

UTILIZING OPEN-SOURCE INTELLIGENCE AND SATELLITE IMAGERY FOR ANALYSIS OF CHINA'S MILITARY MODERNIZATION

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Abstract: The exponential growth of open-access satellite data and analytical platforms is transforming the landscape of modern intelligence collection. This article explores the strategic and operational utility of OSINT derived from satellite imagery, emphasizing how GEOINT can be integrated with publicly available data to support national security, environmental monitoring, and military analysis.

With the proliferation of high-quality satellite missions, intelligence analysts now possess powerful observation capabilities without relying on classified or commercial sources.

The practical part presents a case study on China's military modernization. Using multi-temporal satellite imagery, the analysis identifies potential expansions of airfields, missile systems, and naval facilities. This demonstrates how satellite-based OSINT can provide actionable intelligence without access to classified sources, thereby enhancing both situational awareness and long-term monitoring capabilities for state and non-state actors alike.

ИЗПОЛЗВАНЕ НА РАЗУЗНАВАНЕ С ОТВОРЕН ДОСТЪП И САТЕЛИТНИ ИЗОБРАЖЕНИЯ ЗА АНАЛИЗ НА ВОЕННАТА МОДЕРНИЗАЦИЯ НА КИТАЙ

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Ключови думи: GEOINT, OSINT, военната модернизация на Китай, сателитни данни

Резюме: Експоненциалният растеж на сателитните данни с отворен достъп и аналитичните платформи трансформира пейзажа на съвременното събиране на разузнавателна информация. Тази статия изследва стратегическата и оперативна полезност на OSINT, извлечен от сателитни изображения, като подчертава как GEOINT може да се интегрира с публично достъпни данни, за да подпомогне националната сигурност, мониторинга на околната среда и военния анализ.

С разпространението на мисии с висококачествени сателити, разузнавателните анализатори разполагат с мощни възможности за наблюдение, без да разчитат на класифицирани или търговски източници. Практическата част провежда казусово проучване върху военната модернизация на Китай. Използвайки мулти-времеви сателитни изображения, анализът идентифицира потенциални разширения на летища, ракетни системи и военноморски съоръжения. Това демонстрира как сателитният OSINT може да осигури действена разузнавателна информация без достъп до класифицирани източници, като по този начин подобрява както ситуационната осведоменост, така и дългосрочните възможности за мониторинг за държави и недържавни актьори наравно.

Introduction OSINT and Satellite Imagery

Open-Source Intelligence (OSINT) refers to the systematic collection, processing, and analysis of information derived from publicly accessible sources. OSINT encompasses a wide spectrum of materials, including traditional media, governmental open data, academic literature, and digital content disseminated through the internet and social media platforms [1]. Satellite imagery, in contrast, has traditionally been classified under Imagery Intelligence (IMINT) and Geospatial

Intelligence (GEOINT), involving the acquisition and interpretation of visual or sensor-based data collected from airborne and spaceborne platforms. For much of the twentieth century, satellite imagery intelligence was primarily the preserve of governmental agencies and classified programs, distinctly separated from open information streams.

In recent years, however, the boundary between these domains has become increasingly blurred. The proliferation of commercial satellite constellations and the emergence of advanced analytical technologies have facilitated the integration of satellite imagery within the OSINT discipline. The growing accessibility of high-resolution, cost-effective, and even near-real-time satellite data has transformed open-source analytical capabilities, enabling comprehensive observation of global events without reliance on classified sources.

This convergence of OSINT and GEOINT represents a paradigm shift in contemporary intelligence practice. It allows both state and non-state actors to exploit unclassified satellite imagery for situational awareness, crisis monitoring, and strategic decision-making, thereby democratizing access to geospatial intelligence and redefining traditional notions of secrecy in the intelligence domain. In parallel with the expansion of OSINT, IMINT has followed its own distinctive evolutionary trajectory. The origins of IMINT can be traced back to aerial reconnaissance photography during the First and Second World Wars, when aircraft-based imagery provided critical insights into enemy capabilities and movements. The advent of satellite technology in the mid-twentieth century marked a major turning point in the development of remote sensing and strategic intelligence. The early generation of reconnaissance satellites-most notably the U.S. CORONA program of the 1960s delivered imagery of previously inaccessible or denied territories. However, these capabilities remained highly classified and were restricted to governmental intelligence agencies. For several decades thereafter, satellite-based IMINT was an exclusive domain of the superpowers, employed primarily for strategic surveillance tasks such as monitoring missile installations, military deployments, and other defense-related infrastructure, far removed from public access or transparency.

Institutionally, nations established specialized organizations to manage and exploit imagery intelligence. In the United States, for instance, imagery functions were gradually consolidated into the National Geospatial-Intelligence Agency (NGA) by the early 2000s, reflecting the growing importance of integrating spatial and visual data for national security purposes. The conceptual framework of Geospatial Intelligence (GEOINT) [2] subsequently emerged to highlight the fusion of imagery and geospatial information for enhanced mapping, situational awareness, and analytical applications. Nevertheless, until the closing years of the twentieth century, access to high-resolution satellite imagery remained tightly restricted, with most data classified or under stringent governmental control.

One of the most significant advancements in recent years has been the rapid improvement in satellite image resolution and collection frequency. Early commercial Earth observation satellites in the early 2000s typically provided imagery with a spatial resolution of approximately one meter and could revisit a specific location only once every several days or even weeks. Contemporary commercial platforms, however, have transformed this landscape. Systems such as Maxar WorldView constellation are now capable of delivering optical imagery with a resolution of up to 30 cm, allowing for the identification of individual vehicles, small buildings, and other fine-scale surface features.

Simultaneously, the emergence of large constellations of small satellites. This unprecedented revisit frequency allows analysts to obtain near-continuous updates on ground-level developments, offering temporal and spatial coverage that would have been inconceivable only two decades ago. The expansion of the satellite imaging industry, driven by declining launch costs, advances in sensor miniaturization, and the rise of private-sector innovation, has dramatically increased the number of active Earth observation platforms. Recent analyses indicate that the total number of operational satellites dedicated to Earth observation has multiplied several-fold over the past five years, largely due to commercial launches. As a result, an extensive temporal archive of imagery now exists, often enabling retrieval of visual data from almost any point on the planet within the preceding 24 hours or even in some cases, even within the past few hours.

For open-source intelligence practitioners, this abundance of high-temporal and very-high-resolution (VHR) imagery represents a transformative capability. Critical global events such as missile launches, natural disasters, or military mobilizations can be monitored and analyzed in near-real time rather than retrospectively. Recent studies [3] demonstrate how VHR satellite imagery has been employed to document and visualize armed conflicts, including the movement of military assets and the destruction of critical infrastructure shortly after such events occur. This unprecedented timeliness significantly enhances the analytical power of OSINT, enabling rapid verification or refutation of information through direct geospatial observation effectively providing analysts with “eyes in the sky” for real-time situational awareness.

OSINT Methodologies and the Intelligence Cycle

The integration of open-source intelligence (OSINT) with satellite imagery necessitates a robust theoretical foundation that bridges methodologies in intelligence analysis and geospatial science. As satellite-based remote sensing becomes increasingly democratized via open data initiatives and commercial platforms, the ability to extract actionable intelligence from such imagery hinges not only on technical expertise in data processing but also on a nuanced conceptual grasp of how intelligence is systematically structured, generated, and validated.

As defined by NATO and by U.S. intelligence authorities [4], OSINT encompasses publicly and legally obtained information that is systematically validated, analyzed and disseminated to address specific intelligence requirements. The U.S. government definition characterizes OSINT as information collected [5], exploited and disseminated in a timely manner to the appropriate audience for intelligence purposes emphasizing both the legal and open nature of its sources.

OSINT adheres to the classical intelligence cycle [6] comprising the stages of planning and direction, collection, processing and exploitation, analysis and production, and dissemination, while adapting each phase to the unique characteristics of opensource data. Each step of the OSINT workflow places a strong emphasis on the legality, transparency and ethical integrity of information gathering. Unlike covert forms of intelligence such as HUMINT, OSINT practitioners rely exclusively on publicly available sources, however, they employ comparable analytic tradecraft. Analysts must critically assess source reliability, maintain objectivity by countering confirmation bias and subject their conclusions to peer or supervisory review. The intelligence cycle provides a systematic framework ensuring that OSINT activities remain structured, goal-oriented and aligned with decision-making needs.

Every intelligence process begins with structured planning, and OSINT follows the same logic. During this phase, analysts define key intelligence questions, identify information requirements, and translate them into a collection strategy focused on open sources. Tasks may include monitoring military movements or gathering recent satellite imagery of border zones each tied directly to decision-makers needs. Effective OSINT planning also determines which datasets, repositories or platforms will yield the most relevant information while ensuring legal and ethical compliance [7]. Analysts document sources, keywords, and timeframes, creating a structured plan that aligns with laws on data protection and privacy. The outcome is a clear, lawful and goal-oriented framework that directs all subsequent collection efforts.

The Collection phase implements the intelligence plan by systematically gathering raw data from open sources, including media, public databases, satellite imagery, and social networks. Modern OSINT employs automated tools (web crawlers, API queries) alongside manual research to acquire relevant, legally accessible data, while maintaining overt compliance and avoiding unauthorized access. To combat data overload, analysts prioritize high-value sources, for example, Copernicus imagery or AIS data for military tasks, or extremist forums and regional media for terrorism analysis. Through filtering and prioritization, this phase yields targeted raw datasets for subsequent processing. In the Processing phase, raw OSINT data is refined into structured, analysis-ready formats via cleaning, deduplication, standardization, translation, and metadata tagging. Tools like OCR enable text extraction, while translation systems ensure linguistic accessibility. Given the prevalence of noise and misinformation in open data, this stage is essential for upholding reliability and integrity. Additional steps, such as geolocation, time-tagging, GIS integration, image calibration, enhancement, and change detection, convert visuals into actionable GEOINT [8], resulting in a coherent, validated dataset organized chronologically and thematically. The Analysis and Production phase forms the interpretive core of OSINT, where analysts assess source reliability and information accuracy through cross-validation across independent sources to counter misinformation. Employing pattern recognition, spatio-temporal analysis and data correlation [9], they uncover trends and anomalies, with machine learning aiding in insight generation but human judgment remaining pivotal. The outcome is a validated OSINT report that delivers evidence-based conclusions addressing the initial intelligence requirements.

Observing China military modernization using OSINT and GEOINT

China's rapid military modernization over the past decade has increasingly come into focus through the combined application of OSINT and GEOINT. Unlike traditional classified intelligence, OSINT-GEOINT relies on publicly available data ranging from commercial satellite imagery to open online sources to monitor developments [10] within the People's Liberation Army (PLA). While many aspects of China's defense expansion remain opaque, high-resolution optical and radar satellite imagery, combined with open-source data analytics, has provided unprecedented insight into the scope and pace of Beijing's military advances. Notably, several key discoveries about the PLA's evolving capabilities have originated not from government intelligence agencies but from independent

researchers employing tools such as Google Earth, Sentinel imagery and commercial satellite constellations. These findings have rendered previously hidden developments such as the construction of new missile silo fields, naval bases, and stealth aircraft production facilities visible to the global analytical community.

Among the most revealing aspects of this modernization is the expansion of the PLA Rocket Force (PLARF), responsible for China's land-based ballistic and cruise missile arsenal. Open-source satellite monitoring has enabled analysts to document the proliferation of missile brigades, new launch systems, and extensive silo construction across the country. Over the past decade, China has roughly doubled the number of operational missile brigades while introducing new dual-capable conventional nuclear platforms and hypersonic glide vehicles, signaling both quantitative and qualitative improvements in strategic capability [11]. This section examines two principal trends – the buildup of conventional missile brigades and intermediate-range systems and the emergence of fixed missile infrastructure, particularly silo fields for intercontinental ballistic missiles (ICBMs), as identified through open-source satellite observation.

Although the overall launcher count has remained relatively stable since 2022, major construction projects are transforming key PLARF facilities. A notable example is the redevelopment of the 611th Brigade compound (30.6903° N, 117.9011° E) near Rongcheng, east of Chizhou in Anhui Province. President Xi Jinping inspected this site in October 2024, where he was briefed on the unit's modernization and observed training with the DF-26 intermediate-range ballistic missile, which has replaced the older DF-21A system since 2021. Satellite imagery from 2024–2025 reveals that an extensive redevelopment program initiated in 2023 is nearing completion, transforming the complex into a purpose-built DF-26 base – a configuration unprecedented among known PLARF facilities (Kristensen et al. 2025) (Figure 1).



Fig. 1. 611 Brigade near Chizhou [12]

China's modernization of the PLARF extends well beyond the 611th Brigade in Anhui. A broader series of garrisons is being reshaped to accommodate the DF-26 IRBM (Biggers 2024), facilitating deployment across China's northwestern regions (Figures 2 and 3). One of the most visible indicators of this expansion was observed at the 642nd Brigade's training grounds near Datong, Qinghai, where commercial satellite imagery from March 2022 captured roughly two dozen DF-26 TELs positioned along newly constructed firing pads tracing a mountain valley west of Changwu. Analysts believe these launchers were deployed for advanced field exercises at Base 64's missile school near Xining before reassignment to permanent bases elsewhere.

That permanent base is now widely assessed to be the 647th Brigade compound under construction approximately 240 km north-northwest of Datong, near Zhangye. The garrison's twin semicircular berms and 12 drive-through garages per arc appear purpose-built for a 24-launcher DF-26 unit the same formation observed at Datong strongly suggesting an imminent relocation upon completion. With Zhangye operational, PLARF will field eight DF-26 brigades, though open-source assessments indicate that only a fraction of the roughly 250 launchers are equipped with nuclear

payloads. Approximately 100 nuclear warheads are believed assigned, given that the missile exists in three primary variants, including a conventional-only anti-ship model.

The 646th Brigade at Korla exemplifies Beijing's emerging "swing-role" philosophy, training to conduct both conventional and nuclear missions. Crews reportedly practice rapid in-field warhead exchanges without removing the missile from its launcher. While this flexibility supports China's doctrine of escalation control and deterrence versatility, it introduces serious crisis-management challenges: adversaries monitoring satellite imagery cannot discern whether a launcher [13] is armed with a conventional or nuclear warhead, thereby increasing the risk of misinterpretation.



Fig. 2. DF-31AG on the road are within the boundaries of new military training zone

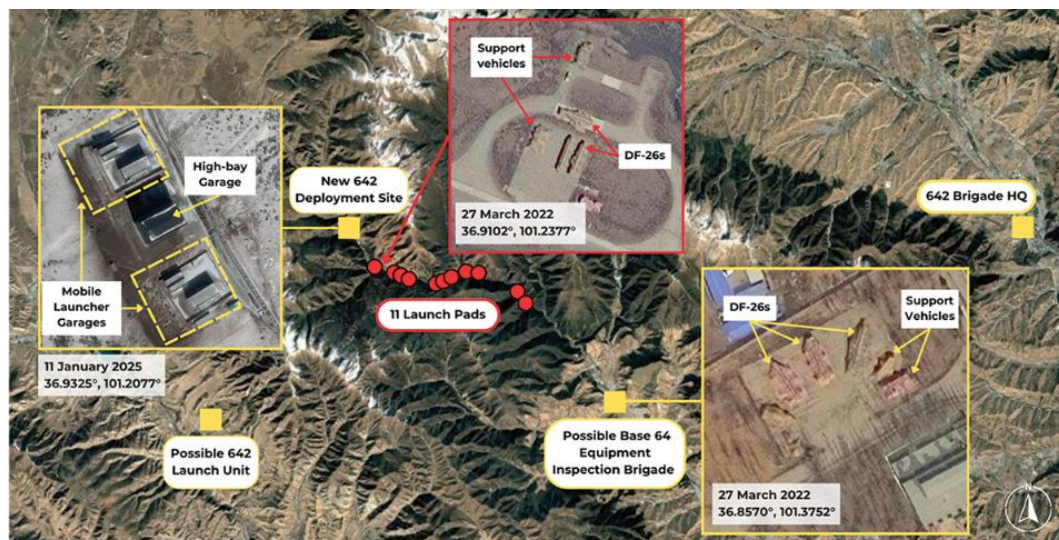


Fig. 3. DF-26 launchers and DF-31AG missile infrastructure [14]

The Pentagon's 2024 China Military Power Report identifies the DF-26 as "the most likely weapon system to field a lower-yield warhead in the near term," a view reinforced by U.S. Strategic Command's 2025 testimony, which highlights China's investment in precision, theater-range systems. Meanwhile, earlier speculation that the DF-17 hypersonic-glide missile might adopt a nuclear role has faded - recent U.S. reports classify it solely as conventional, and the older DF-21A medium-range ballistic missile has been omitted from the latest nuclear inventories. Collectively, the Datong exercise, the near-complete Zhangye garrison, and U.S. assessments of lower-yield developments underscore the DF-26's emergence as the PLARF's principal theater-range platform, a dual-capable system that blurs the line between conventional deterrence and nuclear signaling across the western Pacific.

Conclusion

By combining open-access satellite imagery with systematic intelligence analysis, researchers can now detect and assess key military trends from infrastructure expansion and missile deployments to organizational reforms—using purely public data.

The case study of the PLARF illustrates how multi-temporal satellite monitoring enables accurate identification of new missile garrisons, launcher deployments, and doctrinal shifts. The observed proliferation of DF-26 intermediate-range ballistic missiles and the construction of new facilities, such as those in Anhui and Zhangye, demonstrate both the scale and sophistication of China's evolving strategic capabilities. More importantly, these findings highlight how geospatial intelligence can reveal not only physical changes but also deeper strategic intentions, such as Beijing's move toward dual-capable and rapid-response systems.

Ultimately, this research underscores the growing analytical power and strategic value of satellite-based intelligence. The democratization of high-resolution imagery and advanced analytic tools allows state and non-state actors alike to enhance situational awareness, verify information independently, and contribute to transparency in global security affairs. As the accessibility and precision of satellite data continue to expand, OSINT–GEOINT fusion will remain an essential methodology for monitoring military modernization, supporting informed policymaking, and strengthening the broader framework of international stability and arms control.

References:

1. Colquhoun, C. A brief history of open-source intelligence. Bellingcat, 2016-07-14. Available online at: <https://web.archive.org/web/20250627035723/https://www.bellingcat.com/resources/articles/2016/07/14/a-brief-history-of-open-source-intelligence/>
2. Van Wyk, J. Pixels, politics and peace: the forensic use of satellite imagery. *Journal of African Foreign Affairs*, 6(2), 31–50, 2019. Available online at: <https://www.jstor.org/stable/26798960>
3. Bennett, M. M., et al. Improving satellite monitoring of armed conflicts. *Earth's Future*, 10(9), e2022EF002904, 2022. <https://doi.org/10.1029/2022EF002904>
4. Office of the Director of National Intelligence and Central Intelligence Agency, *Intelligence Community OSINT Strategy 2024–2026*. Washington, DC, 2024. Available online at: <https://web.archive.org/web/20250627040237/https://www.dni.gov/index.php/newsroom/reports-publications/reports-publications-2024/3785-the-ic-osintstrategy-2024-2026>
5. Nikolov, B. and D. Nikolov. A scenario-based approach to cybersecurity training for seafarers. In: *Proceedings of the 24th International Association of Maritime Universities (IAMU) Conference*, Massachusetts Maritime Academy, United States, 2024, pp. 385–390. ISSN: 2706-6762
6. Adams, S. The intelligence cycle: generating OSINT from OSINF. *Skopenow Blog*, 2022-03-25. Available online at: <https://web.archive.org/web/20250627035434/https://www.skopenow.com/news/the-intelligence-cycle-creating-osint-from-osinf>
7. Pedram, M., et al. When open-source information backfires: satellite imagery and privacy breaches. *Vanderbilt Journal of Transnational Law*, 58(1), 119–156, 2025
8. Sutherland, M. The augmentative effect of AI in the OSINT cycle. *The Security Distillery*, 2021-07-17. Available online at: <https://web.archive.org/web/20250627035919/https://thesecuritydistillery.org/all-articles/the-augmentative-effect-of-ai-in-the-open-source-intelligence-cycle>
9. Dimitrov, I. et al. Design and implement an automatic smart buoy system for Bulgarian safe beach areas – Part 1. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 19(2), 381–386, 2025. <https://doi.org/10.12716/1001.19.02.05>
10. Colonna Vilasi, A. The intelligence cycle. *Open Journal of Political Science*, 8, 35–46, 2018. <https://doi.org/10.4236/ojps.2018.81003>
11. Zhu, Z., et al. Benefits of the free and open Landsat data policy. *Remote Sensing of Environment*, 224, 382–385, 2019. <https://doi.org/10.1016/j.rse.2019.02.001>
12. Kristensen, H. M., et al. Chinese nuclear weapons, 2025. *Bulletin of the Atomic Scientists*, 2025-03-12. Available online at: <https://web.archive.org/web/20250627060903/https://thebulletin.org/premium/2025-03/chinese-nuclear-weapons-2025/>
13. Biggers, C. China expands DF-26 launcher inventory. *Janes*, 2024-10-25. Available online at: <https://web.archive.org/web/20250627035558/https://www.janes.com/osint-insights/defence-news/defence/china-expands-df-26-launcher-inventory>
14. Kristensen, H. M., et al. Chinese nuclear weapons, 2024. *Bulletin of the Atomic Scientists*, 80(1), 49–72, 2024. <https://doi.org/10.1080/00963402.2023.2295206>