The War of the Skies: A Technological Revolution Above Our Heads

David Bensoussan

The author is a science professor at the University of Quebec

The Russian invasion of Ukraine has led Western countries to revise their defense strategies. As NATO countries prepare to increase their defense budgets to 2% of GDP, it is highly likely that investments will be directed toward acquiring stealth aircraft like the F-35, missiles, and missile-defense systems.

Despite the prevalence of terms such as rockets, missiles, drones, and UAVs in international news, distinctions between these devices often remain unclear. This article provides an overview of the main categories of airborne devices, other than fighter jets, to better understand the technology central to modern conflicts.

Recent conflicts in Ukraine and Israel have offered crucial insights, particularly in the realm of missile warfare. Israel's experience in this domain warrants special attention, as it offers solutions developed in response to these threats.

Categories of Airborne Devices

Rockets: Typically launched over distances less than 50 km and capable of reaching hypersonic speeds of 10,000 km/h, rockets follow a predetermined trajectory.

Drones: Controlled remotely or autonomously (e.g., surveillance or kamikaze drones), drones can cover distances between 100 and 200 km.

Missiles: Equipped with advanced navigation systems, missiles can be subsonic, supersonic, or hypersonic. Hypersonic missiles, capable of altering their trajectory mid-flight, are revolutionizing modern warfare with their extraordinary speed.

Ballistic Missiles: These include short-range missiles (up to 1,000 km), medium-range (1,000–3,000 km), intermediate-range (3,000–5,500 km), and

intercontinental ballistic missiles (ICBMs), which travel at supersonic speeds above Earth's atmosphere and exceed 6,000 km in range.
Cruise Missiles: These missiles follow terrain contours by comparing digital maps to the topography they fly over. Flying at low altitudes, they are harder to detect via radar and can reach ranges of several hundred kilometers.

Navigation Technologies

The effectiveness of missiles and drones depends on sophisticated satellite navigation systems. Low Earth Orbit (LEO) satellites, for instance, provide photographic resolutions ten times higher than geostationary satellites. To counter electromagnetic interference, some missiles rely on autonomous inertial navigation systems.
Missile guidance can be manual, such as optical sights that allow operators to track targets for anti-tank missiles, or remote, receiving instructions from radar systems. A missile may track a radar beam aimed at its target, follow radar reflections from the target, or lock onto the target's emitting radar. Near their targets, missiles can explode or home in on infrared heat emissions from aircraft.

Examples

Israel's air defense system includes missiles with various ranges: Arrow 3 (above Earth's atmosphere, 2,400 km); Arrow 2 (1,600 km); David's Sling (300 km); Iron Dome (70 km); Laser Dome (10 km). Israel has also developed 70 drone models.
In April 2023, the Arrow 2 and Arrow 3 systems were tested against a barrage of Iranian ballistic missiles (110–130), cruise missiles (36), and drones (185). These tests marked the first successful interception of a missile outside Earth's atmosphere.

Laser Weapons

The most striking innovations involve lasers to neutralize threats. Laser weapons, capable of concentrating beams with extreme precision, can pierce missiles in seconds.

A laser amplifies light by generating electromagnetic waves oscillating between two mirrors, much like a vibrating string between two walls. One mirror is slightly perforated, emitting a coherent laser beam with in-phase radiation. This concentrated beam can merge with others to create a more powerful ray.

High-power lasers can reach outputs of several thousand watts. A 100 kW laser with a 10 cm beam diameter can penetrate a missile body within 2–3 seconds. Israel has developed 10 kW lasers to counter drones and rockets launched from nearby territories.

However, laser weapons face challenges, including reduced effectiveness in fog or rain. To address this, lasers with outputs up to 1 MW (e.g., Arrow 4) are under development.

The Rise of Artificial Intelligence

The rapid pace of aerial and missile defense advancements is mobilizing enormous financial and intellectual resources. The integration of artificial intelligence is reshaping battlefields, enabling swarms of drones, multi-warhead missiles, and military satellites. AI-driven decision-making is becoming central to military strategies, relegating human supervision to secondary roles. This trend raises significant ethical and security concerns.