

## Civil-Military Knowledge Flows and the Diffusion of UAV Technologies under Economic Security Conditions

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**Abstract:** Unmanned Aerial Vehicles (UAVs) have rapidly developed as emblematic dual-use technologies in which civilian and military sectors interact and jointly shape innovation trajectories. Recent intensifications of economic security policies and geopolitical tensions suggest that both knowledge flows and international technology diffusion in the UAV domain are being reconfigured. Building on our previous analysis presented at Defense and Aerospace Unmanned Systems 2026 (DAUS 2026), this study examines the relationship between national research structures and the international diffusion of attack-type UAVs. In particular, it pays attention to heterogeneity within attack-type UAV diffusion, including differences between armed UAVs and one-way loitering munitions, by combining bibliometric analysis of approximately 180000 Scopus-indexed UAV-related publications (2001–2025) with the CNAS Drone Proliferation Dataset.

The analysis identifies a marked increase in Civil-to-Military (C2M) knowledge flows since the late 2010s, indicating the growing importance of civilian-led technological inputs in military UAV development. This shift corresponds with a structural transformation in global diffusion. Mean-shift analysis detects a first major breakpoint in 2012, when the combined supplier share of China and Turkey rose from near zero to a regime average of 0.52, followed by a second breakpoint in 2018, when the average annual number of adoption events increased from 2.7 to 24.8.

These findings suggest a staged transformation in which changes in supplier-side institutional and industrial structures preceded the subsequent expansion of international UAV adoption. Importantly, the results suggest a sequential transformation in which supply-side structural changes precede and condition subsequent diffusion expansion. Recent geopolitical shocks appear to have accelerated this process by shifting diffusion from unarmed baseline systems toward attack-capable platforms, including the rapid expansion of non-traditional suppliers such as Iran in the loitering munition segment. Overall, the study identifies a systematic alignment between (non-causal) changes in national research structures and patterns of technology diffusion, highlighting the growing role of military organizations as absorptive users of civilian-led innovation under contemporary economic security conditions.

**Keywords:** UAV diffusion, Dual-use technology, Economic security, Bibliometric analysis, Civil–military knowledge flow.

### 1. Introduction

Unmanned Aerial Vehicles (UAVs) represent one of the most rapidly diffusing military technologies [1], with the proliferation of reusable armed UAVs and one-way loitering munitions fundamentally transforming modern military operations [2]. This

diffusion process represents a staged transformation often catalyzed by geopolitical shocks. Simultaneously, UAV technologies are becoming pervasive in civilian domains such as agriculture, logistics [3], and disaster response [4, 5], further blurring the technological boundaries between military and civilian sectors.

As geopolitical competition intensifies, UAV-related technologies have increasingly become subject to economic security policies, including export controls, research-security regimes, and procurement restrictions [6]. This perspective aligns with the concept of “weaponized interdependence,” in which states leverage their position within global technological and economic networks to exert strategic influence through regulatory and access-based mechanisms [6]. Technological development in such fields does not proceed in a linear manner from basic research to application, but evolves through iterative interactions among knowledge production, use environments, and institutional conditions [7].

In the development of such dual-use technologies, the direction and intensity of knowledge flows – specifically transfers from civilian research to military applications and vice versa – play a decisive role in shaping technological trajectories [6, 8]. However, systematic empirical analysis focusing explicitly on these civil–military knowledge flows within the UAV domain remains limited, particularly regarding the military domain's role as an absorptive user of civilian-led innovations during the shift from unarmed to attack-type platforms.

Building on our previous conference paper presented at DAUS 2026 [9], the present study extends the earlier analysis in three respects. First, it disaggregates attack-type UAV diffusion into reusable armed UAVs and one-way loitering munitions, allowing a closer examination of heterogeneity in supplier structure and diffusion pathways. Second, it explicitly distinguishes Civil-to-Military (C2M) and Military-to-Civil (M2C) citation flows in order to

analyze the directional structure of knowledge circulation. Third, it more systematically integrates bibliometric evidence with the CNAS diffusion dataset, linking changes in citation structures to shifts in supplier composition and proliferation volume.

To do so, the study combines two types of evidence. First, it analyzes directional citation flows – Civil-to-Military (C2M) and Military-to-Civil (M2C) – within a large corpus of Scopus-indexed UAV-related publications (2001–2025). Second, it relates these knowledge-flow patterns to updated international diffusion data for attack-type UAVs (1995–2023) based on the CNAS Drone Proliferation Dataset [10]. This design allows us to examine whether changes in knowledge circulation correspond to structural shifts in supplier composition and proliferation volume.

## 2. Data and Methodology

The analysis utilizes a bibliometric dataset of 182291 UAV-related publications indexed in Scopus over the period from 2001 to 2025, based on records retrieved on 1 December 2025. Fig. 1 provides an overview of the Scopus search and rule-based classification procedure, while the full search query and keyword dictionaries are reported in Appendix A for transparency and reproducibility. To improve transparency, the rule-based search logic and classification criteria used for military, civilian, and dual-use categories are described more explicitly in this section, and the full search query and keyword dictionaries are provided in Appendix A.

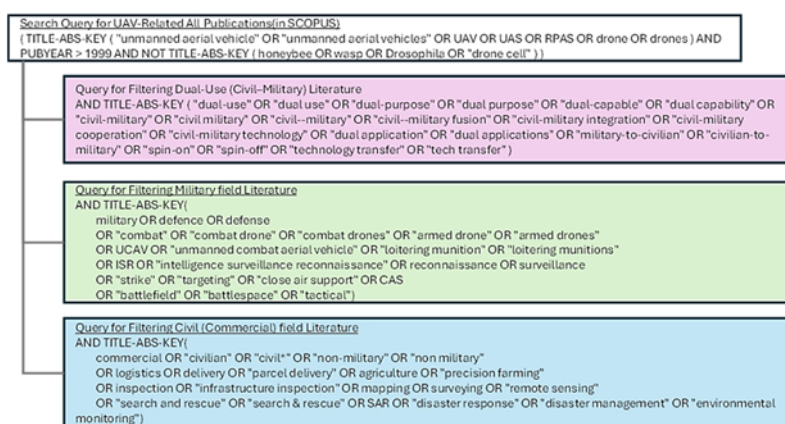


Fig. 1. Overview of the Scopus search and rule-based classification procedure.

The classification is based on keyword filters applied to titles, abstracts, and author keywords, and is intended as an analytical coding procedure for identifying directional knowledge relationships rather than as a definitive classification of all UAV-related publications. It is not designed to exhaustively label the full literature, but to provide directional signals for citation-based analysis, which serves as the primary

basis of the analysis. In the present study, the dual-use category refers to records explicitly identified through dual-use-related terms, while directional citation analysis is used separately to capture cross-domain knowledge relationships. Using this procedure, we classified the literature into military (23024), civilian (57720), and dual-use (332) categories, building on the classification approach developed in our

earlier study [9]. The remaining approximately 100000 publications primarily consist of foundational research that lacks domain-specific labels but serves as a technological resource for both sectors. Although only 332 papers are explicitly labeled as “dual-use,” the much larger volume of C2M citations suggests that the dual-use character of UAV technology is more visible in cross-domain knowledge absorption than in formal publication labels. Two directional citation indicators were then constructed: C2M citations, representing military absorption of civilian research (“spin-on”), and M2C citations, representing civilian spillovers from military research (“spin-off”).

In parallel, we utilized the CNAS Drone Proliferation Dataset, which tracks drone transfers from 1995 to 1 September 2023 [10], to analyze the international spread of attack-type UAV systems across countries and over time. A small number of earlier entries (1992–1993) appear in the raw dataset; however, these correspond to non-armed UAV observations and fall outside the attack-type UAV subset used in this study, and therefore do not affect the results reported here. In this study, following the CNAS codebook definitions, the category of “attack-type UAVs” is disaggregated into two distinct platform types: reusable armed UAVs (weapons-capable platforms) and one-way loitering munitions (kamikaze drones). To ensure transparency in platform selection, Appendix Table A1 lists the representative series included in the diffusion analysis, grouped by major supplier country. The appendix table is intended to clarify the operational scope of the dataset rather than to provide an exhaustive inventory of all variants and sub-models.

The dataset includes representative platforms that can be broadly grouped into two distinct diffusion models. The first is a high-end, state-centric model led by the United States and Israel, centered on MALE-type and other high-performance UAVs such as the MQ-1 Predator, MQ-9 Reaper, Heron TP, and Hermes 450. These systems typically rely on state-led R&D and procurement, long-endurance operations, beyond-line-of-sight control via satellite communications, advanced ISR payloads including EO/IR and SAR, and, in armed variants, precision-strike weapons such as the AGM-114 Hellfire. Within this broader diffusion landscape, loitering munitions such as the Harpy, Harop, SkyStriker, and the HERO series represent a more adaptive and cost-conscious segment. These systems generally emphasize loitering capability, flexible target engagement, and lower-cost precision attack, often using combinations of anti-radiation seekers or EO/IR-based man-in-the-loop guidance.

The second is an export-oriented and adaptive model, represented by emerging systems from China, Turkey, and Iran. These suppliers emphasize accessibility, exportability, and rapid iteration, including China’s CH and Wing Loong series, Turkey’s Bayraktar TB2, Akinci, and ANKA series, and Iran’s Ababil and Shahed series, which have

recently established significant footprints outside traditional Western networks.

By combining these bibliometric indicators with documented international platform transfers, this study empirically connects shifts in national research structures with the staged transformation of global technological proliferation. This methodology allows for a systematic examination of how critical structural breaks – such as the 2012 supplier share shift and the 2018 acceleration in adoption – correlate with the military domain’s evolving capacity to absorb civilian-led innovations.

### **3. Results**

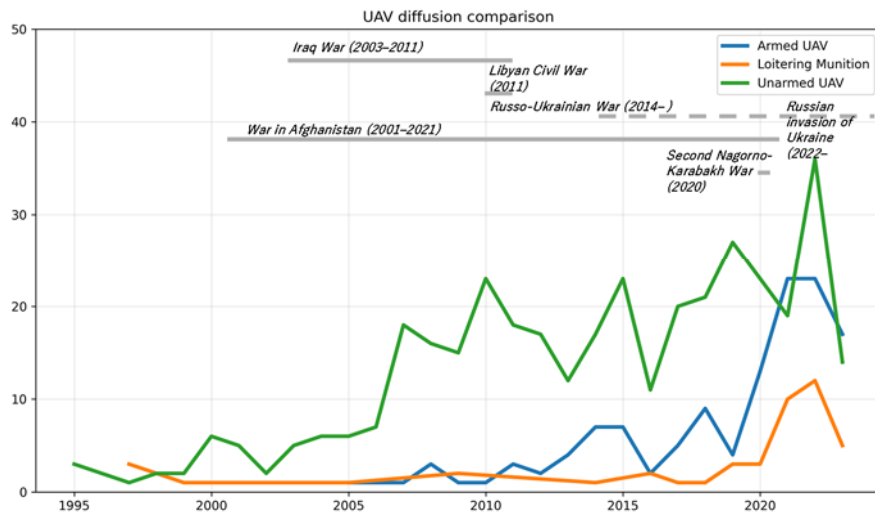
#### **3.1. International Diffusion of Attack-Type UAVs**

The global diffusion of attack-capable UAVs has undergone a structural shift described as a staged transformation, where the widespread adoption of unarmed systems provided the foundation for a subsequent surge of attack-type platforms (see Fig. 2). This process was significantly catalyzed by geopolitical shocks, with a structural breakpoint in 2018, when the annual average number of adoption events increased from 2.7 to 24.8 (see Fig. 7b for details). While the 2000s were dominated by the U.S.–Israel-led high-end/state-centric model, the late 2010s have been defined by China- and Turkey-centered export-oriented/adaptive models. This shift is characterized by greater accessibility and a rapid increase in the volume of international transfers, where competitive advantage is increasingly associated with development speed and the capability to incorporate operational feedback.

To clarify how this overall shift was distributed across suppliers and platform types, the next section disaggregates diffusion patterns by country and system category.

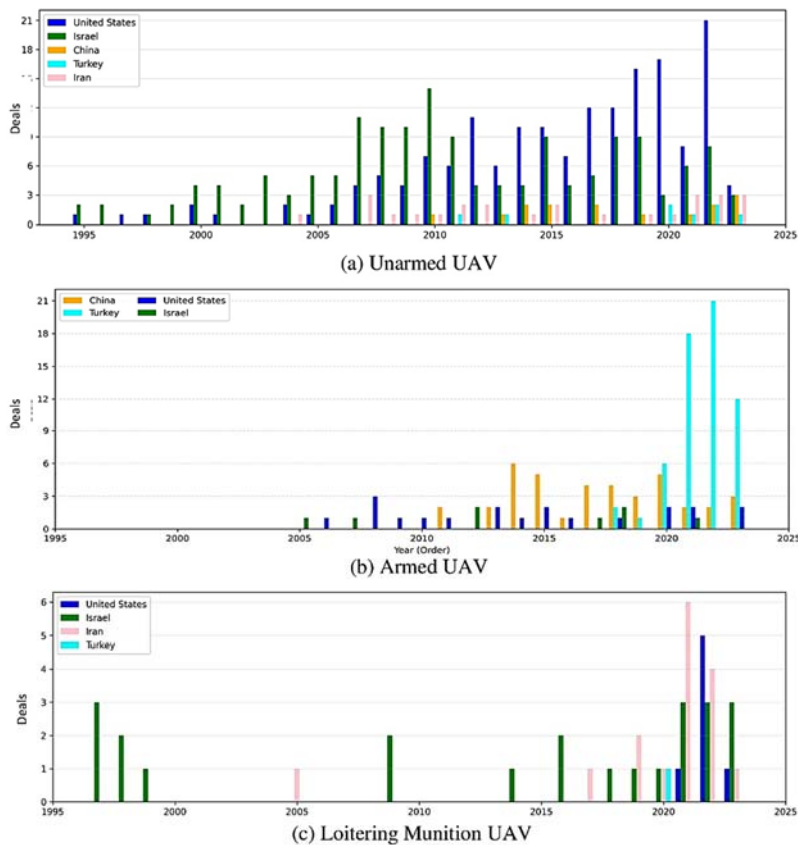
#### **3.2. Regional Diffusion Patterns and Platform Dominance**

Taken together, Figs. 3-5 show diffusion at three connected levels: supplier composition, regional network expansion, and platform-level transfer volume. Fig. 3 disaggregates global UAV proliferation by supplier country and platform type. The figure shows that unarmed UAV diffusion was initially led by the United States and Israel, whereas the later spread of armed UAVs increasingly involved China and Turkey. In the loitering munition segment, Israel appears as an early supplier, while Iran emerged rapidly in the late 2010s and early 2020s. These country-level differences indicate that the diffusion of UAV technologies has become more diversified over time, with distinct supplier profiles depending on platform type.



**Fig. 2.** Comparison of UAV diffusion by type (1995–2023).

**Note:** The figure illustrates the temporal evolution of adoption events across unarmed UAVs, armed UAVs, and loitering munitions. The results indicate a gradual transition from early commercial UAV diffusion to increased adoption of armed UAVs and loitering munitions in recent years.



**Fig. 3.** Global Proliferation of UAVs by supplier country.

**Note:** To minimize gaps in the time-series data, the annual number of UAV adoption events prioritizes the "Year of Order" from the CNAS dataset. Where this data is missing, it is supplemented by the "Year of First Delivery," followed by the "Year Identified, Completed, or Canceled" and the "Year of Interest" to ensure maximum data coverage.

The expanded regional supplier–seeker network reveals distinct geopolitical footprints among the six major suppliers (see Fig. 4). While the United States and Israel maintain strong ties with seekers in Europe and the Asia-Pacific, China and Turkey have established particularly strong positions in the Middle

East and Africa through their export-oriented/adaptive models. Notably, Iran has developed distinctive supply routes to the Americas (specifically Venezuela) and East Africa (e.g., Ethiopia and Sudan), suggesting a diversification of supply channels outside traditional Western-centered networks.

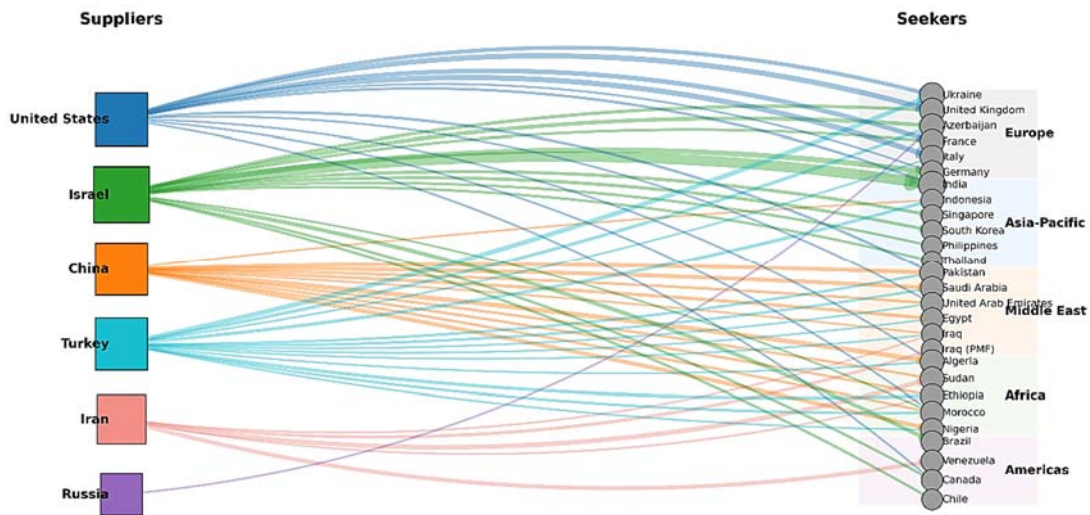


Fig. 4. Expanded Regionalized Supplier-Seeker Network of Attack-type UAV Diffusion.

Transfer volume data by series further clarifies the drivers of this diffusion (see Fig. 5). The Bayraktar TB2 (Turkey) stands out as a particularly notable case in the adaptive category for reusable armed UAVs, with more than 40 documented transfer events, second only to Israel’s long-standing Hermes/Heron series.

Furthermore, specifically in the loitering munition segment, Iranian series such as the Ababil and Shahed series exhibit transfer volumes comparable to established Chinese platforms such as the Wing Loong series and have become primary drivers of proliferation in recent conflict zones.

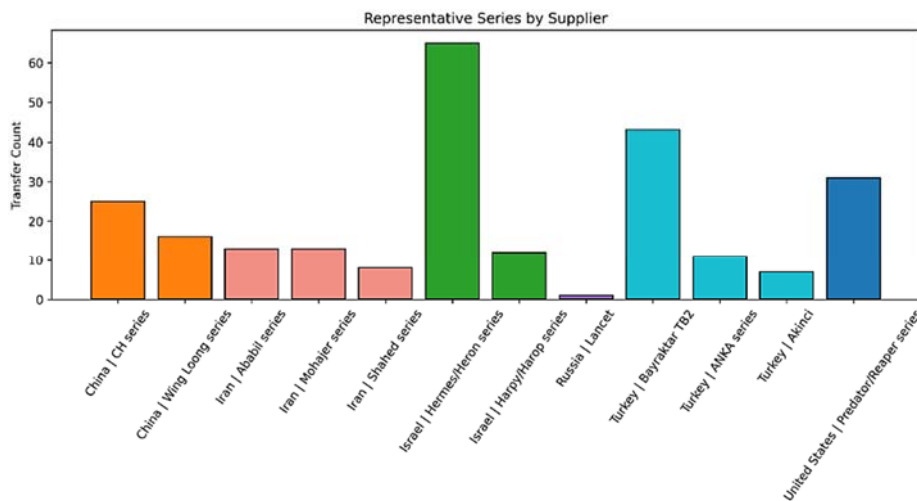


Fig. 5. Representative Attack-type UAV Series by Supplier.

These observations suggest that the staged transformation identified in this study is driven not only by increased transfer volume, but also by the emergence of highly competitive non-traditional supplier models that rapidly weaponize the civilian-led technological base while prioritizing accessibility and regional strategic alignment.

### 3.3. Military/Civil Publication Ratio (Fig. 6)

To interpret the knowledge conditions underlying this diffusion shift, we next examine whether the

research base itself has become more civilian-led over time.

Globally, UAV-related publications have increased steadily since the early 2000s, with particularly rapid growth after 2014. Analysis of the Military/Civil publication ratio reveals a global trend toward civilian-led knowledge production, as the ratio has declined in most countries since 2001. This highlights the growing importance of commercial technologies – such as sensors, autonomy, and AI – as foundational inputs into UAV development. This suggests that the knowledge base has structurally shifted toward civilian-dominated production, increasing the potential for military absorption.

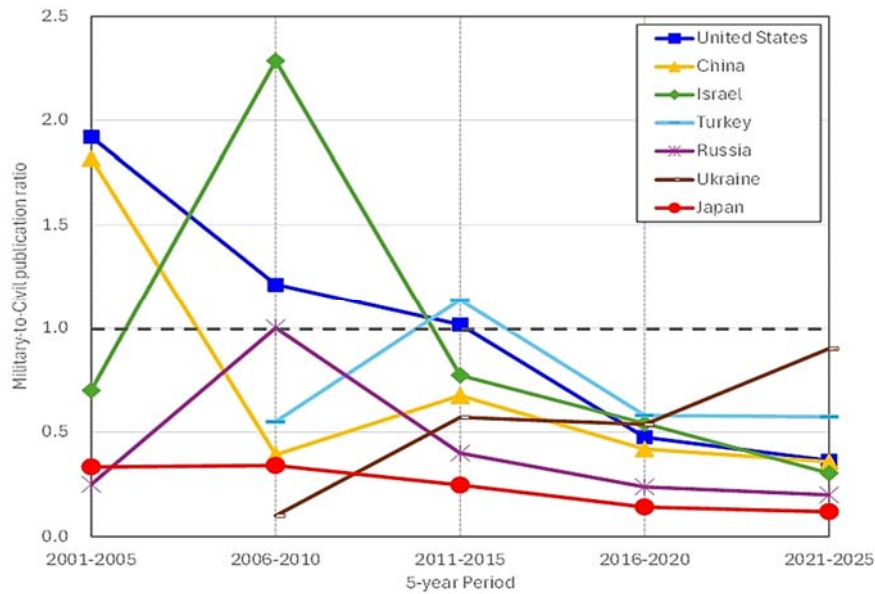


Fig. 6. Military/Civil UAV Publications Ratio by Country (5-year periods).

This civilian-led knowledge base provides a reservoir that military domains can absorb during periods of strategic necessity. Ukraine is an important exception, showing a more security-driven knowledge structure from the mid-2000s onward.

### 3.4. Structural Break Analysis of Proliferation Dynamics (Fig. 7)

To identify structural changes in UAV proliferation, we applied a two-regime Poisson mean-shift model to annual adoption data and a mean-shift model to supplier shares for the period 2000 to 2023. The estimation procedure follows a likelihood-based segmentation approach, in which candidate breakpoints are evaluated by comparing model fit across alternative partitions of the time series using a penalized criterion (BIC). These procedures are used here as exploratory tools for detecting regime-level discontinuities in the data. The analysis identifies two critical breakpoints. First, a shift in the supplier base occurred in 2012, after which the combined average share of China and Turkey for the subsequent regime rose from near zero to 0.52 (52 %) (Fig. 7a). Second, a major break in proliferation volume was detected in 2018, when the average annual number of proliferation events shifted from 2.7 to 24.8 (Fig. 7b). The identified breakpoints are interpreted as empirically observed structural shifts without causal identification rather than as definitive causal estimates.

Together, these results demonstrate the staged nature of this transformation in UAV diffusion, in which structural changes in the supplier ecosystem around 2012 established the supply-side capacity that was subsequently activated by geopolitical shocks. These shocks acted as catalysts, triggering the sharp acceleration of adoption after 2018, as seekers shifted

from unarmed systems to battle-proven armed UAVs and loitering munitions. This transition underscores the military domain's evolving role as an absorptive user capable of rapidly weaponizing the civilian technological base in response to regional conflicts.

### 3.5. Citation Relationships and Knowledge Flows (Fig. 8)

To assess whether this diffusion shift was accompanied by a corresponding reorientation in knowledge circulation, we finally examine directional citation flows.

Citation analysis reveals a clear asymmetry in knowledge circulation across national innovation ecosystems. Globally, C2M citation flows have increased significantly (reaching 91642 citations), indicating that the civilian domain has become a primary source of technological inputs for military UAV development.

In contrast, M2C citation flows exhibit more stagnant and heterogeneous patterns across major UAV-producing countries.

These observations suggest that while knowledge absorption from civilian technology (spin-on) is accelerating, it creates a pervasive technological reservoir that enables the staged transformation of the ecosystem, allowing the military domain to act as an "absorptive user" during strategic shocks. Conversely, spillovers back into the civilian domain (spin-off) remain uneven and dependent on specific institutional configurations.

These citation patterns should, however, be interpreted with caution, since military knowledge production is not always fully visible in open publications [11] and may therefore be underrepresented in bibliometric data.

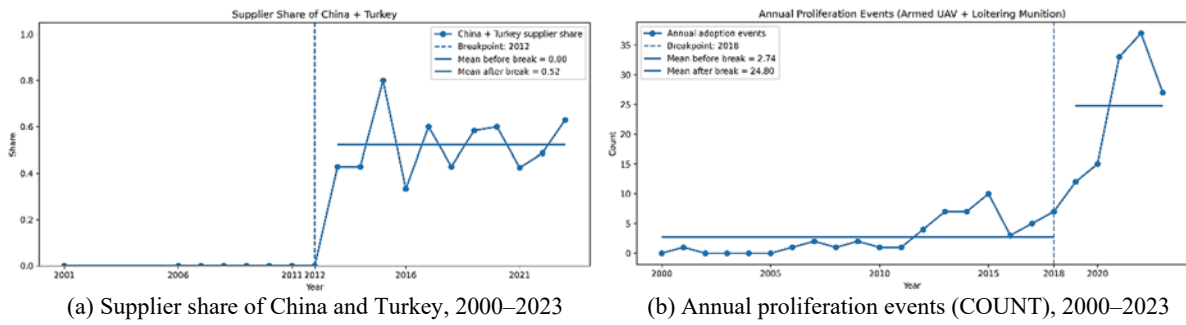
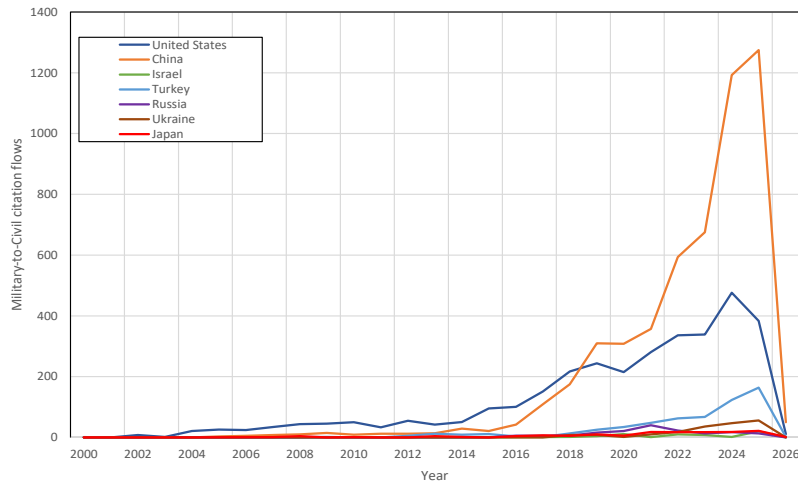
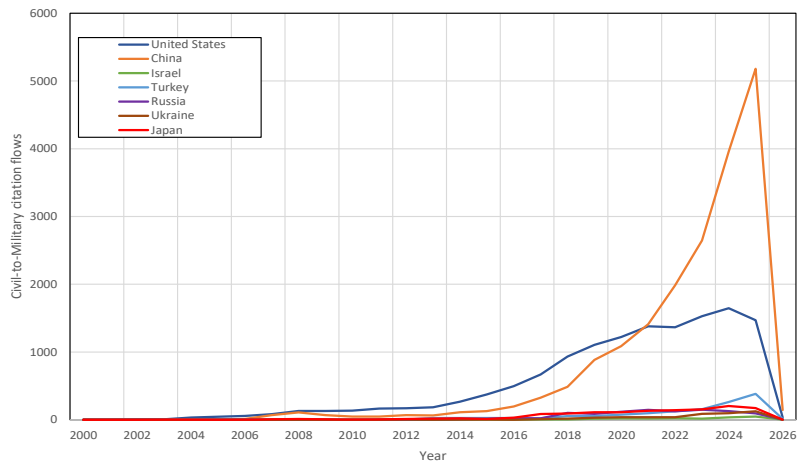


Fig. 7. Structural breaks analysis of proliferation events and armed UAV supplier shares (2000–2023).



(a) M2C citation flows



(b) C2M citation flows

Fig. 8. M2C and C2M citation flows in UAV-related research (2001–2025).

#### 4. Discussion

The main implication of these findings is that the strategic value of UAV-related innovation depends not only on indigenous technological performance, but also on how effectively civilian-led knowledge can be absorbed and mobilized under conditions of geopolitical stress. This dynamic is particularly pronounced in UAV technologies, where modular architectures, rapid iteration cycles, and operational

feedback loops enable fast translation of civilian components into deployable military systems.

Recent empirical evidence from the 2018 breakpoint suggests that this diffusion is not merely linear [7], but follows a staged transformation path where geopolitical shocks act as critical catalysts. These shocks bridge the gap between the civilian-led knowledge base and the rapid proliferation of attack-type platforms, including both reusable armed UAVs and loitering munitions. This is further

evidenced by the emergence of non-traditional suppliers like Iran, which has successfully weaponized established technology bases to capture significant shares in the loitering munition segment.

These results further suggest that under economic security constraints, the capacity to iterate and absorb external knowledge may become as decisive as the ability to translate indigenous technological performance into operational capabilities [12, 13]. This underscores the importance of adaptive supplier models, like those of Turkey and China, which established the necessary supply-side capacity (achieving a 0.52 market share) following the 2012 structural shift. Ultimately, an ecosystem's strategic impact is determined by its primary transmission channels, which dictate the speed at which accumulated civilian-led innovations are absorbed and converted into military capabilities during periods of strategic necessity.

These dynamics are consistent with broader empirical evidence that military-related innovations can diffuse as effectively as civilian ones, particularly when they function as general-purpose technologies that overcome institutional barriers [11]. Furthermore, the development of such critical technologies has been shown to generate substantial spillover effects, stimulating R&D activities across the wider innovation ecosystem, even among organizations not directly involved in military projects [14].

For Japan, this implies that economic security policy [15] should address not only the protection of critical technologies, but also the institutional constraints on civil–military integration, which may limit the effective absorption of rapidly evolving civilian UAV technologies and potentially create a structural disadvantage in adaptive capability.

## 5. Conclusion

This study yields three main findings. First, UAV research has increasingly shifted toward a structure in which military development draws on a growing civilian-led knowledge base. Second, the international diffusion of attack-type UAVs accelerated sharply from the late 2010s, following an earlier structural shift in the supplier base. Third, these results suggest a systematic correspondence between changes in knowledge circulation and patterns of technology diffusion under economic security conditions.

This study is also subject to the limitation that military knowledge is less likely to be fully disclosed in open publications, which may lead to an underestimation of military knowledge production in bibliometric and citation-based analysis. The observed relationship between knowledge circulation and technology diffusion should therefore be interpreted as a structural association rather than a causal effect.

Taken together, these findings highlight the importance of understanding knowledge circulation when analyzing the evolution of dual-use technologies under economic security conditions.

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## Appendix

Table A1 summarizes the representative attack-type UAV series included in the network and diffusion analysis. The table groups platforms by major supplier countries and distinguishes between armed UAVs and loitering munitions where relevant. Its purpose is to clarify the analytical coverage of the

study by showing which platform families were treated as representative cases in the construction of the dataset. The table should therefore be read as an operational classification for analysis, rather than as a complete catalog of all exported UAV variants.

UAV-related publications into military, civilian/commercial, and dual-use categories. The purpose of this appendix is to improve transparency and reproducibility by presenting the search logic and classification procedure in text form.

## Appendix A. Full Scopus Search Query and Operational Classification Rules

This appendix provides the full Scopus search query and the operational rules used to classify

### A1. Search Field and Retrieval Date

The bibliometric corpus was retrieved from Scopus on **1 December 2025**. The search was applied to **titles, abstracts, and author keywords (TITLE-ABS-KEY)**.

**Table A1.** Representative attack-type UAV series included in the diffusion analysis (CNAS data).

| United States      | Israel             | China                | Turkey             | Iran               |
|--------------------|--------------------|----------------------|--------------------|--------------------|
| Armed UAV          | Armed UAV          | Armed UAV            | Armed UAV          | Loitering Munition |
| • MQ-1 Predator    | • Hermes 450       | • CH-3               | • Bayraktar TB2    | • Ababil-2T        |
| • MQ-9 Reaper      | • Heron TP         | • CH-4               | • Akinci           | • Ababil-T         |
|                    |                    | • CH-4B              | • ANKA             | • Jenin            |
| Loitering Munition | Loitering Munition | • CH-5               | • ANKA-S           | • Khatif-1         |
| • Phoenix Ghost    | • Harop            | • CH-92              | • Aksungur         | • Khatif-2         |
| • Switchblade 300  | • Harpy            | • CH-95              | • Karayel          | • Murad-5          |
| • Switchblade 600  | • Skystriker       | • Wing Loong I       | • Songar           | • Samad-2          |
|                    | • Hero-30          | • Wing Loong II      |                    | • Samad-3          |
|                    | • Hero-120         | • Wing Loong ID      | Loitering Munition | • Shahed           |
|                    | • Mini Harpy       | • CR500 Golden Eagle | • Kargu            | • Shahed-131       |
|                    | • Orbiter 3        | • WZ-7 Xianglong     |                    | • Shahed-136       |
|                    | • Orbiter-1K       | • Unnamed System     |                    | • Shihab           |
|                    | • SpyX             | (Unknown name)       |                    |                    |

**Note:** The table reports representative platform families used for the diffusion analysis. Minor variants and closely related sub-models were aggregated where appropriate to maintain analytical comparability and visual readability.

### A2. Broad UAV Search Query

The broad UAV corpus was constructed using the following Scopus query: [TITLE-ABS-KEY ("unmanned aerial vehicle" OR "unmanned aerial vehicles" OR UAV OR UAS OR RPAS OR drone OR drones) AND PUBYEAR > 1999 AND NOT TITLE-ABS-KEY (honeybee OR wasp OR Drosophila OR "drone cell")].

This query was designed to capture the broad UAV-related literature across both military and civilian/commercial contexts.

### A3. Domain-Specific Query Sets

After retrieval of the broad UAV corpus, rule-based keyword filters were used to identify domain-specific subsets.

#### A3.1. Dual-Use Query Set

Records were classified as dual-use when they were explicitly identified through the following dual-use-related query set: [AND TITLE-ABS-KEY

("dual-use" OR "dual use" OR "dual-purpose" OR "dual purpose" OR "dual-capable" OR "dual capability" OR "civil-military" OR "civil military" OR "civil--military" OR "civil--military fusion" OR "civil-military integration" OR "civil-military cooperation" OR "civil-military technology" OR "dual application" OR "dual applications" OR "military-to-civilian" OR "civilian-to-military" OR "spin-on" OR "spin-off" OR "technology transfer" OR "tech transfer")].

In the present study, the dual-use category refers to records explicitly identified through dual-use-related terms. Cross-domain knowledge relationships were not inferred from keyword overlap alone, but were examined separately through directional citation analysis.

#### A3.2. Military-Oriented Query Set

Records were classified as military-oriented when they matched the following military-related query set: [AND TITLE-ABS-KEY(military OR defence OR defense OR "combat" OR "combat drone" OR "combat drones" OR "armed drone" OR "armed drones" OR UCAV OR "unmanned combat aerial

vehicle" OR "loitering munition" OR "loitering munitions" OR ISR OR "intelligence surveillance reconnaissance" OR reconnaissance OR surveillance OR "strike" OR "targeting" OR "close air support" OR CAS OR "battlefield" OR "battlespace" OR "tactical"]].

This query set was intended to identify publications associated with defense, combat, reconnaissance, targeting, strike, surveillance, and related military mission contexts.

### A3.3. Civilian/Commercial-Oriented Query Set

Records were classified as civilian/commercial-oriented when they matched the following non-military query set: [AND TITLE-ABS-KEY(commercial OR "civilian" OR "civil\*" OR "non-military" OR "non military" OR logistics OR delivery OR "parcel delivery" OR agriculture OR "precision farming" OR inspection OR "infrastructure inspection" OR mapping OR surveying OR "remote sensing" OR "search and rescue" OR "search & rescue" OR SAR OR "disaster response" OR "disaster management" OR "environmental monitoring")].

This query set was intended to identify publications associated with logistics, agriculture, mapping, inspection, monitoring, disaster response, infrastructure, and related civilian or commercial applications.

### A4. Operational Classification Procedure

The classification was implemented according to the following procedure:

1. All records were first required to be included in the broad UAV corpus;
2. Records matching the military-oriented query set were classified as military-oriented;
3. Records matching the civilian/commercial-oriented query set were classified as civilian/commercial-oriented;
4. Records matching the dual-use query set were classified as dual-use;
5. Records not matching these domain-specific query sets were retained in the broad UAV

corpus as foundational or enabling research, but were not assigned to the three focal categories.

This procedure was designed as an **analytical coding framework** for identifying directional knowledge relationships across domains, rather than as a definitive substantive labeling of all UAV-related publications.

### A5. Interpretation of the Dual-Use Category

The dual-use category should be interpreted cautiously. The number of publications identified through explicit dual-use-related terms does not represent the full extent of dual-use knowledge in the UAV field. Rather, it indicates the number of records formally labeled in such terms. In this study, broader cross-domain knowledge relationships are examined through directional citation analysis, especially Civil-to-Military (C2M) and Military-to-Civil (M2C) citation flows.

### A6. Interpretation of Unclassified Publications

A substantial number of UAV-related publications were not assigned to the military, civilian/commercial, or dual-use categories. These records primarily consist of foundational or enabling research lacking explicit domain-specific labels. They were retained in the broad UAV corpus because they still form part of the wider technological knowledge base relevant to both civilian and military development.

### A7. Limitation of the Classification Procedure

A key limitation of this bibliometric approach is that military research is less likely to be fully disclosed in open publications than civilian research. As a result, military-oriented knowledge production may be underrepresented in the observable literature. The present classification should therefore be interpreted with this structural visibility bias in mind.

