Air Forces in the War in Ukraine: Lessons Learned

VADYM SLYUSAR
Doctor of Sciences, Professor

20 – 22 October, 2026

PUBLIC RELEASE


DURING 2022–2026, THE AIR FORCE OF THE ARMED FORCES OF UKRAINE CARRIED OUT 38,367 SORTIES, INCLUDING:
12,280 — for fire strikes and air support to ground forces
21,524 — for fighter air cover
DURING THE YEARS OF THE FULL-SCALE WAR, THE AIR FORCE OF THE DEFENSE FORCES OF UKRAINE DESTROYED MORE THAN 12,000 AERIAL TARGETS, HIT COMMAND POSTS, LOGISTICS FACILITIES, AS WELL AS CONCENTRATIONS OF ENEMY PERSONNEL AND EQUIPMENT.

Ukrainian aircraft fleet of Soviet origin

MIG-29



Su-27UB



GBU-38 JDAM-ER on a Su-27 board



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GBU-38 JDAM-ER



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Su-25



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Su-25 with French AASM Hammer bombs



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Landing on the road



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Ukrainian aircraft fleet of Western origin

F-16



PUBLIC RELEASE

Mirage-2000



PUBLIC RELEASE

Saab 340 AEW&C



PUBLIC RELEASE

ARRIVAL OF WESTERN AIRCRAFT IN UKRAINE BY 2030

1559 DAYS

	AIRCRAFT TYPE	MINIMUM SCENARIO	MAXIMUM SCENARIO
	F-16	75	98
	MIRAGE	5	15
	GRIPEN	16	16
	TOTAL	96	129

PUBLIC RELEASE

Mobile F-16 simulators in Ukraine



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Tactical Russian aircraft fleet

Su-34 with FAB-500 UMPK and dropped UMPB D-30





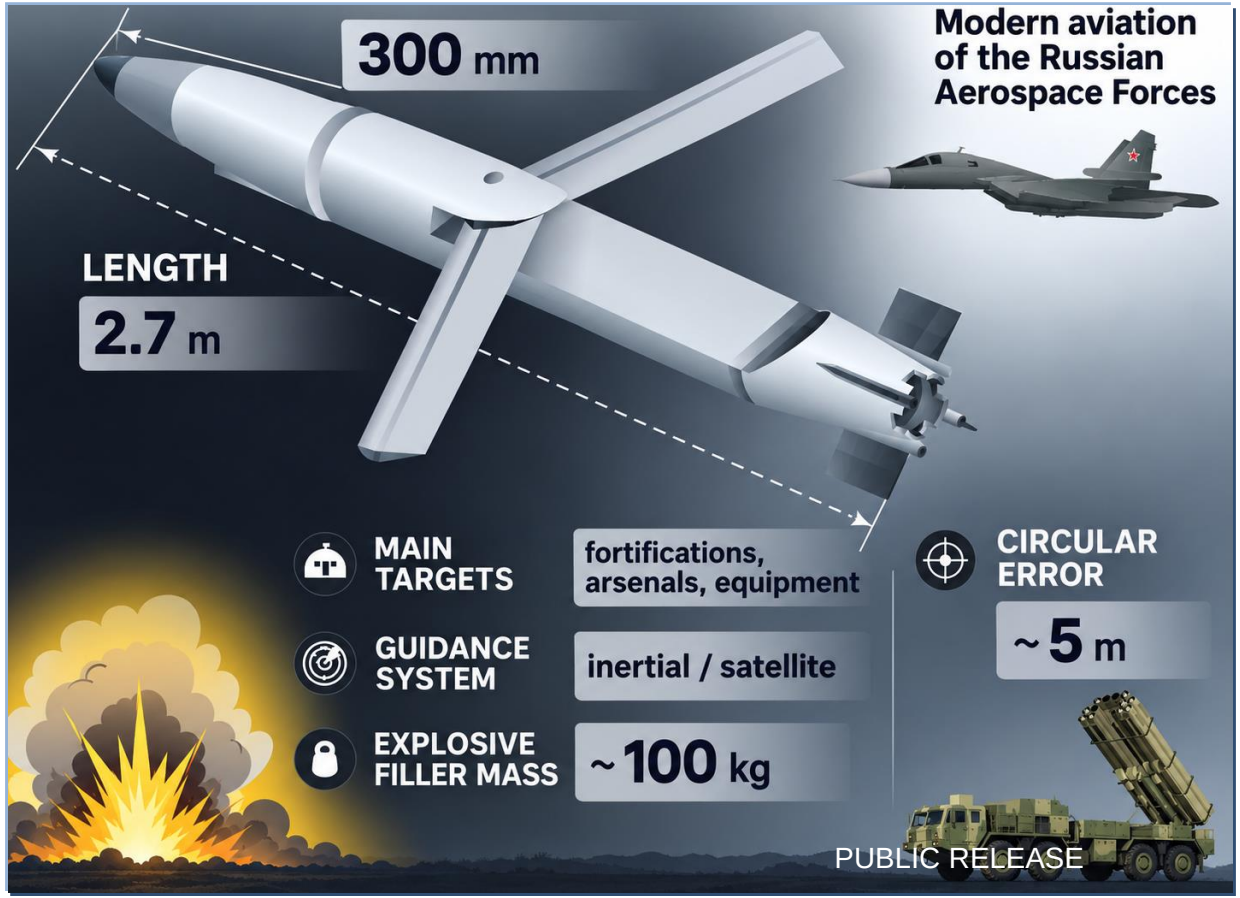


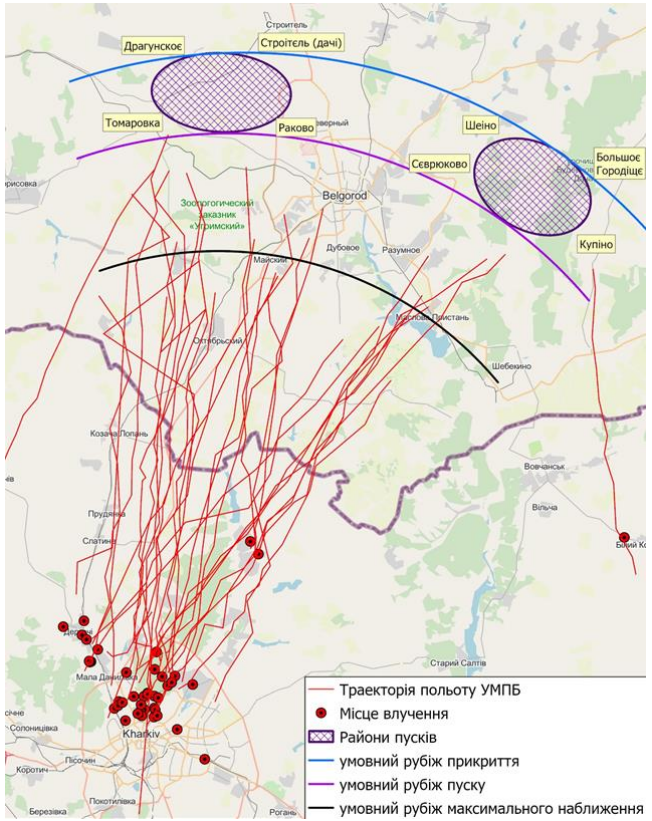
Su-34 as a carrier of FAB-1500 and FAB-3000 with UMPK





Su-34 as a carrier of UMPB D-30SN



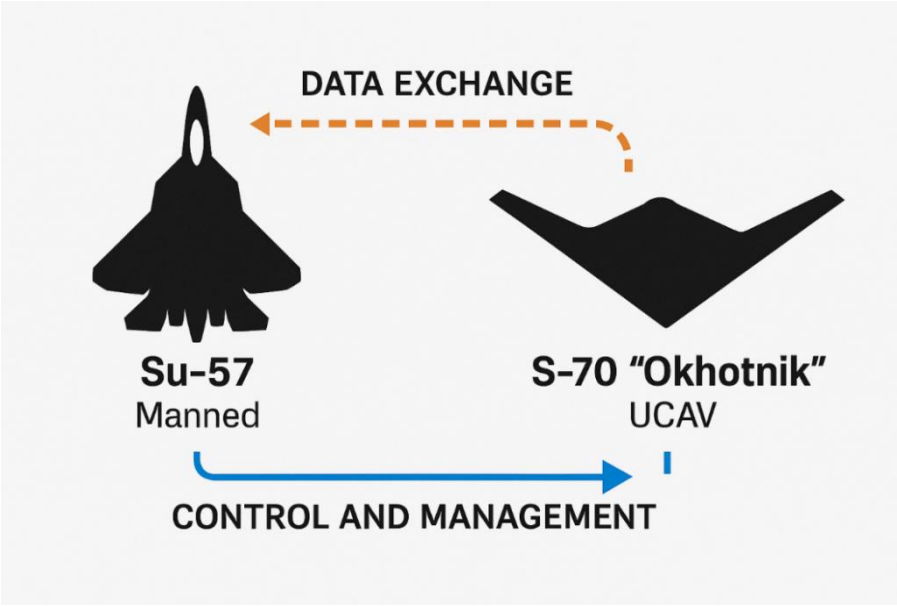


Su-57 (Russian Federation)



PUBLIC RELEASE

Su-57+ UAV S-70 “Ohotnik”





UAV S-70 as the Carrier of Guided Bombs



PUBLIC RELEASE

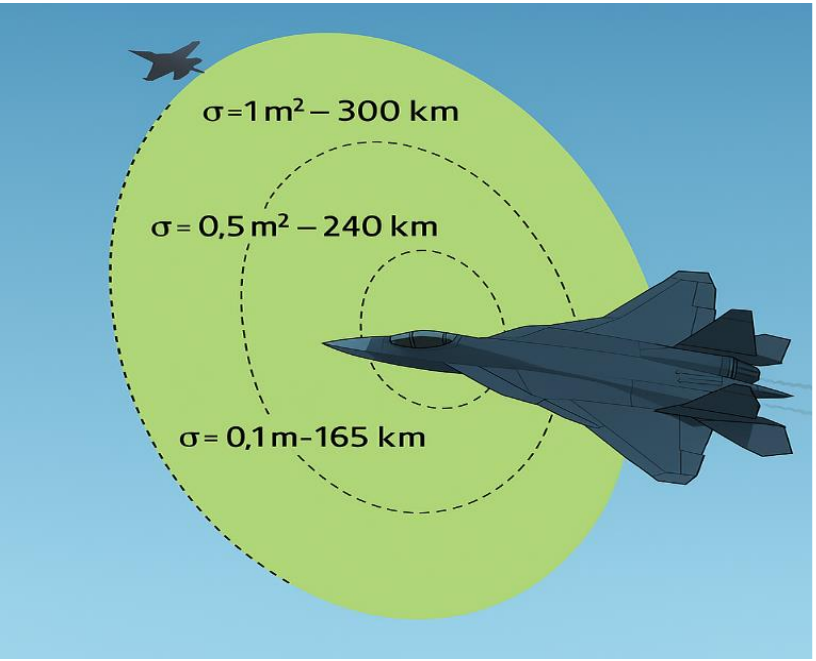
Guided Bomb on the place of the dropping of UAV S-70

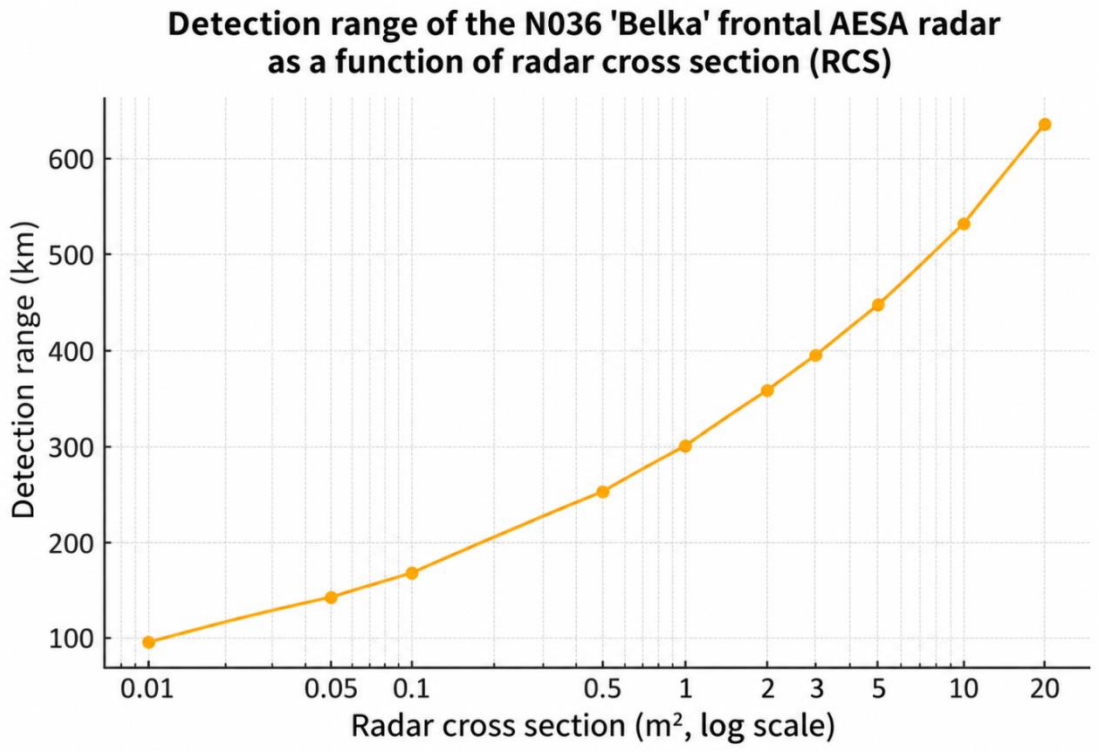




Su-57

AFAR N036 «BELKA» of Su-57





R-37M (RVV-BD)

RUSSIAN VERY-LONG-RANGE AIR-TO-AIR MISSILE

NATO reporting name: **AA-13 Axehead**



KEY SPECIFICATIONS

Maximum range (R-37M)	up to 300 km (public estimates)
Maximum range (export RVV-BD)	up to 200 km
Maximum speed	Mach 6 (≈ 2,040 m/s)
Launch weight	up to 510 kg
Warhead weight	60 kg (high-explosive fragmentation)
Length	4.06 m
Diameter	0.38 m
Engagement altitude	15 m – 25 km
Guidance system	Inertial, datalink correction, active radar homing (ARH)
Primary launch platforms	MiG-31BM, Su-35S (integration with Su-57 reported)

MAIN COMBAT CAPABILITIES

- Engages high-value aerial targets at very long range
- Designed to counter AWACS, reconnaissance aircraft, bombers and fighters
- High speed and large no-escape zone
- Uses inertial guidance with mid-course updates and an active radar seeker for terminal homing

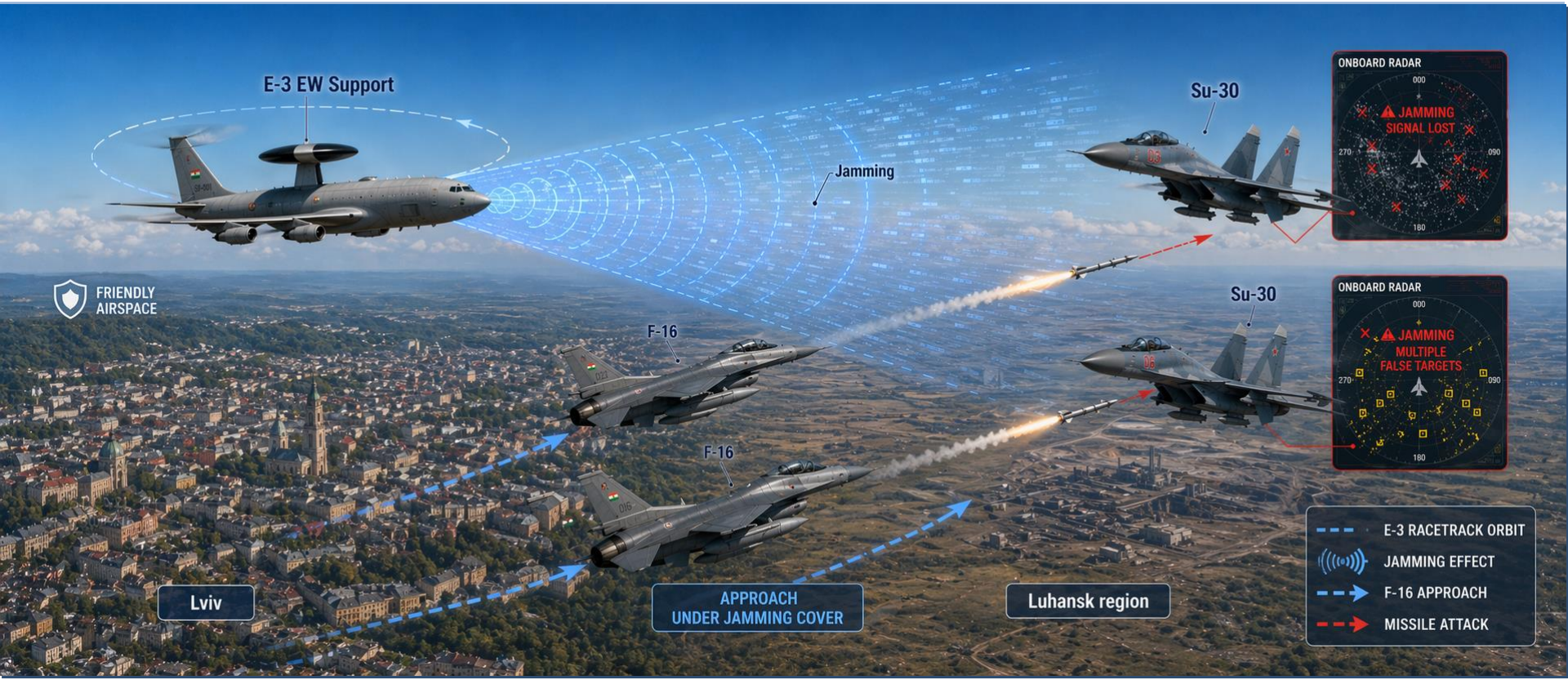
TYPICAL TARGETS



SUMMARY

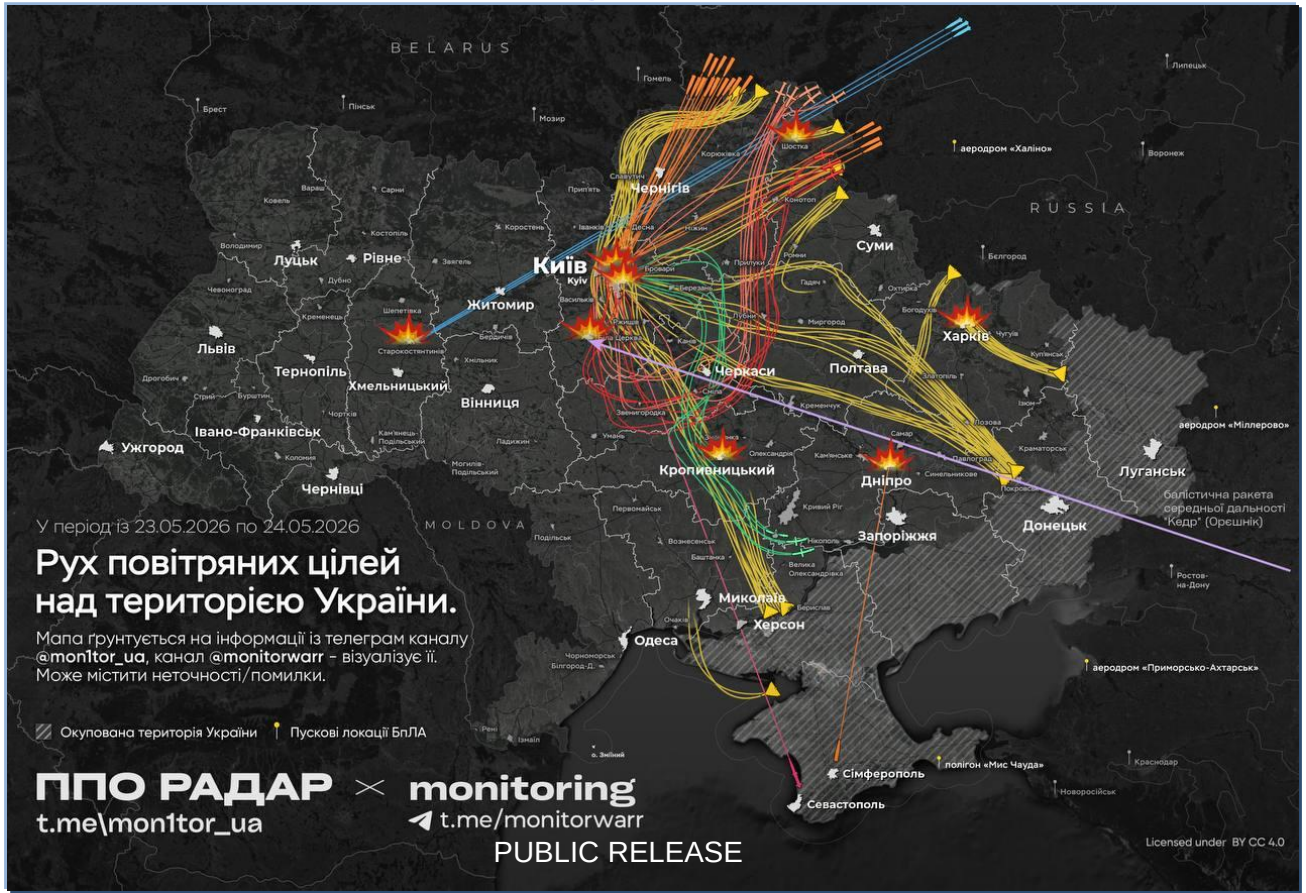
The **R-37M** is a very-long-range air-to-air missile designed to destroy high-value and maneuvering aerial targets. It combines high speed, long range and an active radar seeker, significantly extending the engagement envelope. The maximum stated range should not be equated with a guaranteed kill range against a maneuvering fighter, as effectiveness depends on launch conditions, target type and availability of target designation.

The Concept of Use Jamming Cover



Aviation as a means of air defense

Air Base under Kindgal Srtikes (24 May 2026)



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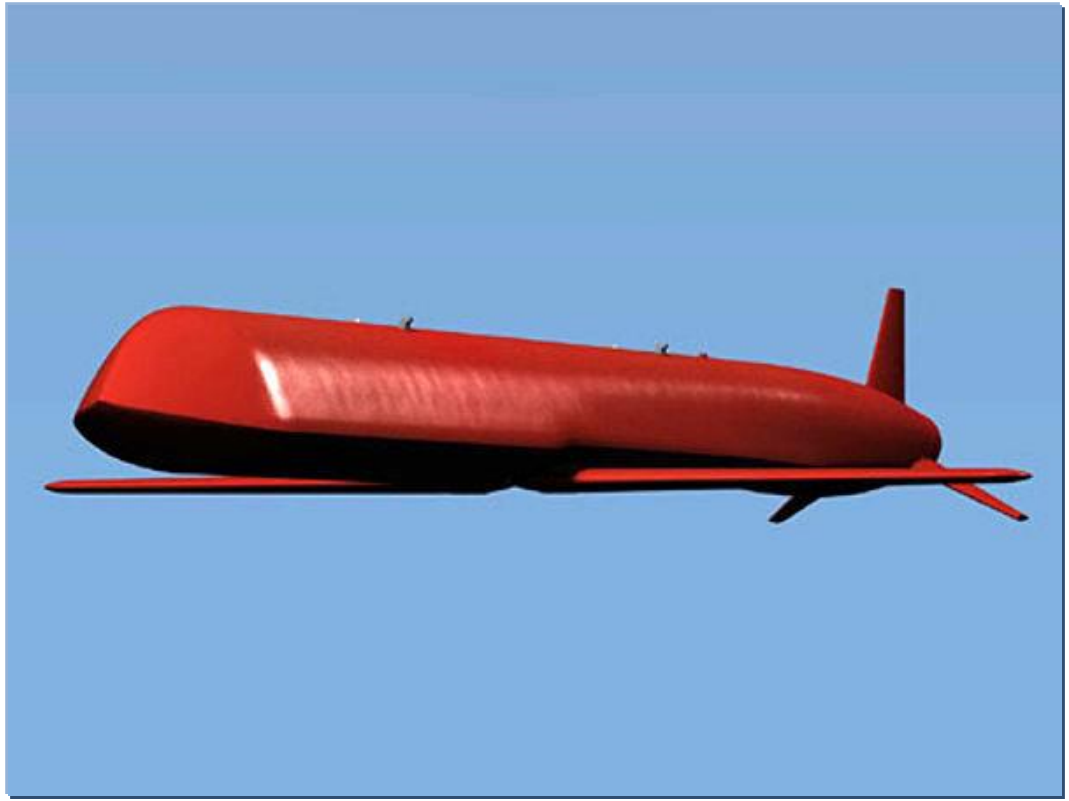
Main threats

Cruise Missile Kh-101



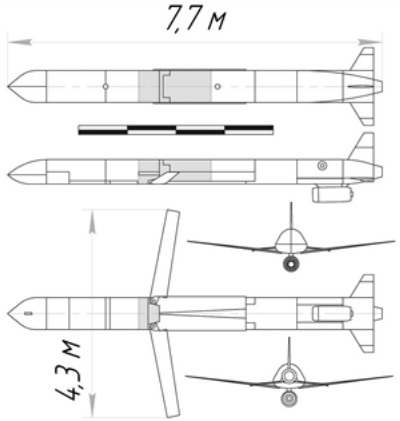


PUBLIC RELEASE

General information on the X-101 cruise missile

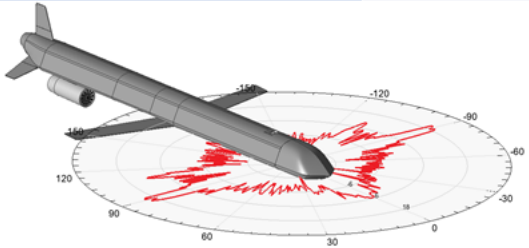
Designer and manufacturer: JSC "GosMKB "Raduga" named after. A. Ya. Bereznyak"

Main tactical and technical specifications X-101	
Missile class	Strategic air-to-surface cruise missile
Flight range, km	to 5500 / 3000
Flight speed, M (m/s)	0,78 (270)
Flight altitude, m	30 – 10000
Mass of the warhead, kg	450 / 800
Type of warhead	High-explosive fragmentation, high-explosive, cluster
Control and guidance system	Inertial navigation system, satellite navigation system SN-99, radio altimeter A-080, optical correlation system, doppler velocity and drift angle meter
Length, m	7,7
Body diameter, m	0,742
Wingspan, m	4,3
Starting mass, kg	to 2400



Median values of the radar cross-section (m^2)



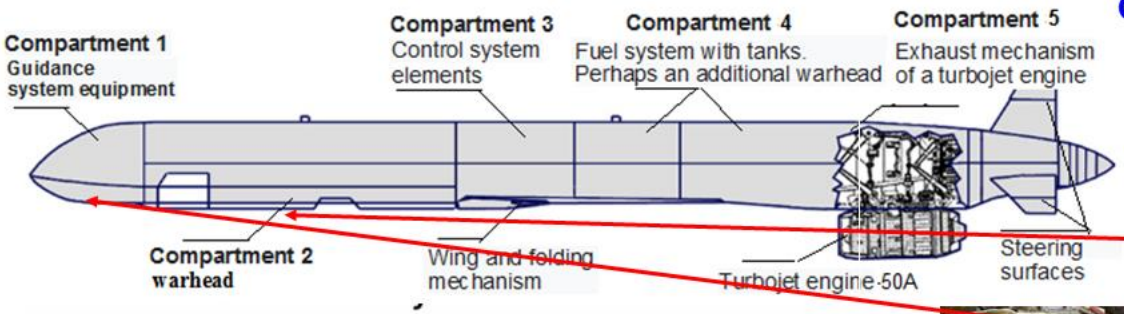


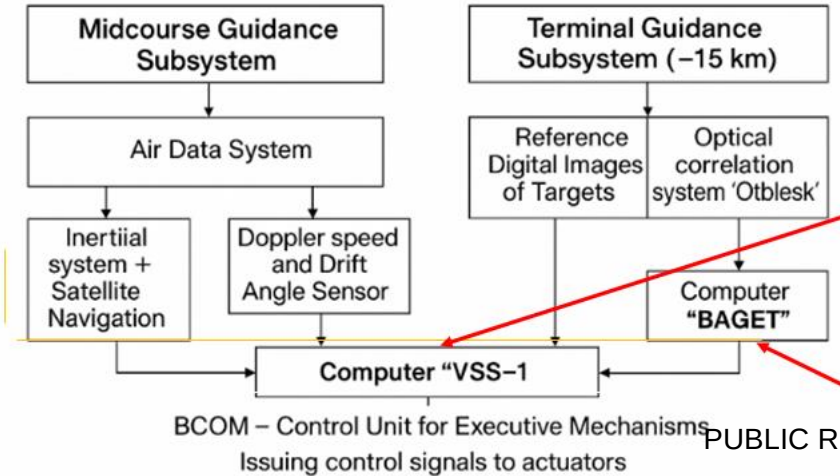
f_0, GHz	Annular	Frontal	Side
3	0,20	0,21	1,34
5,5	0,30	0,34	0,77
9	0,32	0,40	0,76
12	0,44	0,55	0,51

PUBLIC RELEASE

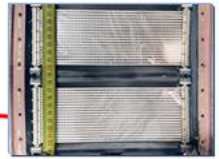
General information on the X-101 cruise missile

Structure and Functional Schematic of the Guidance System





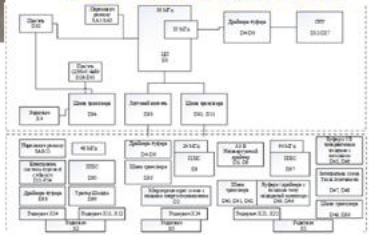
Investigation of On-Board Systems — Component-Level Analysis







CPU BAGET-62-04 includes:
BT33-205
MS TETSA.468354.014
MKR TETSA.467415.001



Kh-69



Mi-28 NM as a launcher of Cruise Missiles “Banderol”




НЕ СТАНОВИТЬСЯ

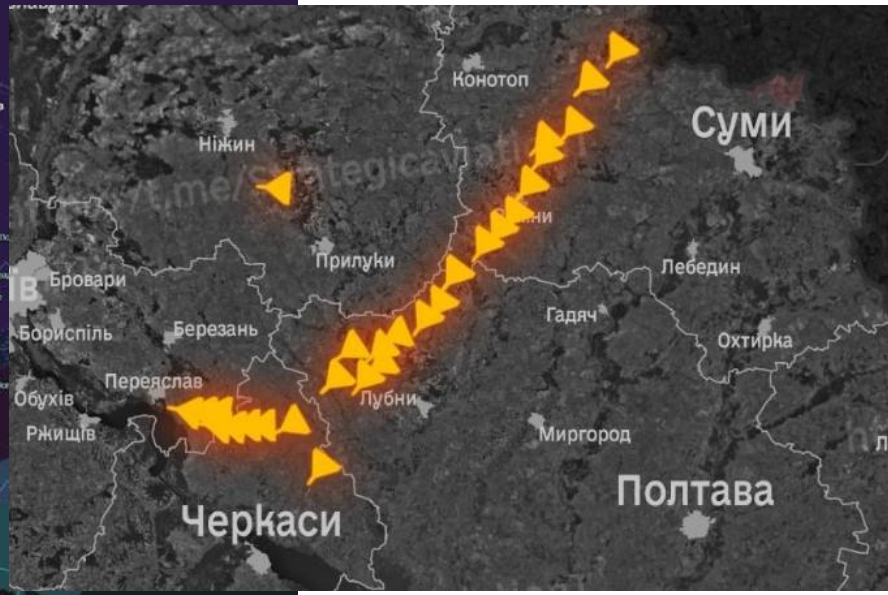
Geran-2 and Gerbera



PUBLIC RELEASE

Formation of a drone chain based on a mesh network





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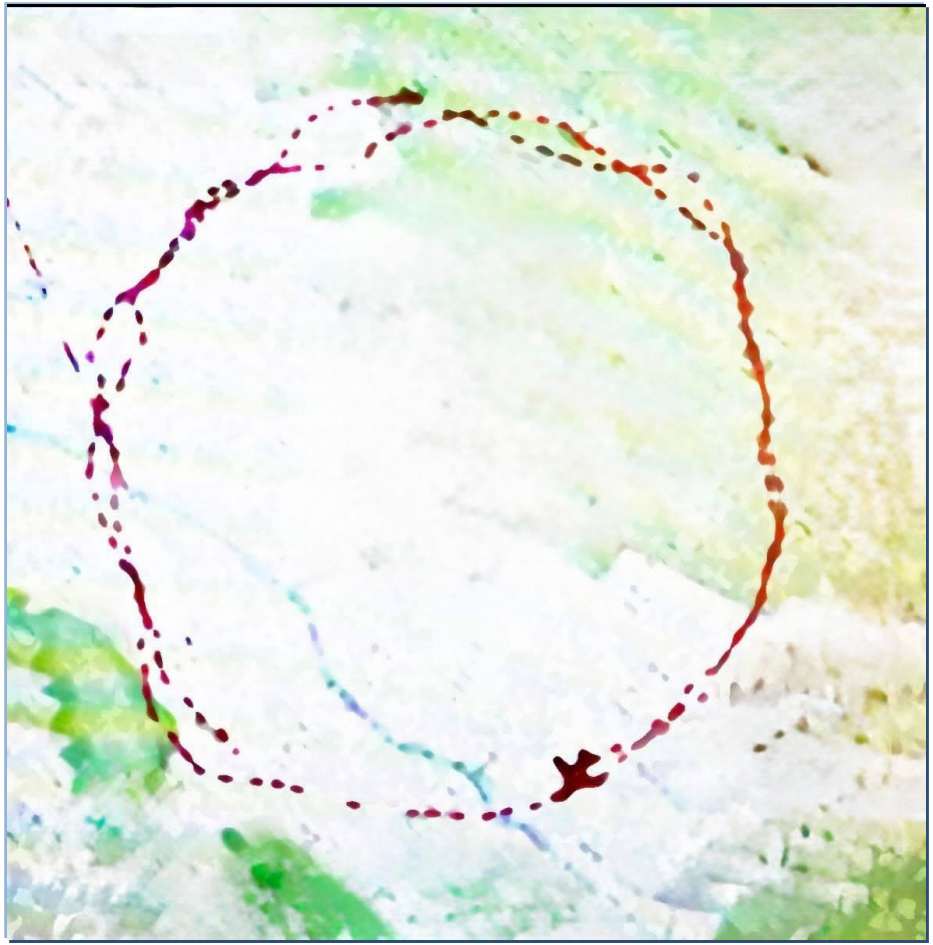
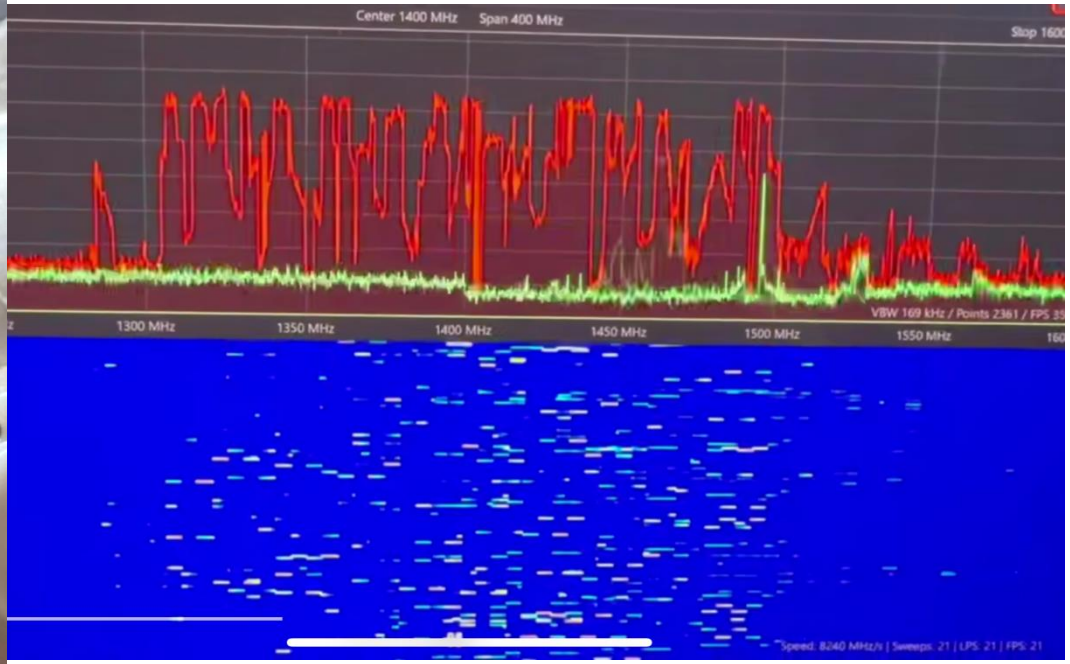
The typical trajectory of GERAN as a Repeater

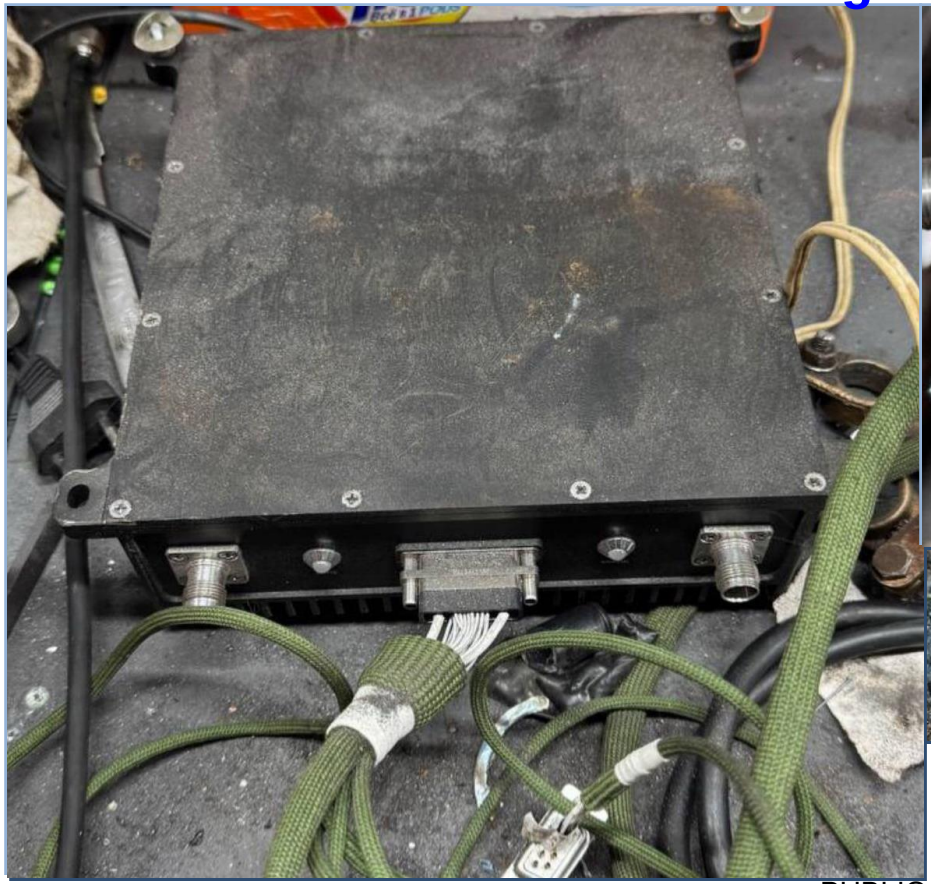


Mesh Networking Modem on 1.3 - 1.5 GHz





Mesh Networking Modem on 3.2 - 3.4 GHz







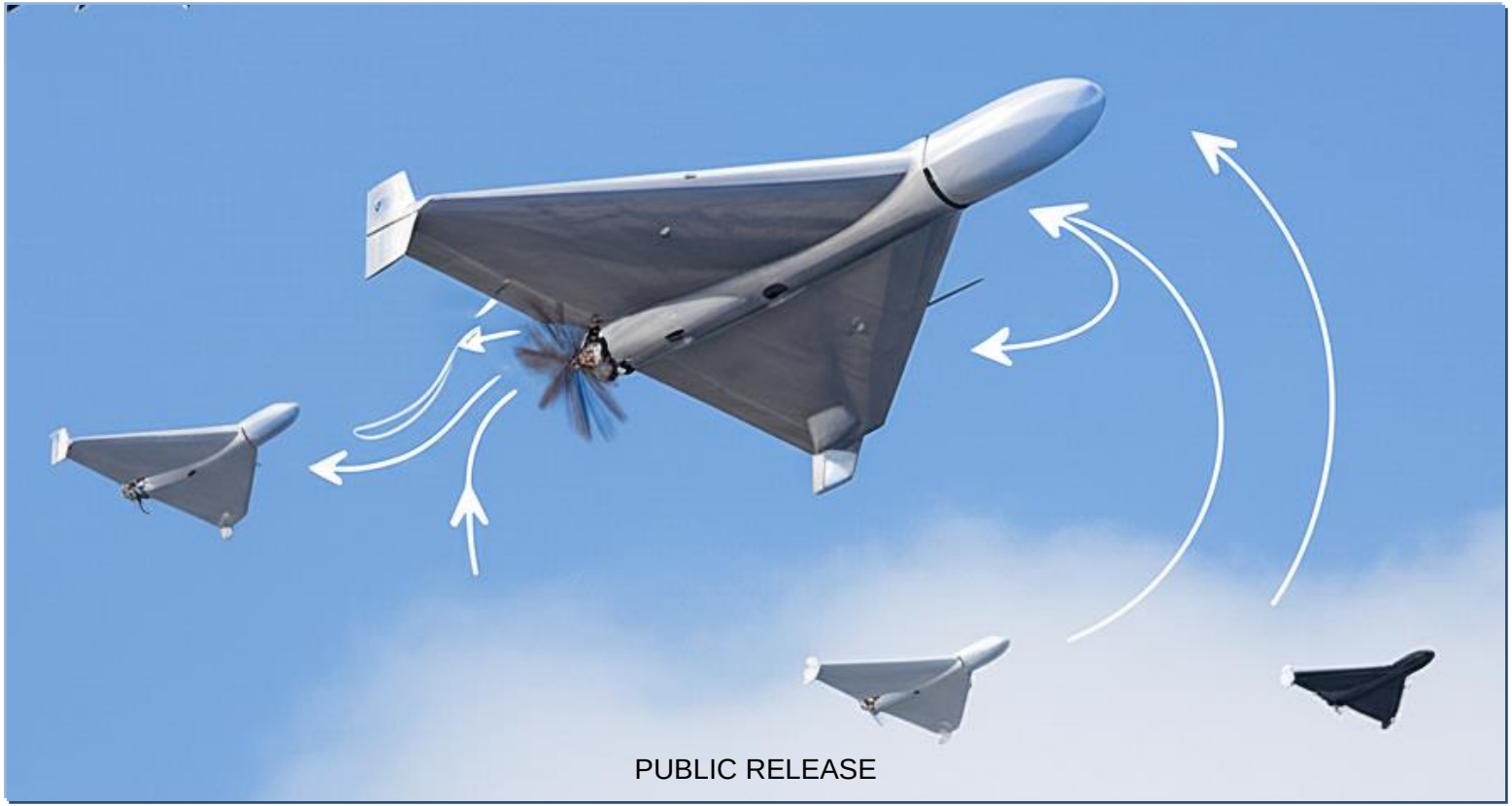




Comparing of the size of Mesh Networking Modems on 1.3 - 1.5 GHz (up to 20 W) and 3.2 - 3.4 GHz (32 W)

t.me/serhii_flash

Rassvet-3 SatCom as a future of Geran-swarm



PUBLIC RELEASE

Launcher effect of First Person View (FPV) UAVs from An-28

FPV drones on the board of Russian UAV “Orlan-10”





FPV drones on the board of An-28



PUBLIC RELEASE

The launch of Interceptors Drones STING from the An-28 (April 2026)

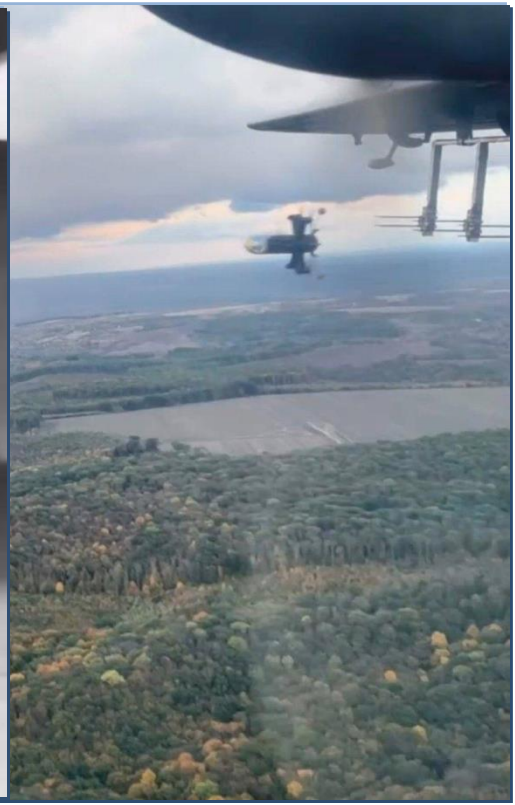


PUBLIC RELEASE

Interceptors Drones on the An-28











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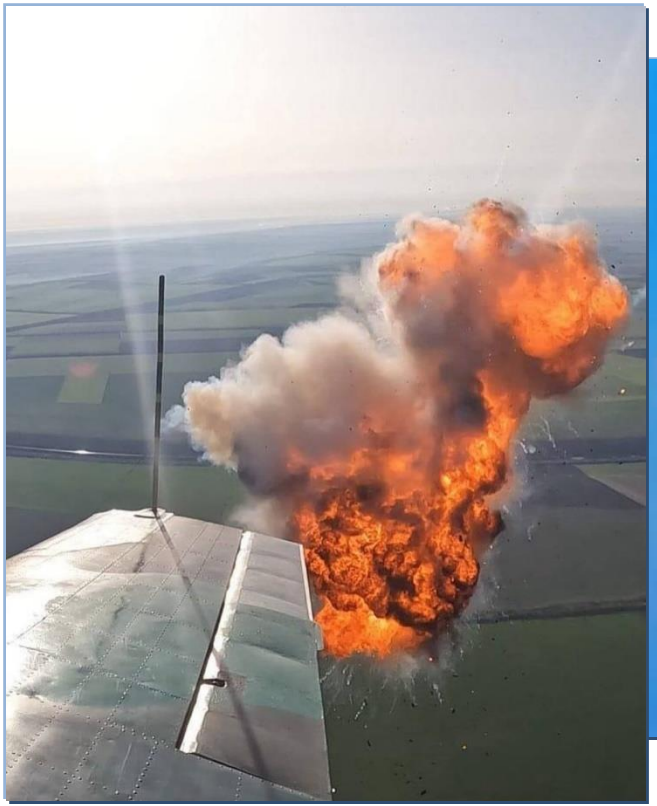
Yak-52 as an Interceptor of Drones





“Geranes” with jet engines as a challenge

Geran-3 with jet engine, 350 - 400 km/hour



PUBLIC RELEASE

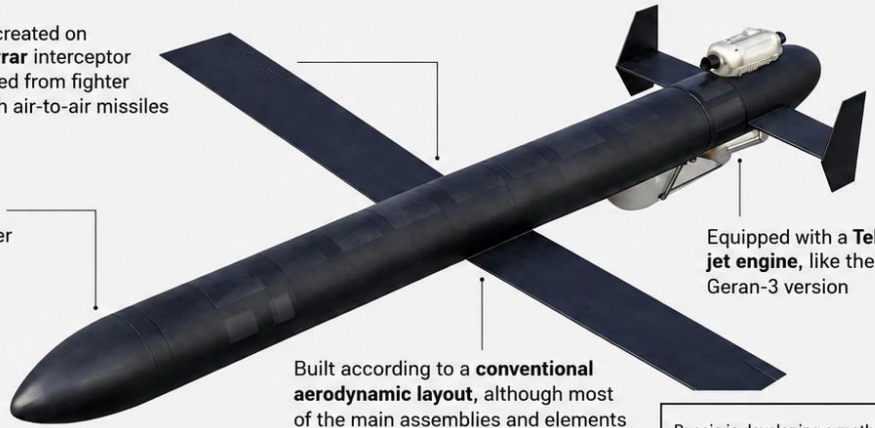

Loitering Munition Drone
Turbojet engine with 160 kgf thrust
Launch: ground launchers or from a Su-25 aircraft
Machine vision and autonomy
Speed: 550 km/h
Warhead mass: 50 kg or missiles
Total mass: 450 kg
Launch range: 800 km
"Geran-4-Seeker"
Low-observable coating and UAV airframe shape

UAV GERAN-5

**A STRIKE UAV UNDER DEVELOPMENT TO ENGAGE GROUND AND AIR TARGETS.
THE RUSSIAN MILITARY FIRST USED THIS DRONE IN JANUARY 2026 TO ATTACK UKRAINE**

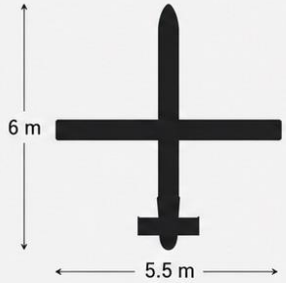
Not an original design, but created on the basis of the **Iranian Karrar** interceptor drone, which can be launched from fighter aircraft and is equipped with air-to-air missiles

Has a 12-channel **Kometa** satellite navigation system, 3G/4G modems, and a tracker based on a Raspberry microcomputer



Equipped with a **Telefly jet engine,** like the Geran-3 version

Built according to a **conventional aerodynamic layout**, although most of the main assemblies and elements are arranged following the pattern of other Geran drones



Russia

Russia is developing a method to launch the drone from airborne carriers, in particular **Su-25** aircraft, and possibly to equip it with **R-73 air-to-air missiles**



Data: Defence Intelligence of Ukraine, Dumskaya

START OF USE	WARHEAD MASS	FLIGHT ALTITUDE	CRUISING SPEED	ATTACK RANGE
2026	90 kg	up to 6 km	up to 600 km/h	~1,000 km

"Our record is 5 drones shot down in a single sortie": a Ukrainian Mirage 2000 pilot tells Le Figaro about his combat missions (Oct. 4, 2026)



LE FIGARO 200 ans

Politique International Économie Société Vox Sport Culture Madame

Réservé aux abonnés

« Nous avons un record de cinq drones abattus en un vol » : un pilote ukrainien de Mirage 2000 raconte ses missions au *Figaro*

Par **Elisabeth Pierson**, à Kiev

Publié le 04/10/2026 à 18h08, mis à jour le 05/10/2026 à 11h33

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guerre en Ukraine

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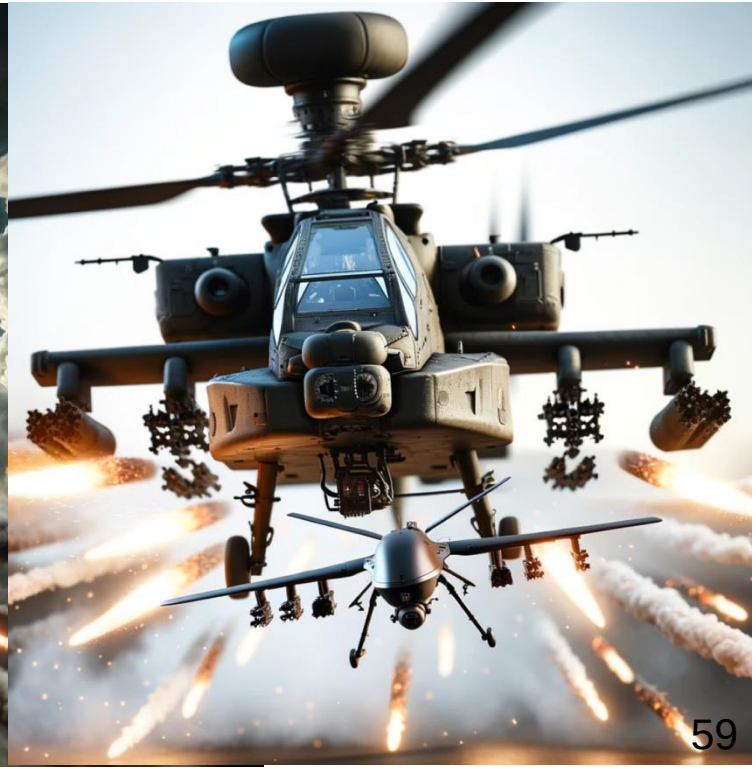
Helicopters against LMs as a means of air defense

The concept of using Helicopters as a mobile air defense unit (author's briefing at the NAAG meeting, 13-14 December 2022)





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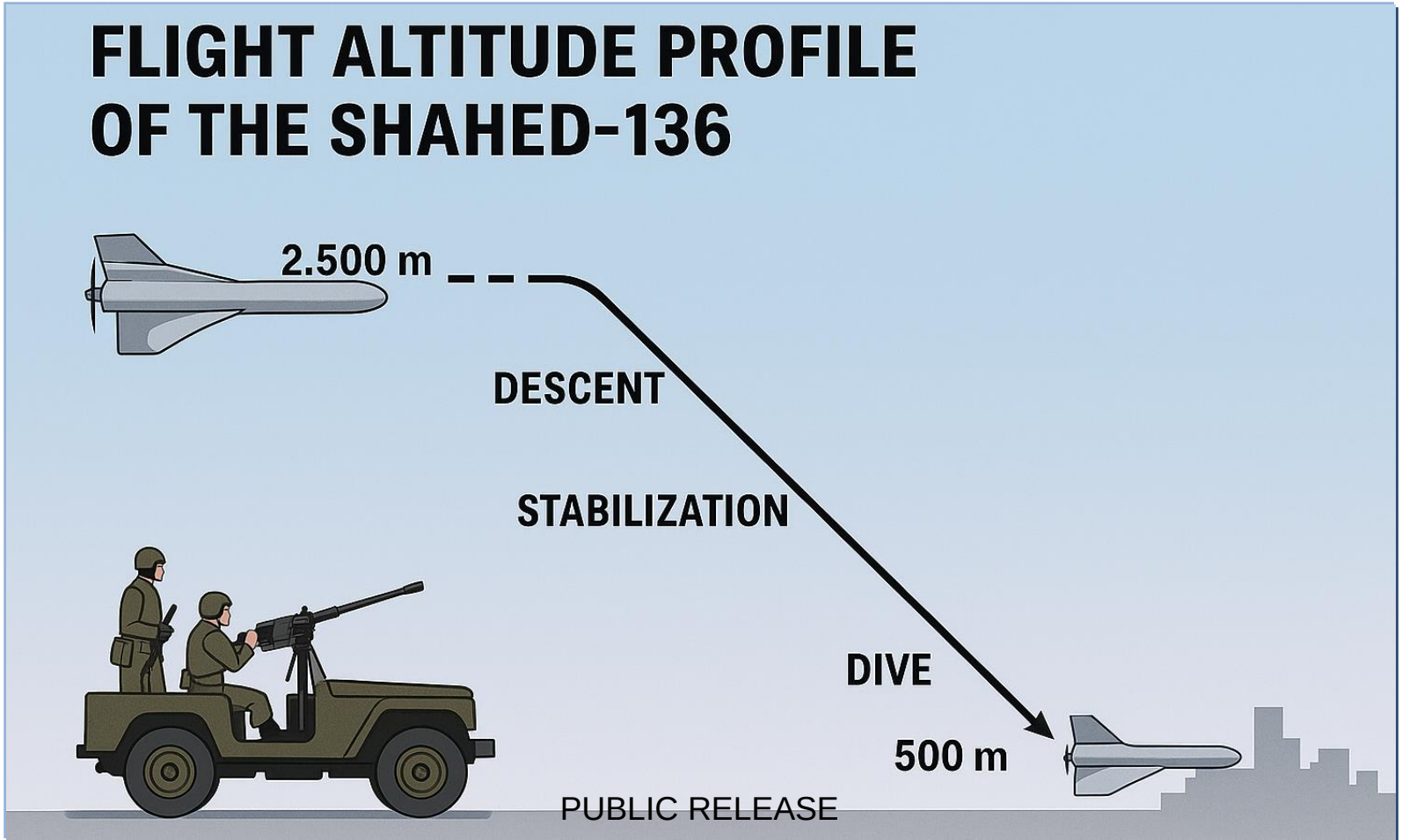
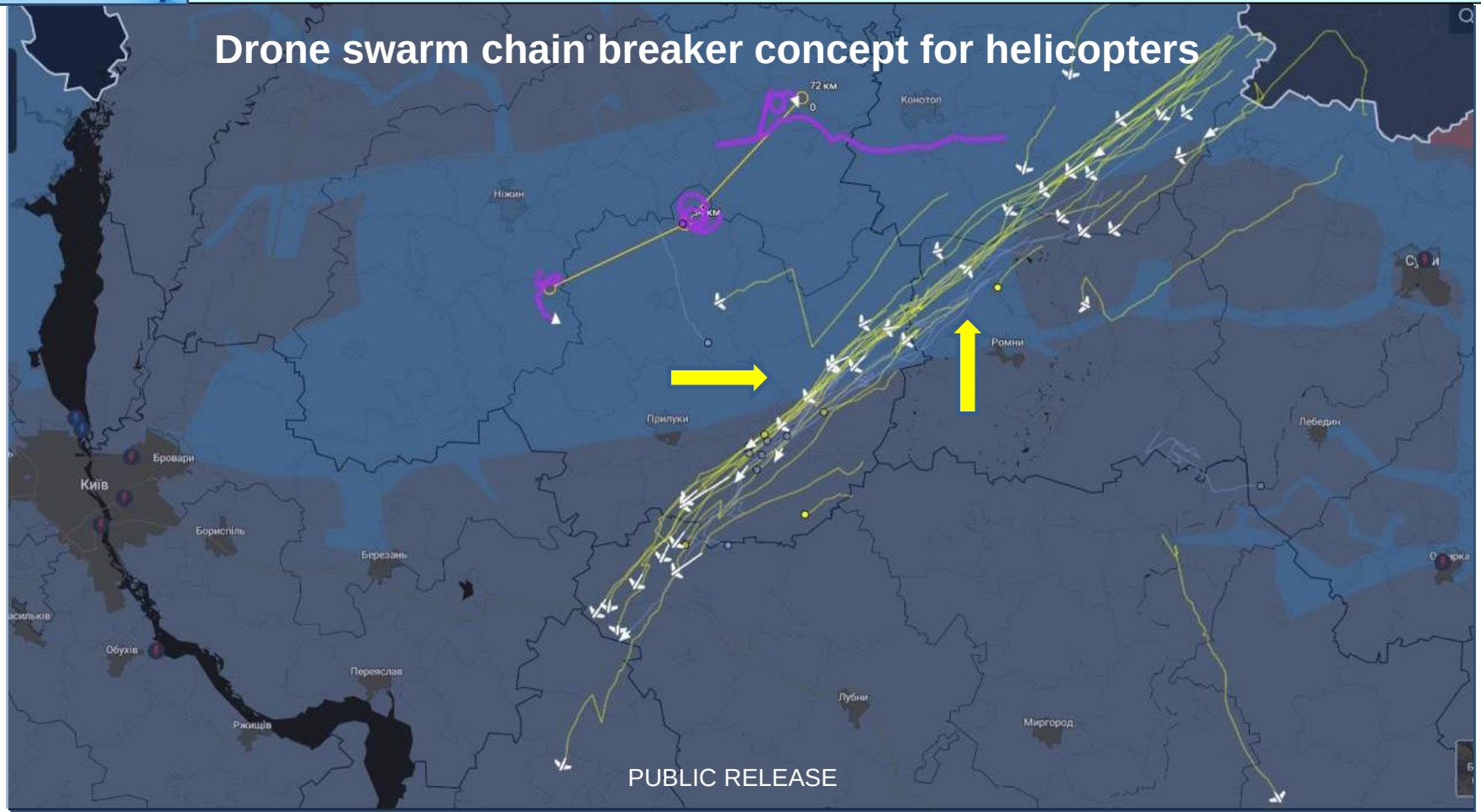


PUBLIC RELEASE

Drone swarm chain breaker concept for helicopters



PUBLIC RELEASE



Author's concept of the use of radars on a Mi-8 board



“Igla” MANPADS on board a Mi-28N helicopter (Russia)





“Igla-S” MANPADS launcher, its missile, and “Strelets” system



PUBLIC RELEASE

The concept of using Helicopters as a mobile air defense unit



PUBLIC RELEASE

XM1225 APEX (30 mm air burst munitions)



PUBLIC RELEASE

Simplifying aviation modernization for countering Shahed-type drones (06 April 2026)

The Government of Ukraine has adopted a decision that makes it possible to more rapidly retrofit aircraft and helicopters for the needs of modern warfare. Weapons, communications systems, navigation equipment, and target detection assets can now be installed without lengthy approval procedures.

The entire process will be reduced to one month. Not only enterprises, but also specialists and military units will be involved in the work.

This will make it possible to respond more quickly to new threats and strengthen the capabilities of our Armed Forces in repelling air attacks.

New Geran-tactics as threats for Helicopters

Self-defense Geran-2 based on MANPADS “Igla”



Self-defense Geran-2 based on Air-to-Air Missiles R-60





Geran-2 with Air-to-Air Missiles R-60 Decoy



PUBLIC RELEASE

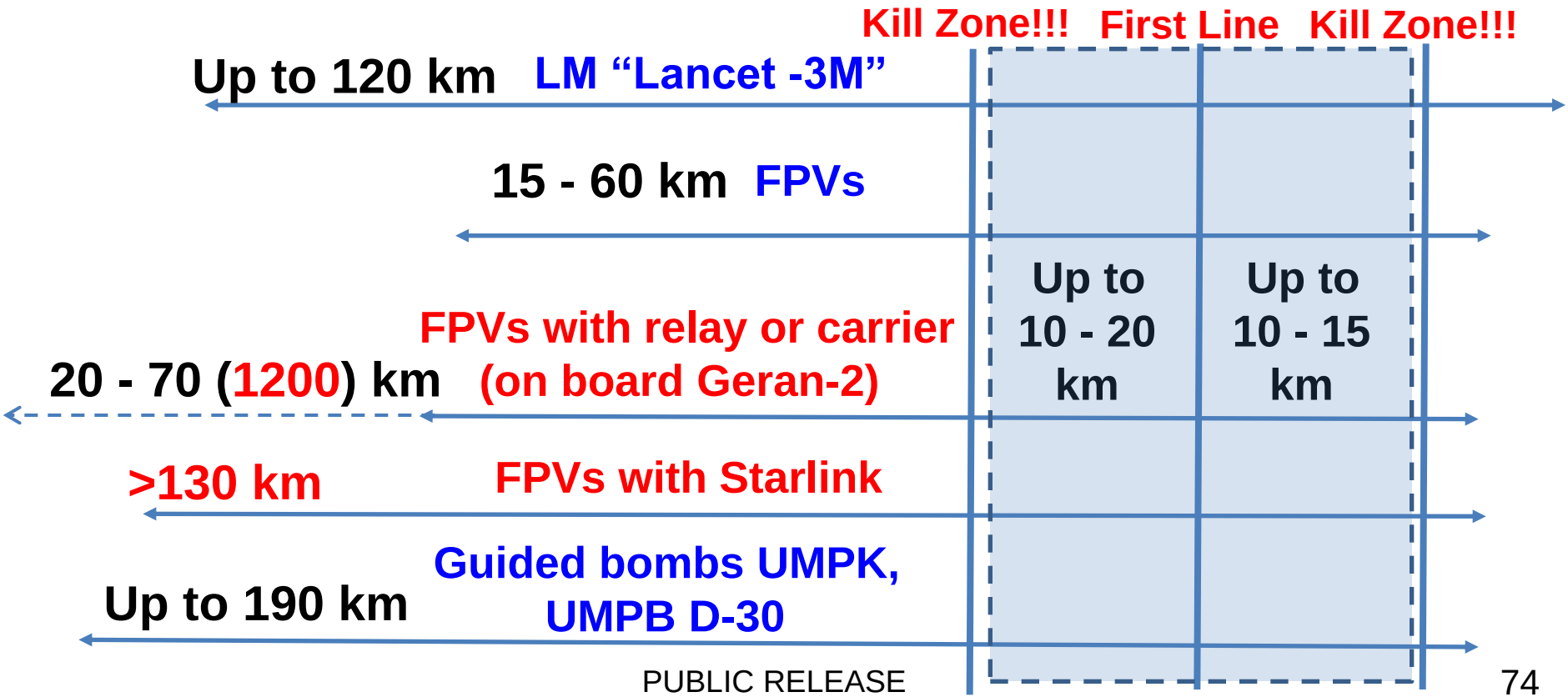
Alarm cameras against drone interceptors



PUBLIC RELEASE

SOME LESSONS LEARNED FROM THE USE OF HELICOPTERS DURING THE WAR IN UKRAINE

Guided bombs, FPVs and LMs as main threats



Shooting in a nose-up pitching mode



PUBLIC RELEASE

Shooting in a nose-up pitching mode (USA)



PUBLIC RELEASE

A pair of Mi-8MT helicopters from a Separate Army Aviation Brigade (Ukraine)

The helicopters are armed with M261 unguided aircraft rocket pods and received elements of the "Anti-Mykola" camouflage, which is intended to reduce losses from friendly fire.



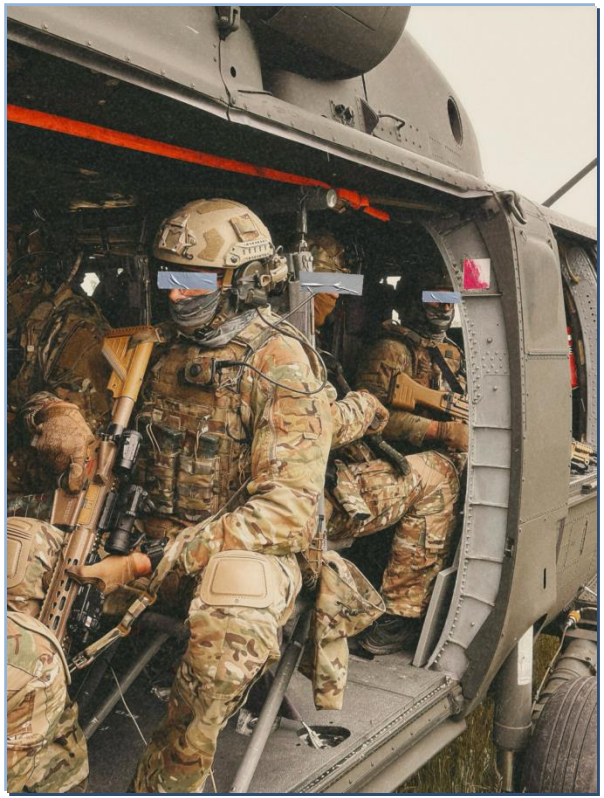
Mi-8MT helicopters





UH-60







Mi-24



Mi-17



PUBLIC RELEASE

Fire fighting



PUBLIC RELEASE

Fire fighting



PUBLIC RELEASE

Main threats for Helicopters

Documenting Helicopters Losses during the Russian Invasion of Ukraine

01 March 2026

Russia

Helicopters (174) of which destroyed: 136, damaged: 36, captured: 2)

- 50 Mi-8 transport helicopter:
- 6 Mi-8MTPR-1 electronic warfare helicopter:
- 4 Mi-24P attack helicopter:
- 4 Mi-24V/P/35M attack helicopter:
- 2 Mi-26 heavy transport helicopter:
- 20 Mi-28 attack helicopter:
- 2 Ka-27/29 naval attack helicopter:
- 10 Mi-35M attack helicopter:
- 68 Ka-52 Alligator attack helicopter:
- 8 Unknown helicopter:

Ukraine

Helicopters (56) of which destroyed: 50, damaged: 3, captured: 3)

- 6 Mi-2 training helicopter:
- 30 Mi-8 transport helicopter:
- 1 Mi-14PS maritime helicopter:
- 3 Mi-17V5:
- 1 Mi-8/17:
- 2 Mi-24P attack helicopter:
- 11 Mi-24 attack helicopter:
- 1 Airbus H225 transport helicopter:
- 1 Westland Sea King:

www.oryxspioenkop.com/2026

Traditional Threats (MANPADs, ATGM)



PUBLIC RELEASE

FPV drones with fiber optics and drones-interceptions against helicopters



1st successful strike of Ukrainian Drone-interceptor with fiber optic against helicopters Ka-52 in March 2026

Remote Controlled Air Mine Field based Loitering Munitions against CM





LM “KLIN” (Russia)

**AI,
120 km,
80 min,
Air Mine
Field,
5 kg**



PUBLIC RELEASE

EW devices on board helicopters as a means of self-defense against UAVs

Russian “Multik” Jammer on Helicopters



- FPV video signal detection range ≈ 1 km;
- Jamming (suppression) range ≈ 500 m;
- Operating frequency range is 700 – 6000 MHz;
- Output power ≈ 25 W;
- Mass ≈ 9.5 kg.



PUBLIC RELEASE



PUBLIC RELEASE



PUBLIC RELEASE



PUBLIC RELEASE



PUBLIC RELEASE

Drone threats on the forward arming and refueling points (FARPs)


On April 29, 2026, Utainian kamikaze drones of the Unmanned Systems Forces struck two Russian helicopters, a Mi-28 and a Mi-17, near Voronezh at their field maintenance site, located 150 km from the front line.
Mi-28
Mi-17
29.04.26
PUBLIC RELEASE

FARFs must be located at a distance of more than 200 km from the front line and equipped with C-UAS systems

Mi-28



Mi-17



Loitering munitions
Lancet-3M

LM Lancet with a PTM-3 Mine







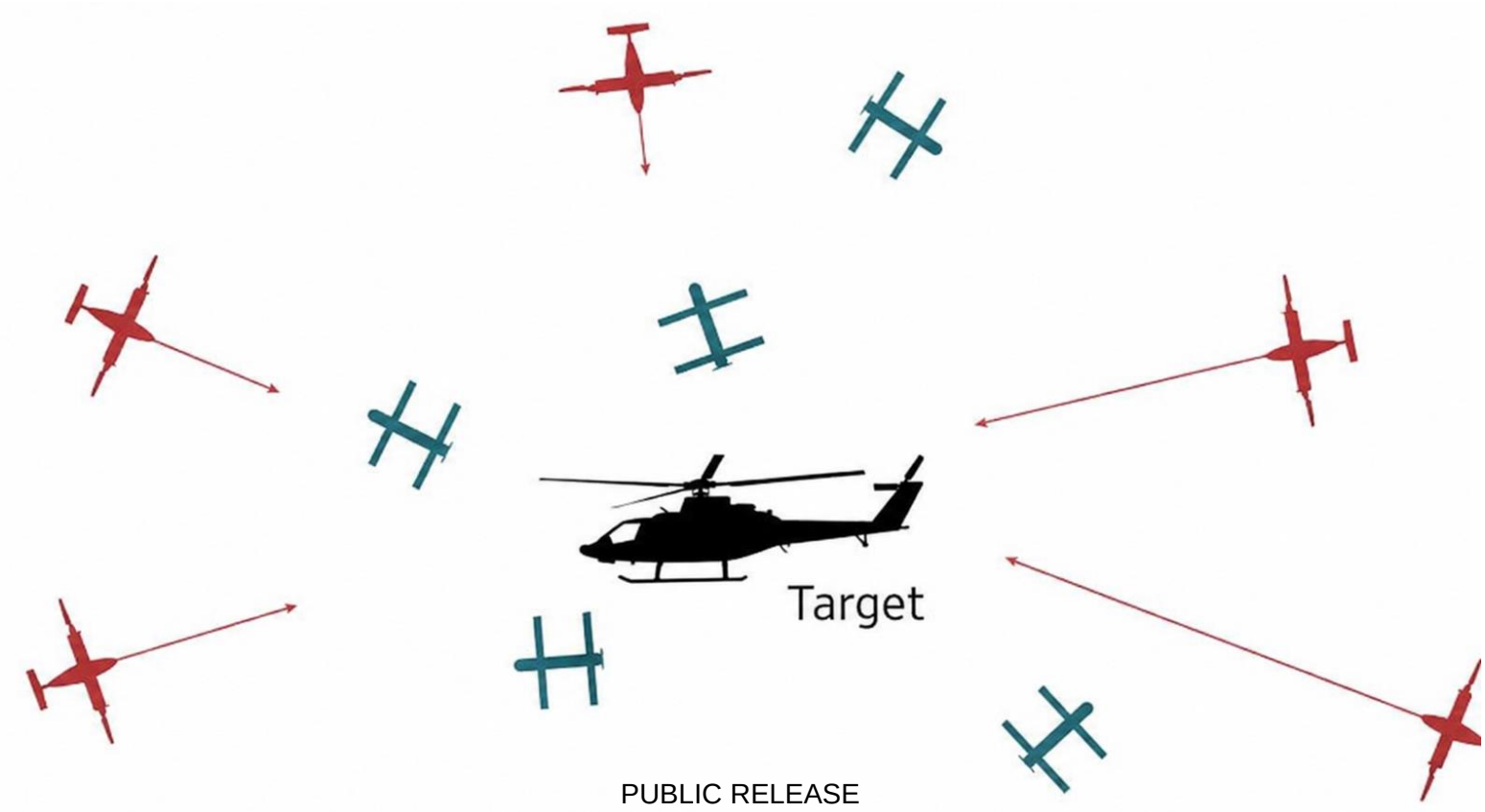


New Version of Lancet-3M

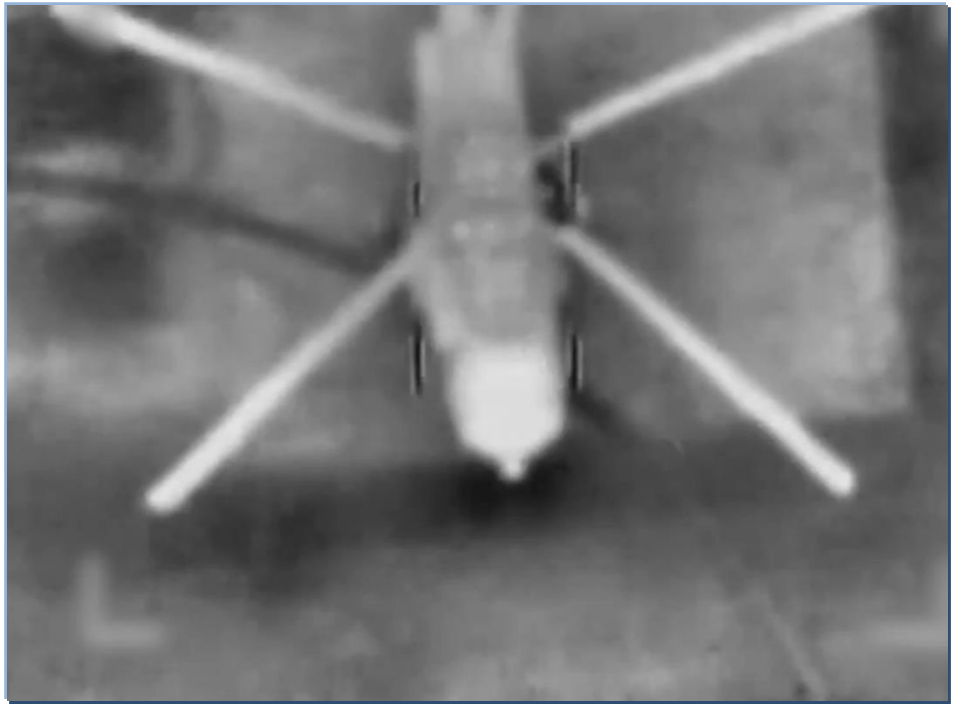


PUBLIC RELEASE

FARFs must be protected from drone swarms



Picture as Decoys of Helicopters (Iran)





Combine protection of airfield infrastructure

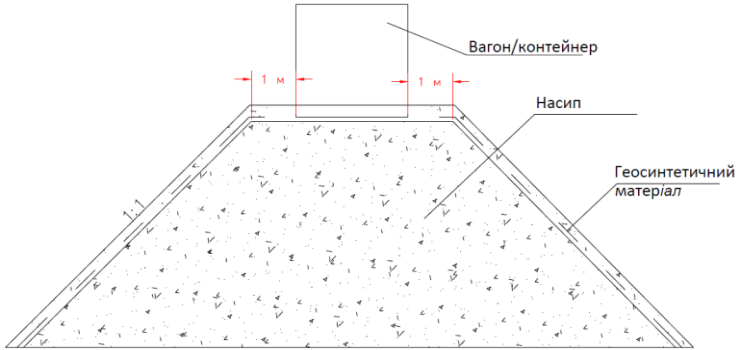
PROTECTION OF HANGAR BUILDINGS FROM UAV ATTACKS AT AIRFIELDS



Shelter using gabion structures



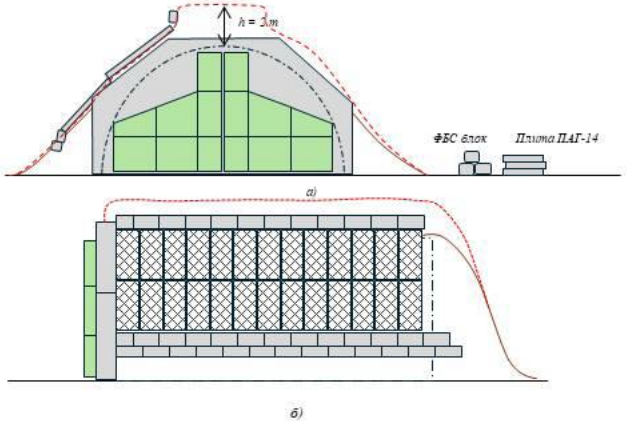
Arched shelters



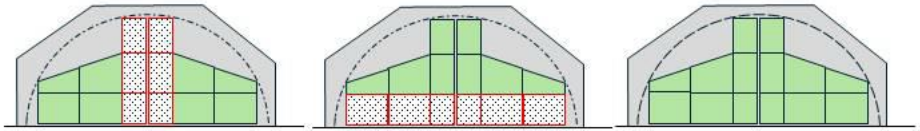
Protective barriers made of earthen embankments (retaining walls)

ADDITIONAL PROTECTION OF HANGAR BUILDINGS FROM UAV ATTACKS AT AIRFIELDS

Options for increasing the protection of hangar structures at an airfield



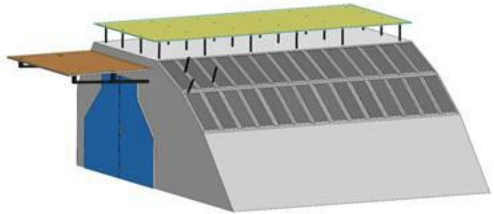
Option I. Strengthening the hangar protection by installing reinforced concrete airfield slabs PAG-14 and additional earth (soil) filling (top – front view; bottom – side view)



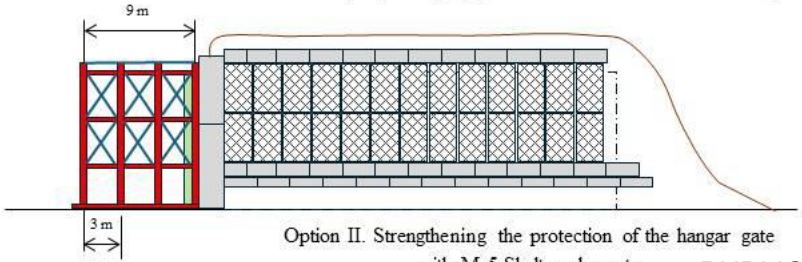
Option IIIa).
Filling the gate with foam-concrete and sand

Option IIIb).
Filling the gate with foam-concrete and sand

Option IIIc).
Filling the gate with sand



Option IV. Strengthening the protection using anti-drone netting, PAG-14 plates and a protective screen above the sliding gate



Option II. Strengthening the protection of the hangar gate with M-5 Shelter elements

PUBLIC RELEASE

C2 Systems update

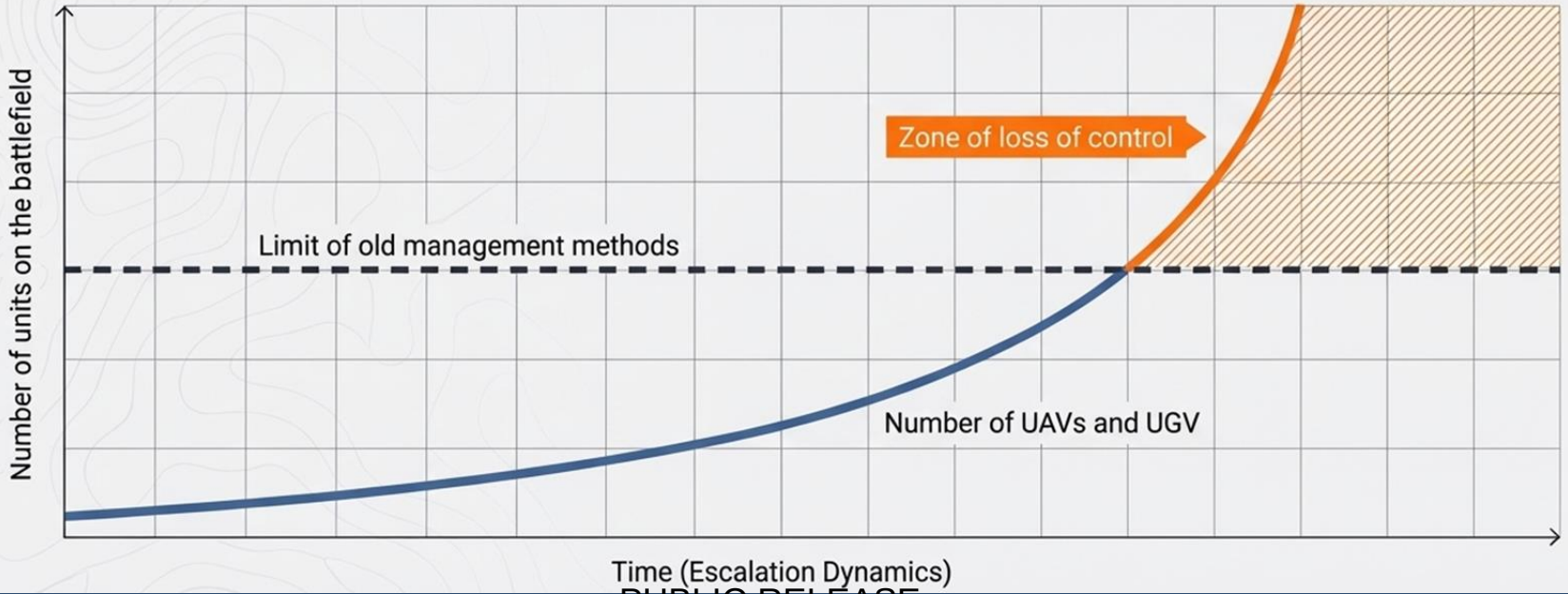
DELTA as a base of new MISSION CONTROL System



PUBLIC RELEASE

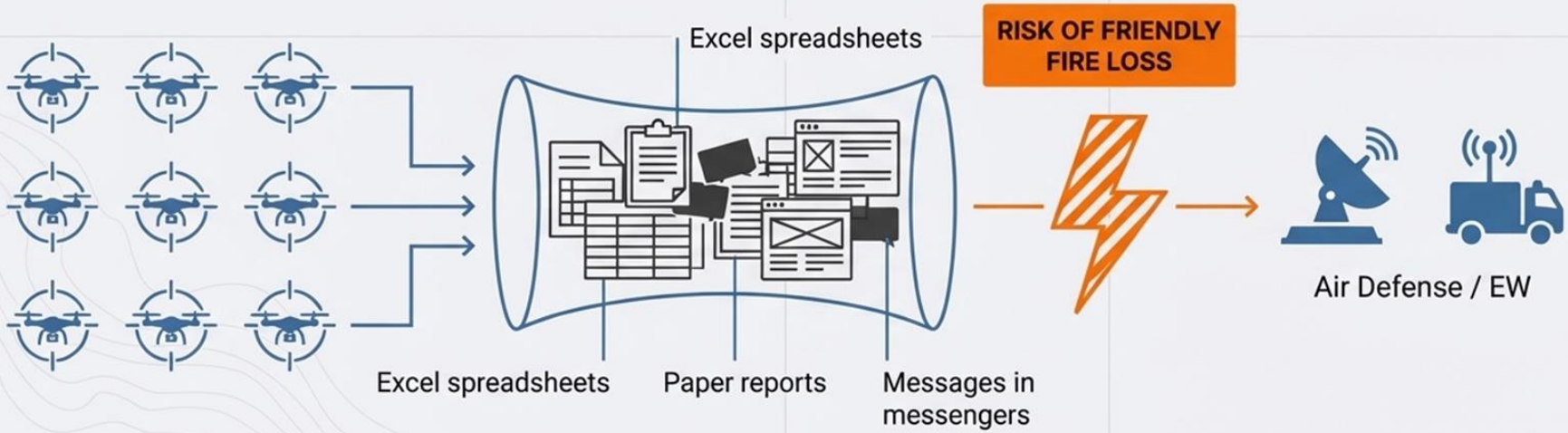
Front Scaling Outpaces Human Coordination Capabilities

Every day the number of UAVs and UGV grows exponentially. Managing disparate crews and massive amounts of equipment becomes critically difficult. Commanders find themselves in conditions of information overload.



Analog control creates a critical bottleneck

Managing drone warfare through manual data collection destroys situational awareness. Data fragmentation between messengers and paper leads to chaos, loss of time, and friendly fire.



Paradigm Shift: Why the Analog Approach Fails

Abandoning manual control for algorithmic coordination is the only path to scaling.

OLD APPROACH	MISSION CONTROL
Tasking: Chaos in messengers, loss of details.	✓ **Tasking:** Directly in the crew's mobile application.
Situational Awareness: Blind spots and fragmentation.	✓ **Situational Awareness:** A unified interactive view of the areas.
AD/EW Safety: High risk of losing own drones.	✓ **AD/EW Safety:** Real-time "friend-or-foe" identification.
Reporting: Paper and Excel tables, manual collection.	✓ **Reporting:** Automated analytics in the system.

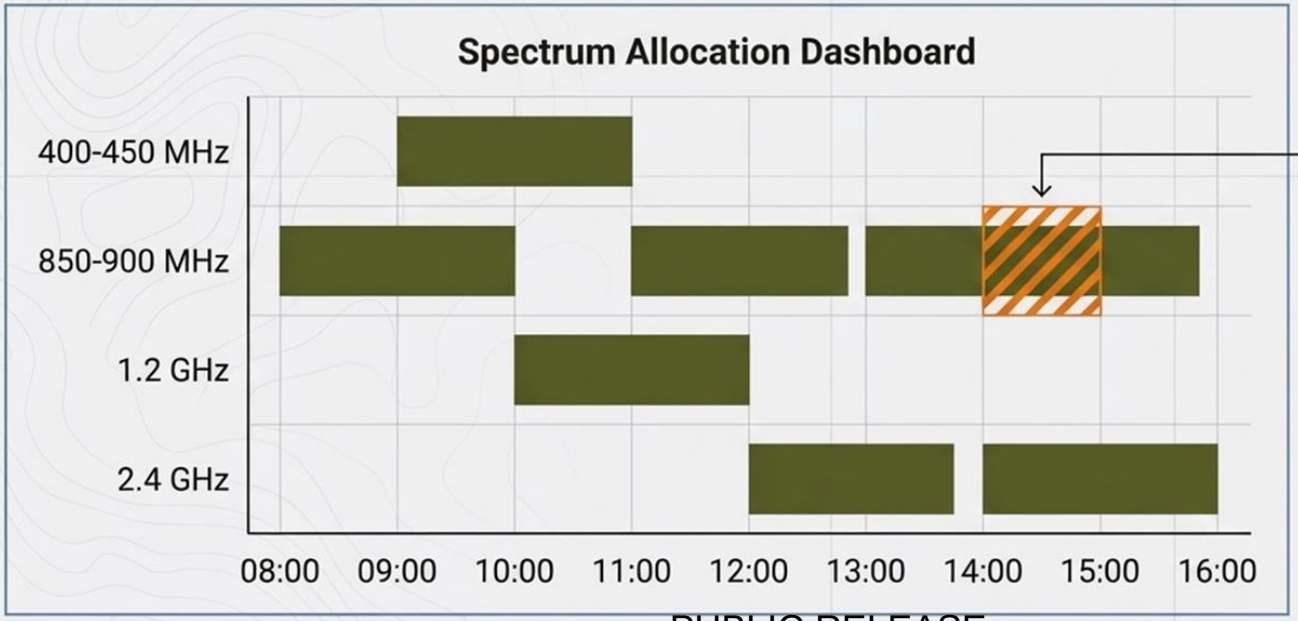
Mission Control creates a unified coordination ecosystem

The module integrates all stages of work — from order to report — into a single digital space. Commanders receive information directly in the system.



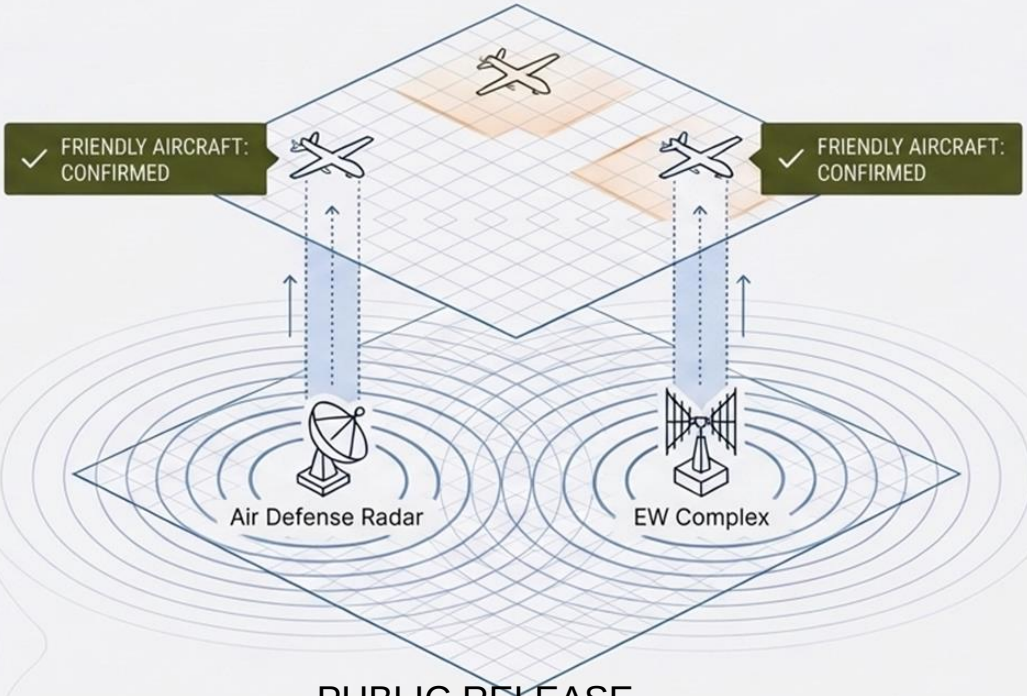
Mathematical accuracy in frequency and resource allocation

Rational use of resources and frequency allocation eliminates internal interference and increases the effectiveness of each sortie already at the planning stage.



Absolute IFF Visibility for Asset Preservation

Duty UAVs, EW and Air Defense clearly see the areas of operation for crews. Understanding which friendly drones are currently airborne critically reduces the level of friendly fire.



ВІДОБРАЖЕННЯ РАЙОНІВ РОБОТИ ЕКІПАЖІВ ТА РІЗНИХ МІСІЙ



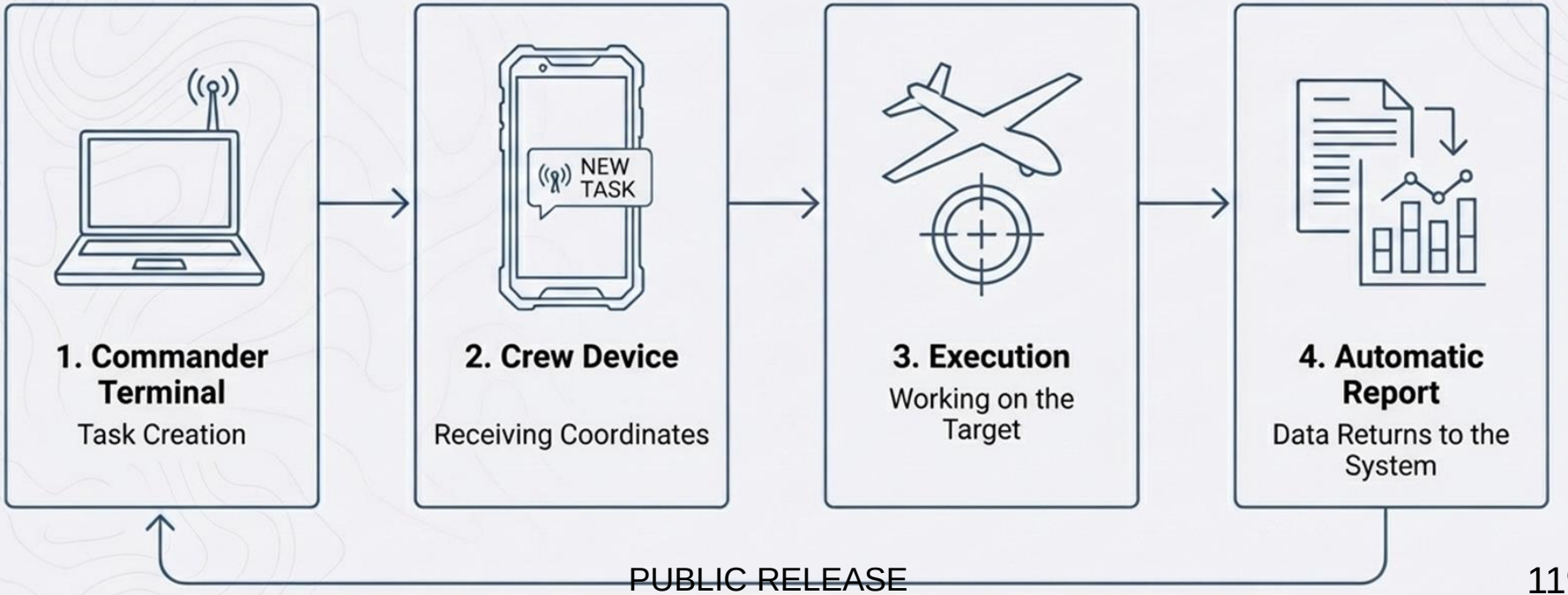






From Order to Action: Integration via Mobile Application

Crews receive precise tasks with coordinates directly on their smartphone. No unnecessary chats — just a clear order and an automatic execution report.



Integration of MISSION CONTROL System with Smartphone



PUBLIC RELEASE

Battlefield Synchronization: Value for Every Link

Mission Control creates a unified ecosystem where the coherence of some guarantees the safety and effectiveness of others.

COMMANDERS



Instead of gathering reports — complete control, rational planning, and management of all assets from a single screen.

UAV CREWS



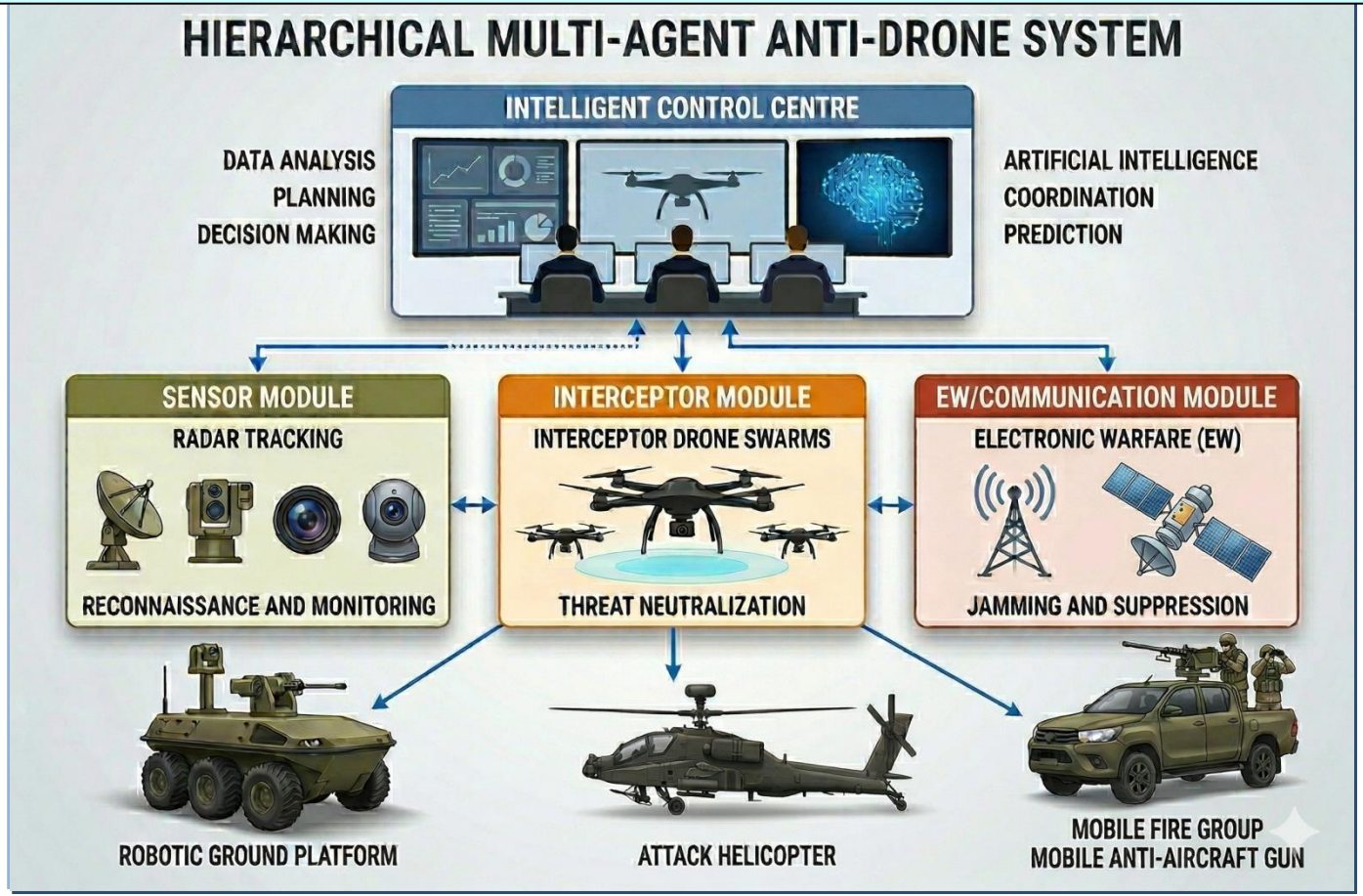
Instead of confusion in orders — clear instructions in a smartphone and focus on the direct execution of the combat mission.

AIR DEFENSE / EW DUTY



Instead of working blind — precise understanding of the situation in the sky, saving lives and avoiding friendly fire on our own assets.

Multi-agent C-UAS based on Agentic AI



Satellite communications as a key direction in the field of communications

Pascal Hamelin. Transforming Battlefield Communications for Stealth, Resilience and Mobility. Thales SIX, DRAKON Product Line Manager.

Mobile Deployable Communications Conference

26 - 27 January 2026. Prague, Czech Republic



HeloSAT. Field Trial, May 2025 (Thales, Prague, Jan. 2026)



DRAKON HeloSatKit for Helicopter (Thales)



OVZON SATCOM Solution

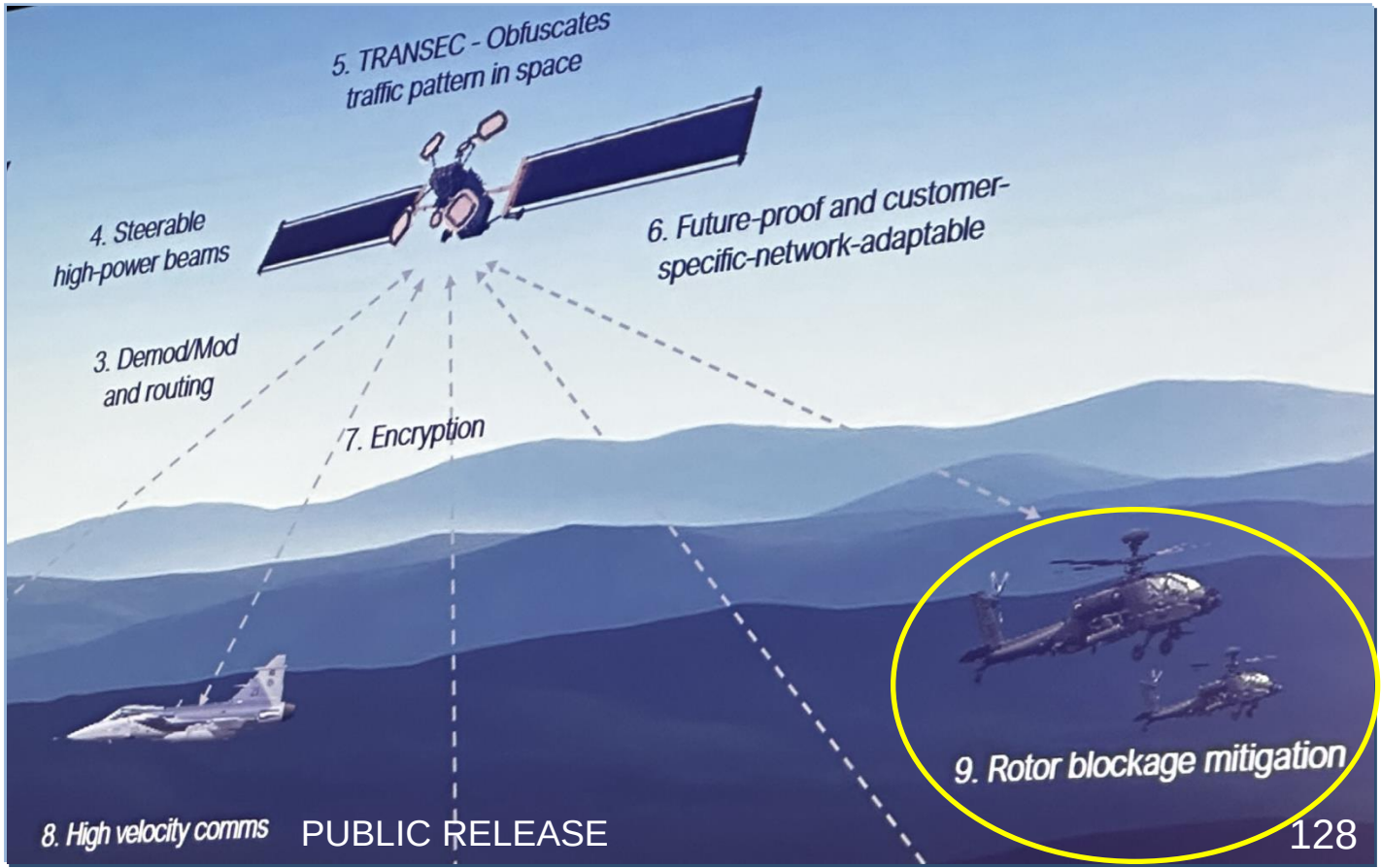
Global MilSatCom Conference, 3rd-6th November, 2025. London, UK



PUBLIC RELEASE

OVZON SATCOM Solution

Global MilSatCom Conference, 3rd-6th November, 2025. London, UK



Using Starlink terminals on board commercial helicopters





New approaches to the combat use of next-generation helicopters

PREAMBLE

Helicopters will not disappear, but their role is changing

1. Moving away from the front line

They will operate on the front line less frequently because of the risk of drone attacks.

2. Transition to “command platforms”

Helicopters may become drone-control centers rather than direct strike assets.

3. Drone hunting

Helicopters are being used to destroy UAVs. This is not merely an episode of the war - it is a signal of a change in the entire military doctrine.

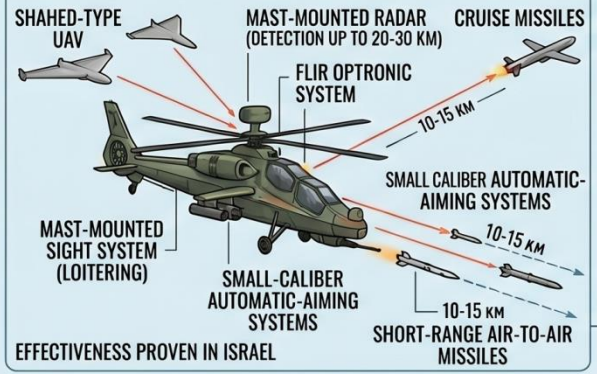
Conclusion

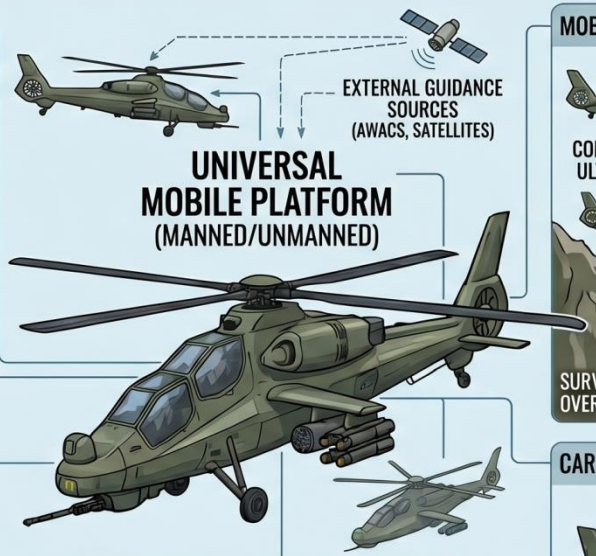
From “hunters,” they are gradually turning into coordinators - and this may completely change the appearance of the modern battlefield.


INTERCEPTION OF AIR THREATS
• Shahed-type UAVs
• Cruise missile
Mast-mounted radar
ENGAGEMENT OF AIR TARGETS
• Long-range missile
Long-range missiles
FLIR
EW
ELECTRONIC WARFARE
• Detection
• Jamming
• Protection
DIRECTED ENERGY (optional)
• Laser / Microwave
• Defeat of small targets
Interceptor drones
• Launch
• Interception
• Reconnaissance
AWACS
SATELLITE
C2
• Data exchange
• Action coordination
• Network-centric operations
C2
GROUND AIR DEFENSE
COMMAND POST
Manned or unmanned
MANNED
UNMANNED
LLM assistant
• Guidance and recommendations
• Threat analysis
• Decision support
• Threat analysis...
• Target priority: high
• Recommended action: interception
• System readiness: 92%
VR training

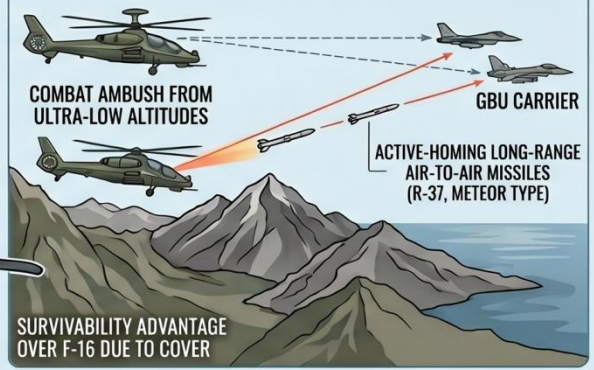
NEW APPROACHES TO NEXT-GENERATION HELICOPTER COMBAT EMPLOYMENT

ANTI-AIR DEFENSE AND COUNTER-UAV





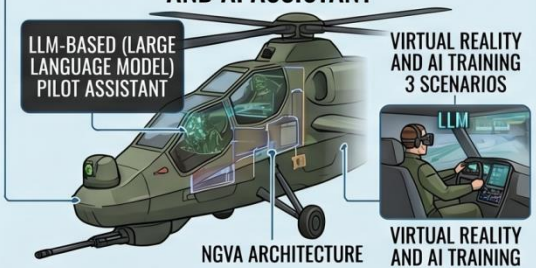
MOBILE AMBUSH AND ENGAGEMENT OF GBU CARRIER AIRCRAFT



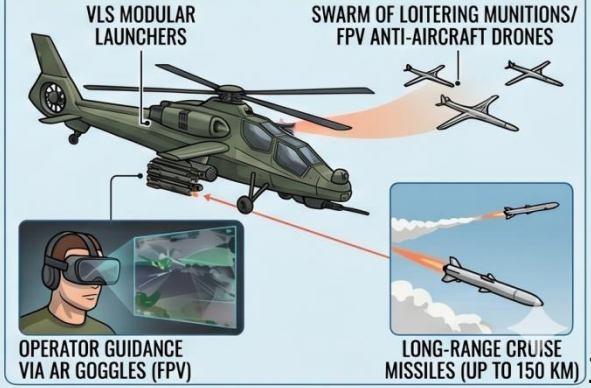
EW AND GROUP COVER JAMMING

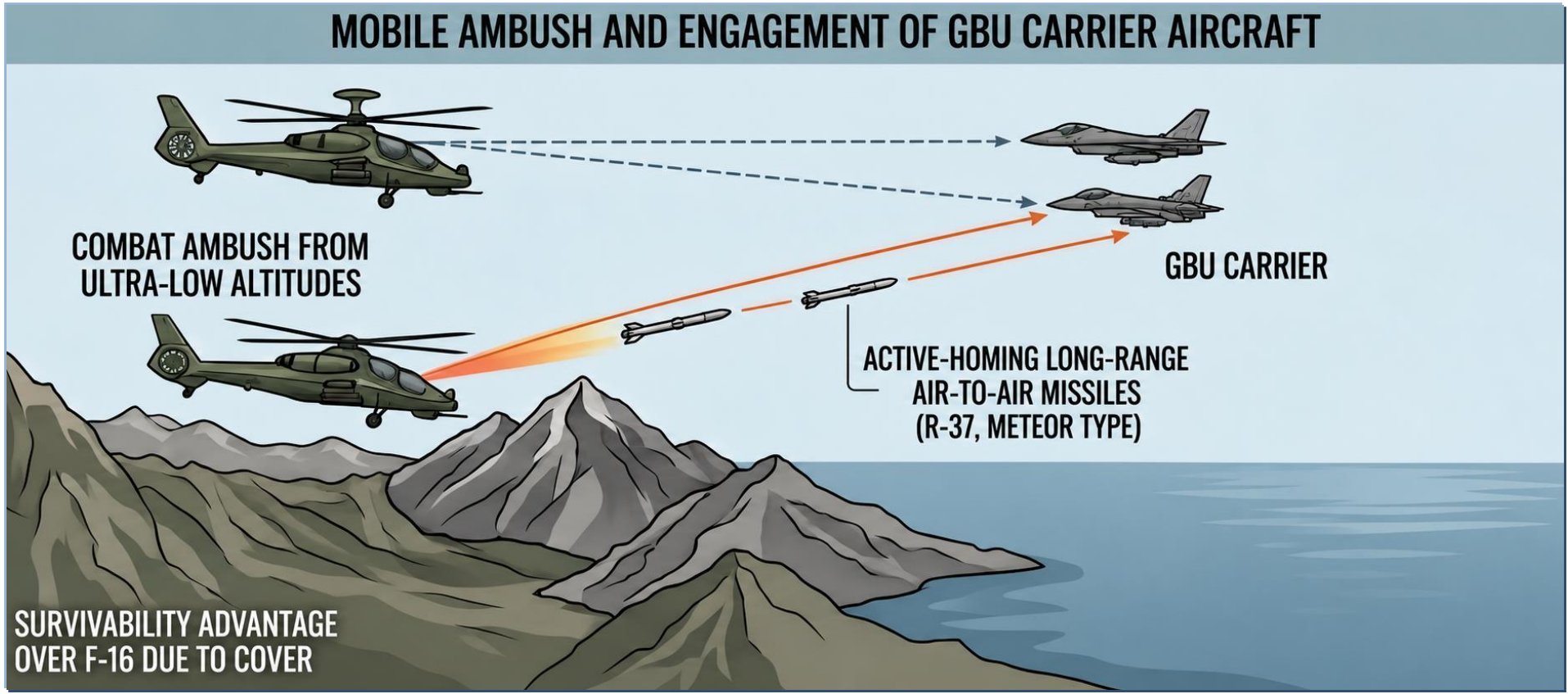


INTEGRATED MANAGEMENT SYSTEM AND AI ASSISTANT



CARRIER OF LOITERING MUNITIONS AND ANTI-AIRCRAFT DRONES

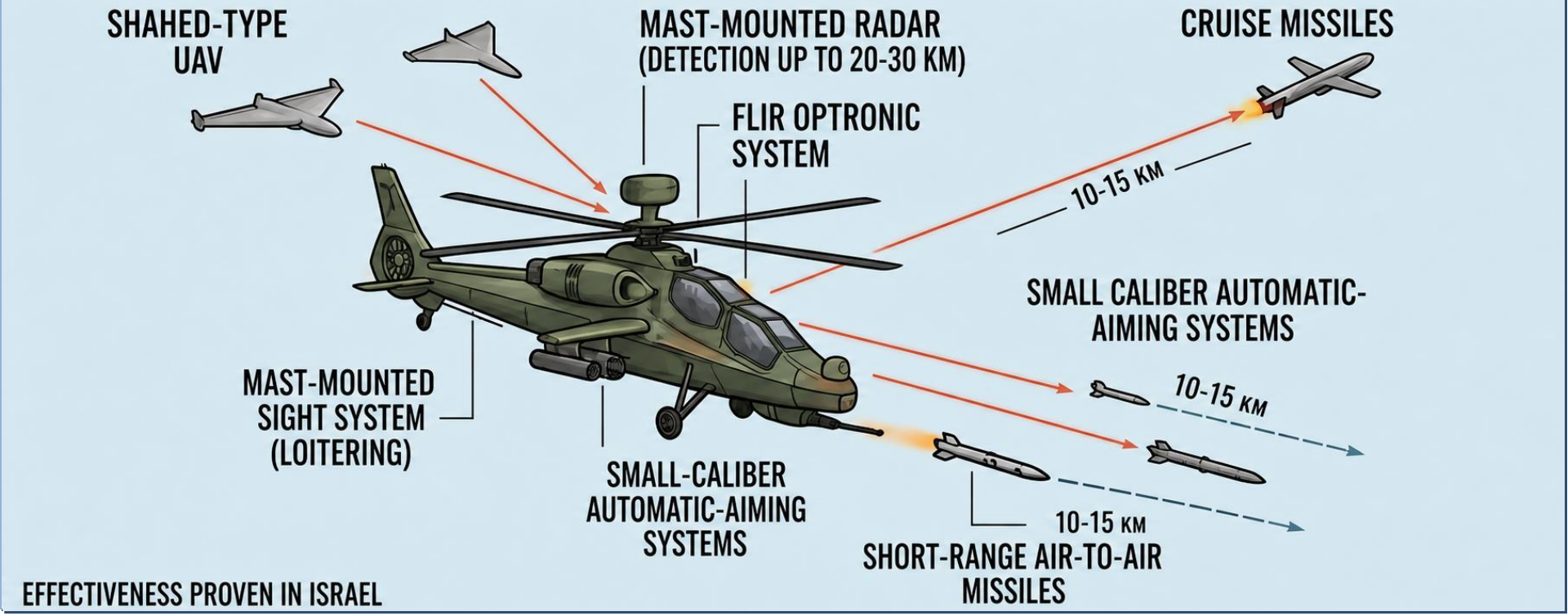


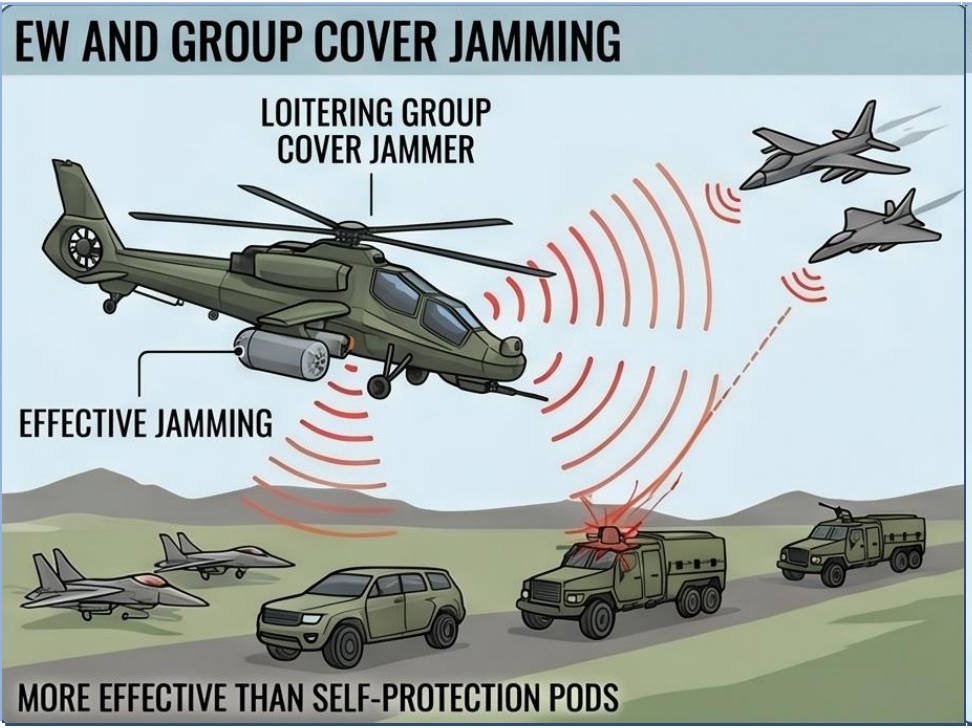

MOBILE AMBUSH AND ENGAGEMENT OF GBU CARRIER AIRCRAFT
COMBAT AMBUSH FROM ULTRA-LOW ALTITUDES
GBU CARRIER
ACTIVE-HOMING LONG-RANGE AIR-TO-AIR MISSILES (R-37, METEOR TYPE)
SURVIVABILITY ADVANTAGE OVER F-16 DUE TO COVER

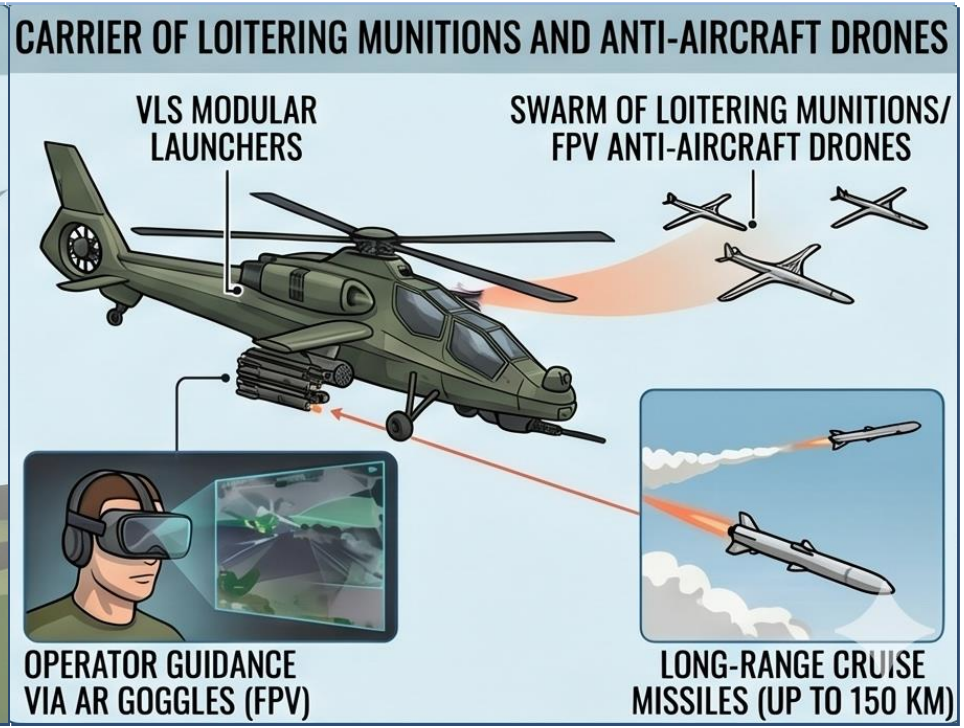
EW umbrella for helicopters strikes

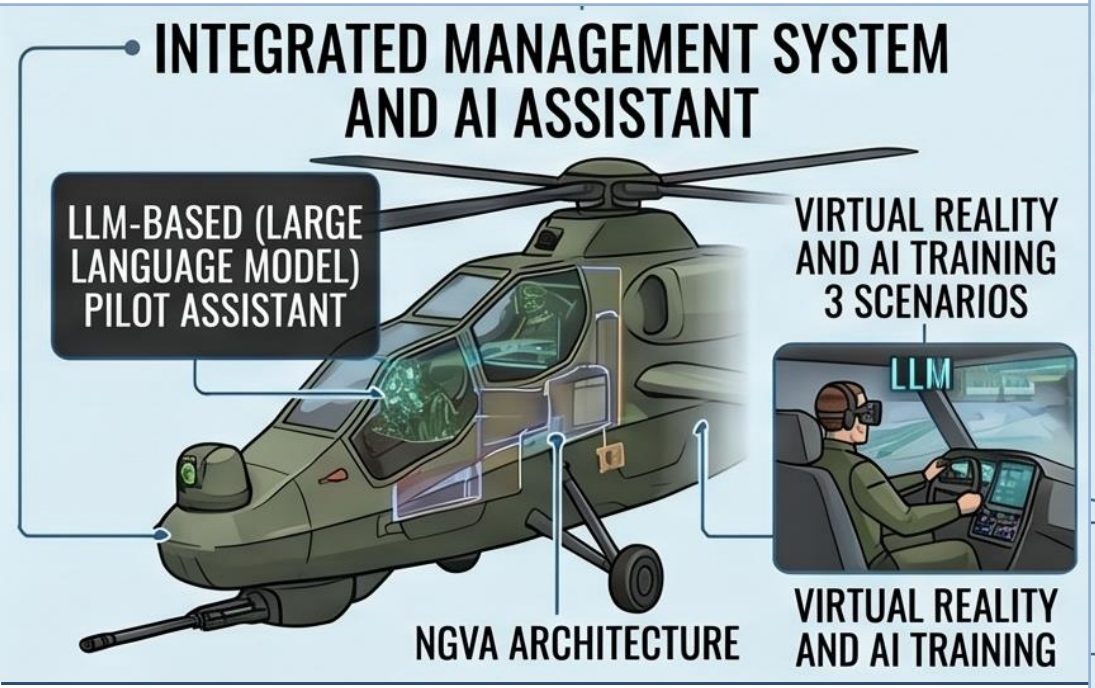


ANTI-AIR DEFENSE AND COUNTER-UAV




EW AND GROUP COVER JAMMING
LOITERING GROUP COVER JAMMER
EFFECTIVE JAMMING
MORE EFFECTIVE THAN SELF-PROTECTION PODS


CARRIER OF LOITERING MUNITIONS AND ANTI-AIRCRAFT DRONES
VLS MODULAR LAUNCHERS
SWARM OF LOITERING MUNITIONS/ FPV ANTI-AIRCRAFT DRONES
OPERATOR GUIDANCE VIA AR GOGGLES (FPV)
LONG-RANGE CRUISE MISSILES (UP TO 150 KM)


INTEGRATED MANAGEMENT SYSTEM AND AI ASSISTANT
LLM-BASED (LARGE LANGUAGE MODEL) PILOT ASSISTANT
VIRTUAL REALITY AND AI TRAINING 3 SCENARIOS
LLM
NGVA ARCHITECTURE
VIRTUAL REALITY AND AI TRAINING


EXTERNAL GUIDANCE SOURCES (AWACS, SATELLITES)
UNIVERSAL MOBILE PLATFORM (MANNED/UNMANNED)

Soldier and Commander Assistant Concept Based on LLM (January 2024)

The Human System Integration (HSI) virtual symposium
12 January 2024

Reducing the Cognitive Burden of a Soldier with the Help of Personal AI and LLM Assistant

VADYM SLYUSAR
Doctor of Sciences, Professor

12 January 2024

PUBLIC RELEASE

Concept of Unmanned Team to protect of a manned Helicopter



PUBLIC RELEASE

Concept of unmanned helicopters as a means for a transporting combat androids

China's Autonomous Killer Robots to Deploy on Battlefields Within Two Years





A Phantom MK-1 humanoid robot, produced by San Francisco-based Foundation in Ukraine



"In February, 2026 two Phantoms were sent to Ukraine - initially for frontline-reconnaissance support. But Foundation is also preparing Phantoms for potential deployment in combat scenarios for the Pentagon…"

Rise of the AI Soldiers, TIME, Mar 10, 2026

https://time.com/article/2026/03/09/ai-robots-soldiers-war/

Helicopter as a means of transporting androids



The androids' backs can act as the outer shell of a helicopter's body



PUBLIC RELEASE

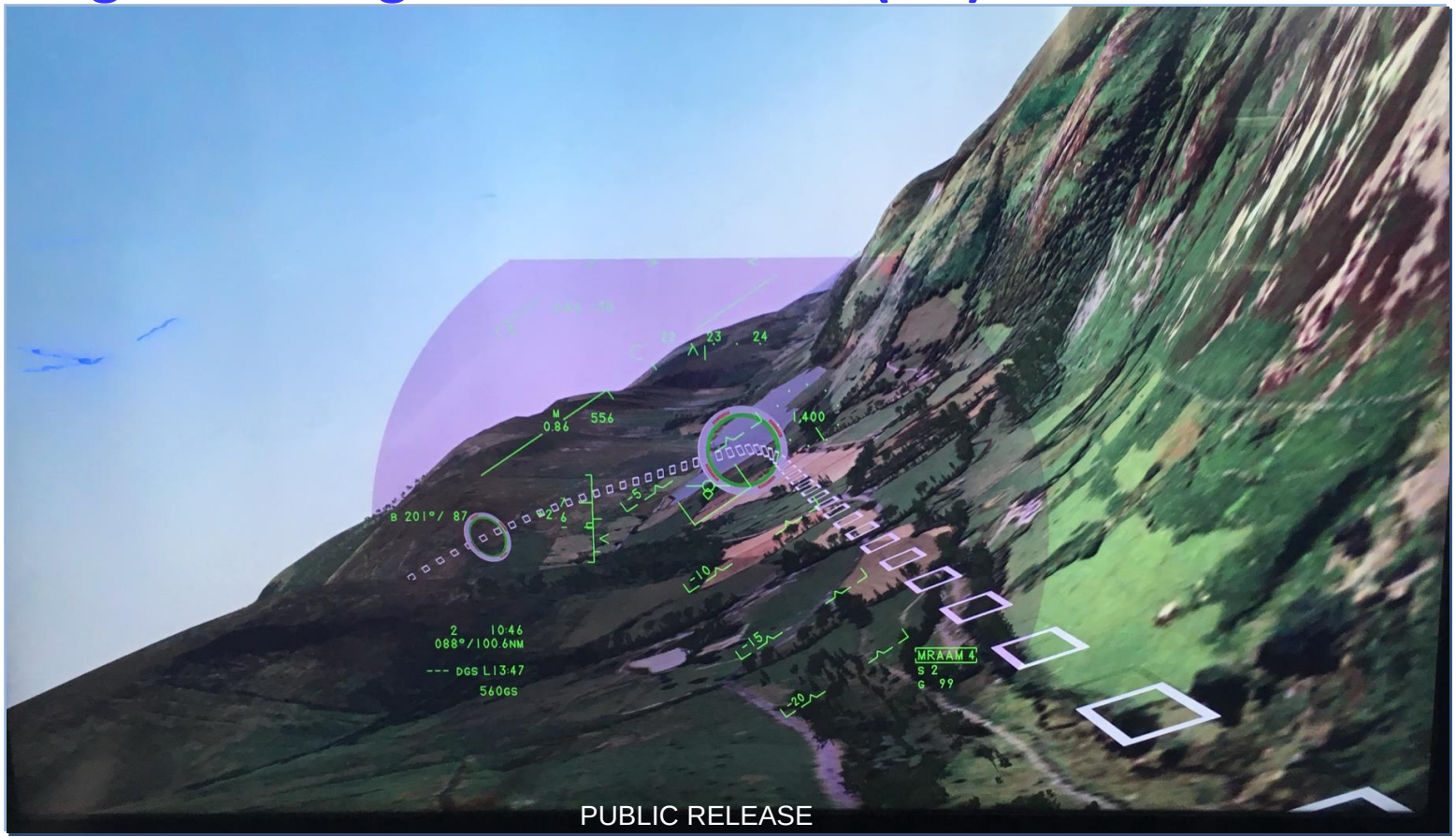
The androids' backs can act as the outer shell of a helicopter's (Ver.2)



PUBLIC RELEASE

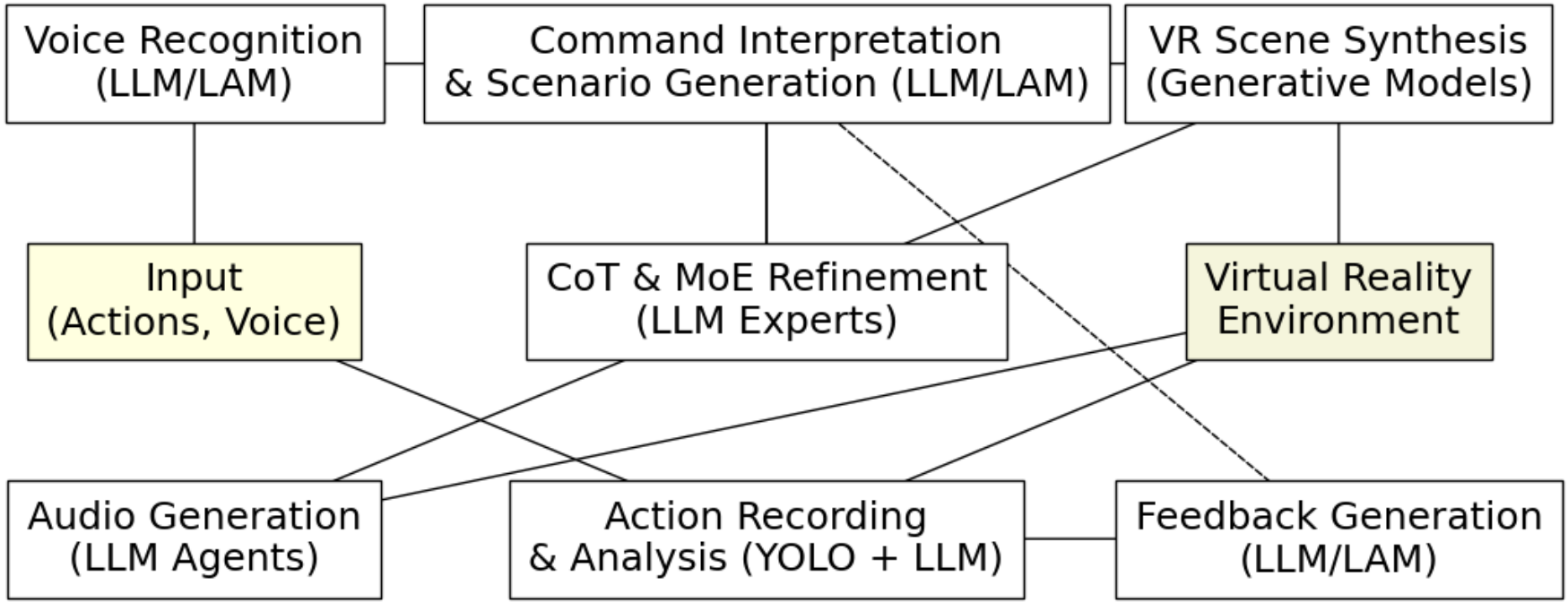
Emerging and disruptive technologies

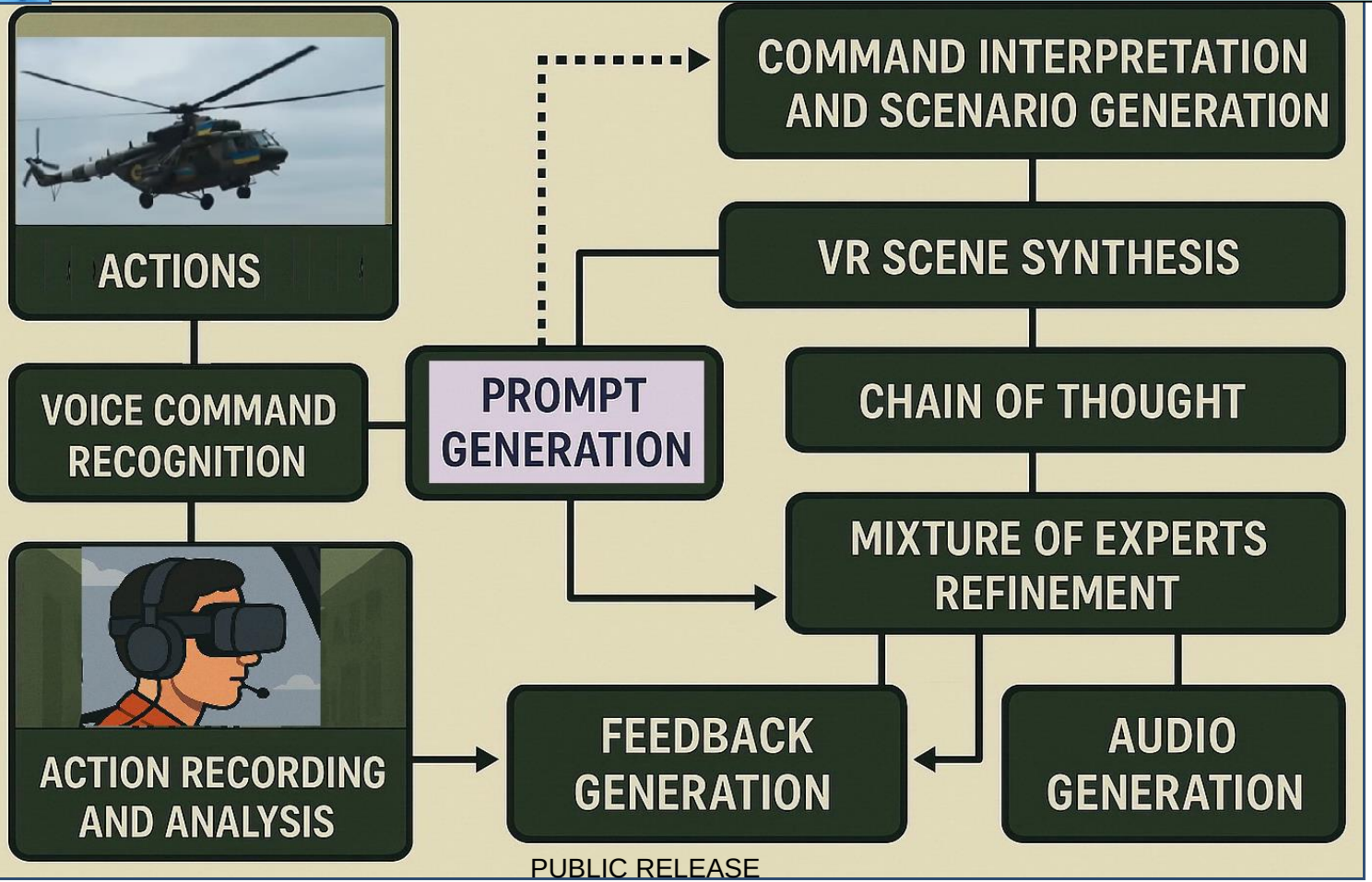
Training Technologies based Virtual (VR) and Mixed Reality



PUBLIC RELEASE

Diagram of LLM/LAM VR Training Process





PUBLIC RELEASE

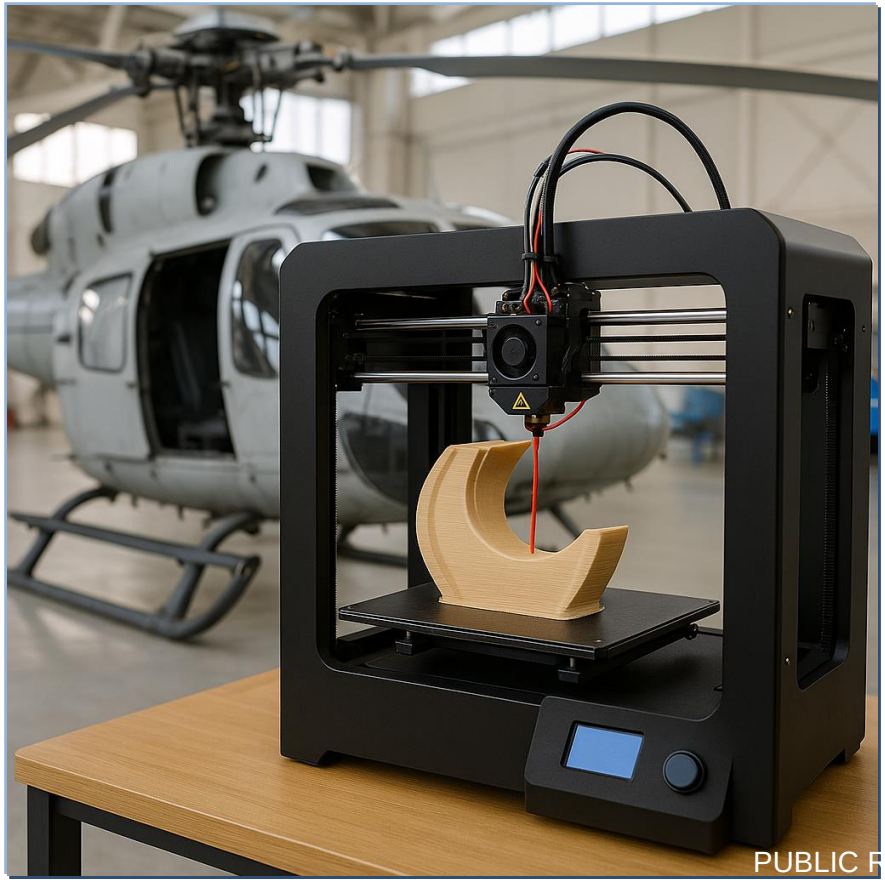
Using Augmented Reality and Digital Twin Technologies in Maintenance and Repair Processes





PUBLIC RELEASE

Using 3D Printing in Repair Processes





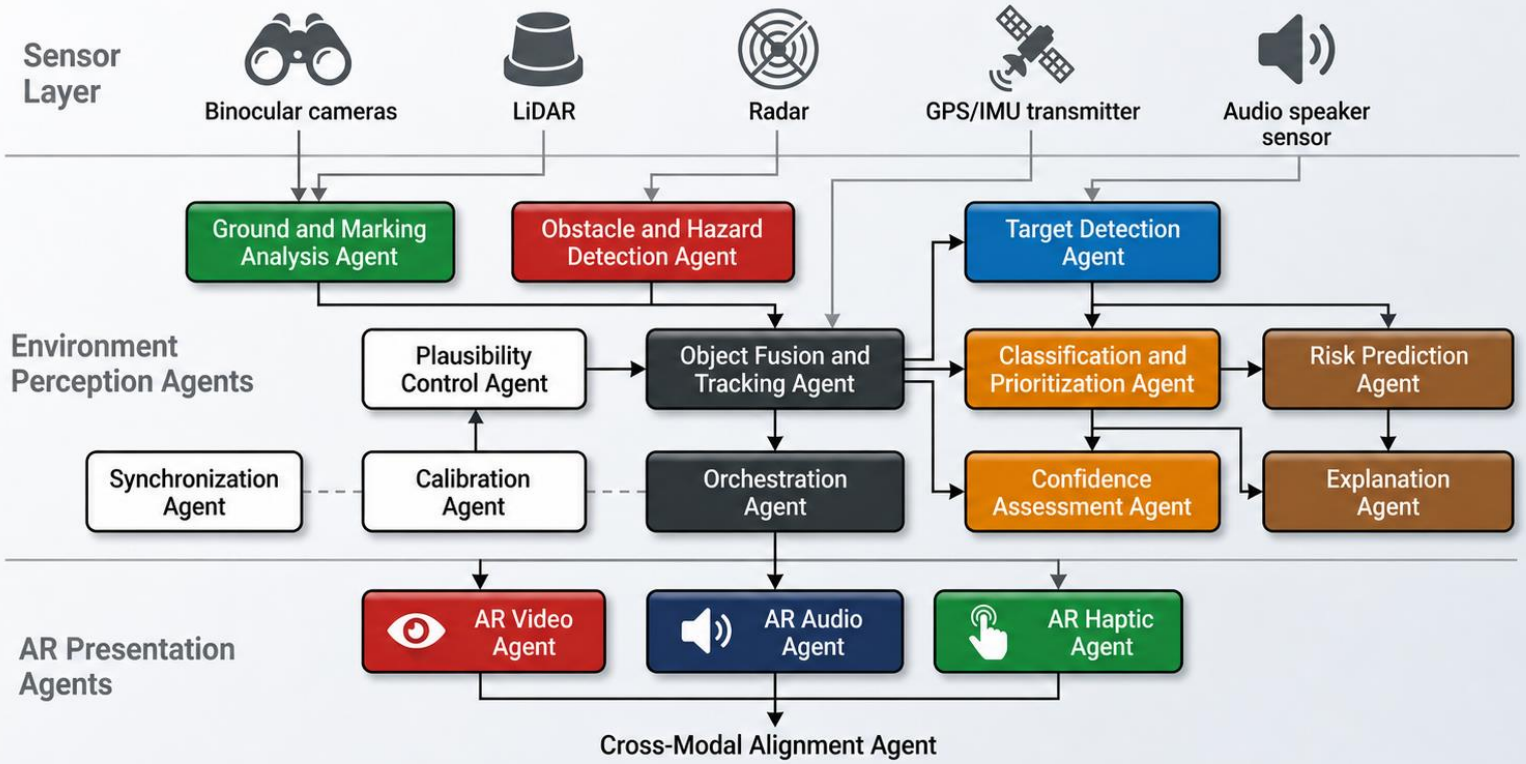
Australia's SPEE3D metal printer

https://wesodonnell.medium.com/how-3d-metal-printers-in-ukraine-are-reinventing-war-logistics-a65152b30965

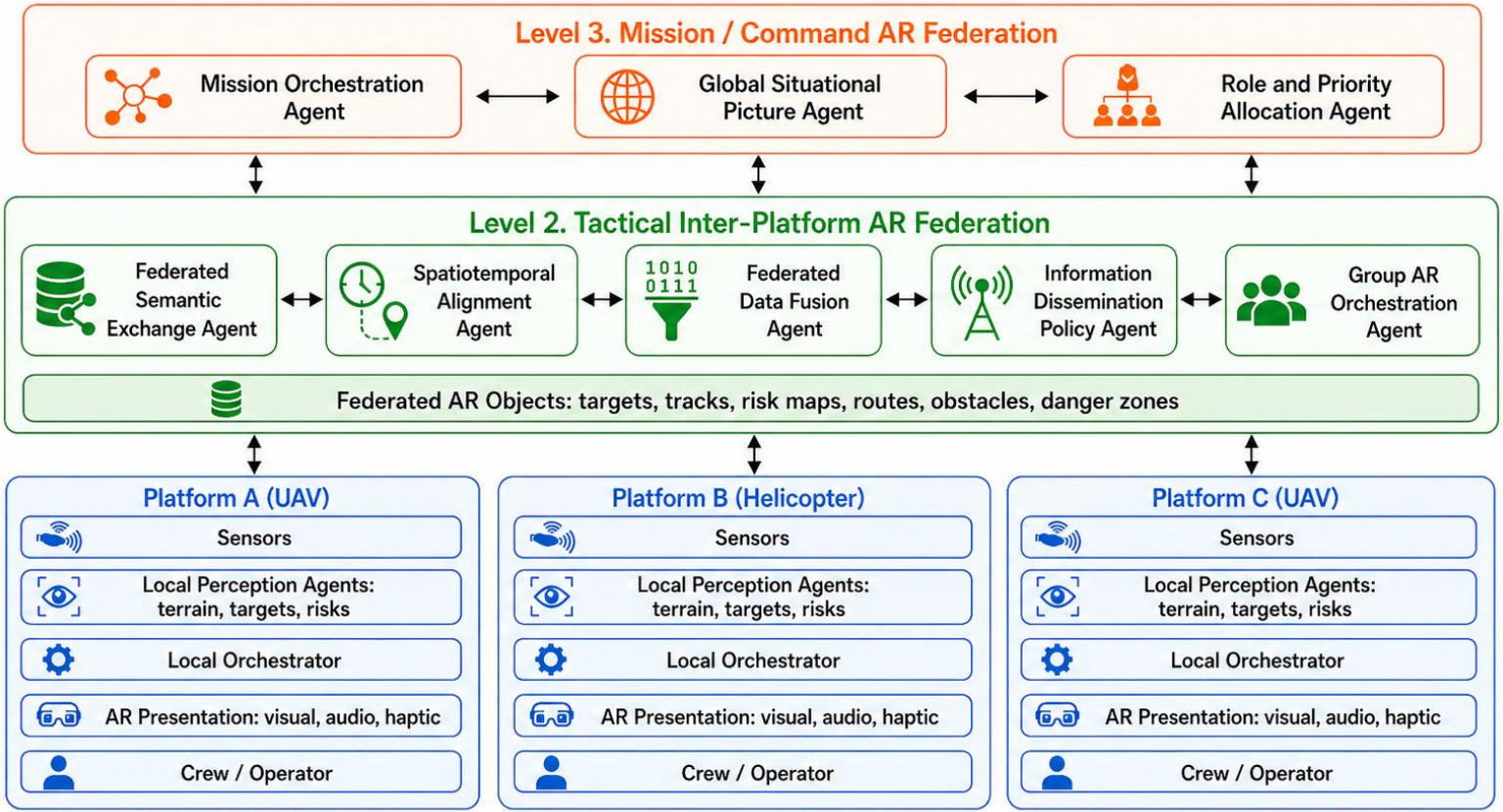
PUBLIC R

Multi-Agent Augmented Reality and Semantic Communications for Next-Generation Helicopters

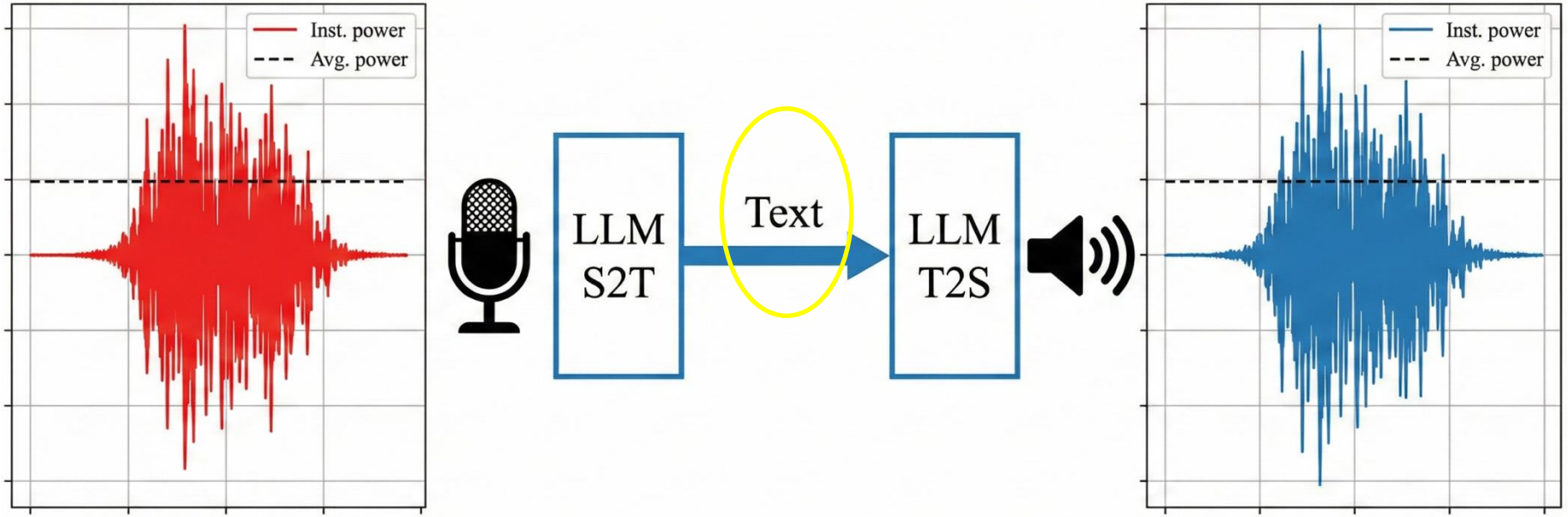
Multi-agent Onboard Augmented Reality System Architecture for Helicopters



Federated Multi-Agent Architecture of the Augmented Reality System for a Network of UAVs and Helicopters



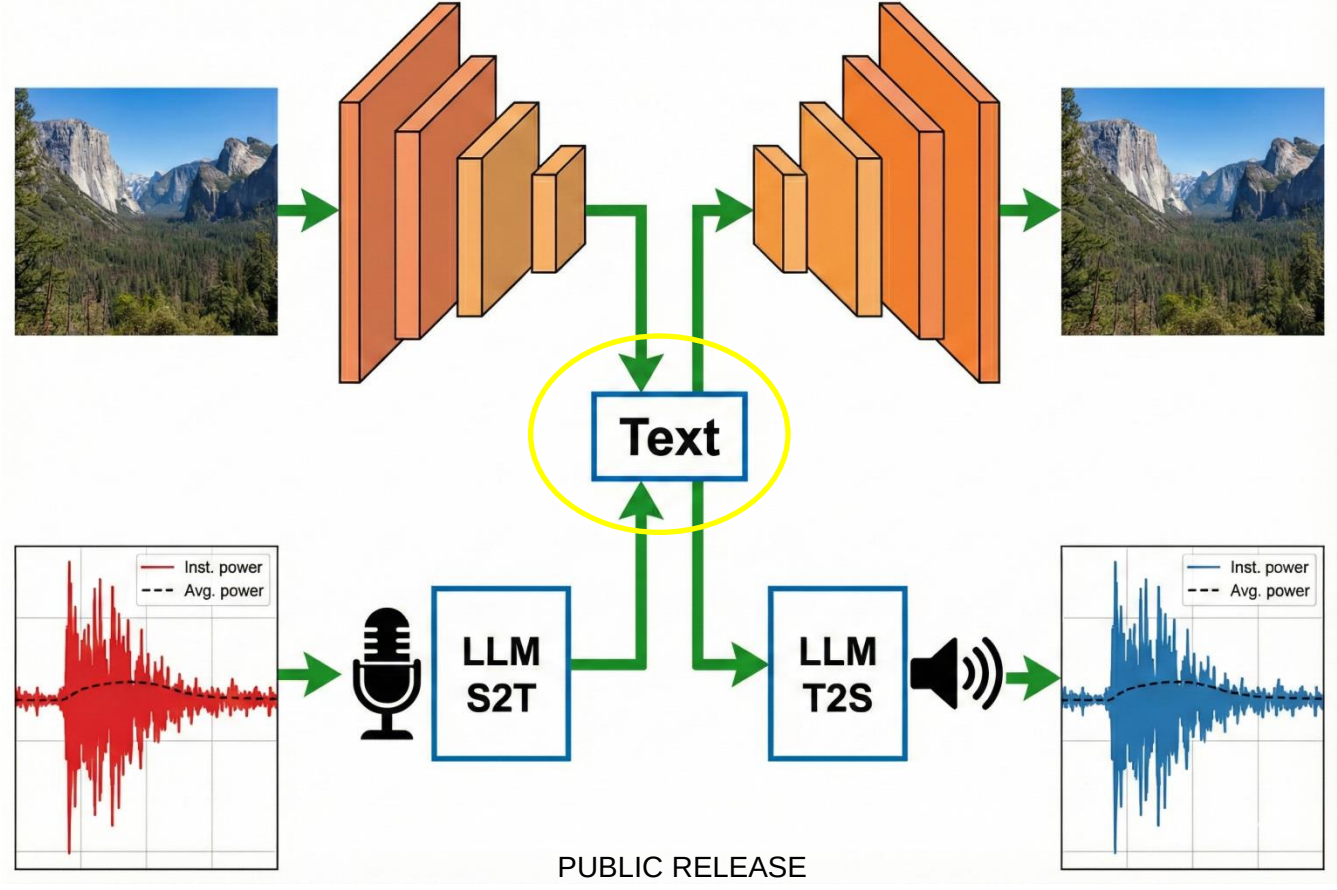
Semantic communication for voice transmitting by using LLMs



Semantic communication for image transmitting by using LLMs



Semantic communication for video streaming by using LLMs



PUBLIC RELEASE

Summary

- **Existing doctrinal approaches** to the employment of helicopters **no longer correspond to the realities** of the modern battlefield, which is saturated with air defence systems, UxS, sensor networks, EW assets, and precision weapons.
- The further development of helicopters should be based not only on the improvement of flight and technical characteristics, but also on the **expansion of its roles within integrated combat systems.**
- **The helicopter of the future** should become a **multifunctional platform** for reconnaissance, fire support, evacuation, logistics, unmanned systems control, data relay, and interaction with robotic assets.
- The introduction of **AI, robotization, autonomous modes, new communications, AR and mixed reality** will make it possible **to transform the helicopter** from a separate combat platform into an adaptive node of a network-centric operation.

THANK YOU
FOR YOUR ATTENTION !

