknowledge that while exploiting the space or countering any enemy use may require knowledge of military geoscience, it is not fundamentally an exclusively specialist task. This paper will use historical cases to demonstrate the need for ground forces and planners to expand their awareness from 360-degree to 3-dimensional. It will then suggest how using this commander-centric 3-dimensional thinking as the basis for developing approaches to frame and conceptualize the subterranean space will create the potential for new, more beneficial ways for geoscientists, engineers, staff, and commanders to communicate.

Improving tactical decision-making in forests: developing forest layers for military applications in Estonia

Kersti Vennik¹, Mait Lang²

¹Estonian Military Academy

²University of Tartu

According to the NATO standard ATP-3.2.1 (2018), warfare in forest environments is considered combat under special conditions. Depending on terrain characteristics, distinct tactical actions must be employed compared to those used in open terrain. These activities also require different types of terrain data than those applied in open environments. In countries with a high proportion of forest cover, such as Estonia, where forests cover more than 50% of the territory, a more detailed understanding of forest conditions and their effects on OCOKA factors is essential.

To address the information requirements of the armed forces in forest environments, a joint project was conducted between 2019 and 2023 by the Estonian Military Academy and the University of Tartu. The project included an analysis of the information requirements of military personnel, field experiments involving infantry fighting vehicles and armoured personnel carriers moving between different forest stands, and visibility measurements in forested areas. As a result of the project, the content of seven distinct map layers was defined. Among these, the most critical and immediate requirement identified was a clear-cut layer. Due to continuous changes in forest cover resulting from forest management activities, the availability of near real-time information on actual forest conditions was considered essential. Medium-resolution satellite imagery, including Landsat-8/9 OLI and Sentinel-2A/B MSI data, proved useful for generating such layers. With the increased use of unmanned aerial vehicles (UAVs), vertical concealment has emerged as a key knowledge requirement. Canopy cover estimates can be derived from airborne LiDAR point cloud data and were applied in the development of map layers. To support the creation of horizontal visibility layers, field measurements were conducted across 100 forest sites. These measurements were used to develop

predictive models, primarily based on LiDAR data. The presentation provides an overview of tactically relevant forest map layers and their development.

“I Always Feel Like Somebody’s Watching Me”: Observation and Control in a Gray Zone Conflict

Rick Wolfel¹

¹Department of Geography and Earth Sciences, United States Military Academy, West Point, NY, 10996

Observation is a critical aspect of any military operation. This is especially relevant in the modern operational space where tools of surveillance are omnipresent. During gray zone conflicts, observation is critical to keep the conflict from escalating.

This research examines the conflict in Northern Ireland, specifically the construction of Divis flats as a tool of observation as part of a gray zone conflict. The “Troubles” in West Belfast and its accompanying British military operation (Operation Banner) shows the complexity of a gray zone operation that intersects nationalism, counterinsurgency doctrine and political conflict. Near the center of this conflict were the Divis flats and the neighboring Divis Tower.

The flats were built starting in 1968 to solve the housing crisis in Belfast. The neighborhood became one of the most challenging environments for the British military’s counterinsurgency and security operations in Belfast. British forces were often drawn into the Divis Flats to create a spectacle and increase support for the Nationalist forces.

In his theory of the prison, Foucault emphasizes that surveillance must be “guaranteed, continuous and general.” The British Army used the nineteenth floor of Divis tower as an observation post in West Belfast during the 1970s. The height of the building not only provided the physical surveillance needed, but following Foucault’s theory of the prison, it demonstrated an attempt at control by the British government by demonstrating guaranteed, continuous, and general surveillance for all within the region.

Geography of Extraction - Strategic Competition over the Central African Copperbelt

Ronan Wordsworth¹

¹Charles University, Prague, Czech Republic

The Central African Copperbelt, spanning the Democratic Republic of Congo and Zambia, has emerged as a critical node in global competition over strategic minerals essential to the energy transition. While existing analyses predominantly frame this competition in geoeconomic terms, this paper examines the Copperbelt through the lens of military geography, emphasising how infrastructure corridors, physical terrain, and need for access shape external power projection.

The paper will examine how the three major actors including China, the United States, and the European Union, are pursuing competing strategies to secure access to copper and cobalt resources deemed critical to 21st Century industrialisation. Central to this competition is the development of transport corridors linking the interior resource basin to maritime export routes. China's long-standing engagement via the TAZARA railway and associated infrastructure reflects a strategy of embedded presence and vertical integration, while the US- and EU-backed Lobito Corridor represents a reconfiguration of westward access routes aimed at diversifying supply chains and reducing strategic dependence on existing Chinese controlled networks and supply chains.

By analysing these competing corridors as geopolitical and geostrategic arteries, the paper highlights how infrastructure functions as both an economic enabler and a mechanism for spatial control. The study integrates resource analysis and corridor vulnerability assessment to demonstrate how geography constrains and enables competing external actors, as well as complimentary paths that are pursued to achieve geopolitical goals including security provision and backroom diplomacy. It further explores how host states leverage this competition to maximise agency, balancing external partnerships while attempting to localise value chains.

Ultimately, the paper argues that the Copperbelt should be understood not merely as a site of resource

extraction, but as a contested strategic space where infrastructure, geography, and external influence intersect. This conceptualisation provides a framework for understanding how future competition over critical minerals may evolve in other resource-rich regions.