WARHEAD WATCH

SURFACE TO AIR MISSILE

TECH REPORT


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FOREWORD

The dynamic and increasingly contested global security environment underscores the critical need for robust, multi-layered air defence systems. In this context, Surface-to-Air Missile (SAM) systems represent a cornerstone of any nation's air defence strategy, serving not only as technological deterrents but also as instruments of sovereign assurance.

This tech report by our MoU Partner IP Bazzaar provides a comprehensive perspective on the current and emerging landscape of SAM systems, focusing on the imperatives of indigenous development, domain integration, capacity enhancement, and resilient supply chains. It also outlines a forward-looking framework to ensure that future SAM architectures are agile, interoperable, and cyber-resilient.

As India advances towards the era of strategic self-reliance in defence technology, it becomes vital to foster convergence among public R&D institutions, armed forces, industry, and academia. The innovation insights captured here reinforce the necessity of such collaboration, while also aligning with our national vision of Atmanirbhar Bharat.

I commend the contributors of this report for their incisive research and actionable recommendations. I am confident that it will serve as a valuable reference for policymakers, technologists, industry leaders, and defence strategists in shaping the future of India's missile defence capability.

Maj Gen (Dr) Ashok Kumar, VSM (Retd)
Director General
Centre for Joint Warfare Studies (CENJOWS)

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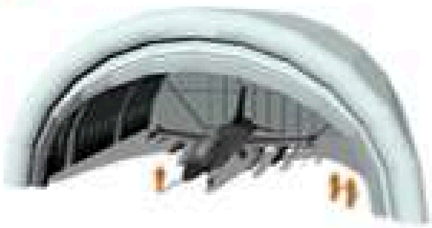

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Surface-to-Air Missiles

History and Origin

The concept of surface-to-air missiles (SAMs) emerged in the early 20th century, but it was during World War II that the need for a system capable of intercepting high-flying enemy bombers became urgent. The earliest known attempt to develop such a weapon was Nazi Germany's Wasserfall missile project, a scaled-down adaptation of the V-2 rocket intended for anti-aircraft use. Though the Wasserfall never became operational due to the war ending, it laid the foundation for future missile defense systems and demonstrated the feasibility of radar-guided missile interception.

Era	Highlights
1940s–50s	Birth of SAMs (Nike Ajax, S-25)
1960s–80s	Global spread, Cold War systems, mobile launchers, AESA radars developed
1990s–2000s	Networked warfare, anti-missile focus, AESE radars become operational
2000s–Now	AESA radars mainstrem stage, active seekers, layered defense, AI integration

Country	System	Key Feature
USA	Nike Ajax (1953)	First operational SAM, radar-guided
USSR	S-25 Berkut (1955)	Deployed around Moscow
UK	Bloodhound (1958)	Long-range SAM using ramjet propulsion

Following the war, both the United States and the Soviet Union accelerated their missile development programs, leveraging captured German technology and scientists. The first operational SAM system was the U.S. Army's Nike Ajax, which entered service in 1953. It was a two-stage, radar-guided missile designed to destroy high-altitude bombers and was deployed around major American cities and strategic targets during the Cold War. Around the same time, the Soviet Union introduced the S-25 Berkut which was a first generation system, designed to defend Moscow through a fixed-site network. Separately, the Soviets developed the more advanced and mobile S-75 Dvina (NATO: SA-2 Guideline), which gained global attention when it shot down a U.S. U-2 spy plane piloted by Gary Powers in 1960, underlining the strategic importance of surface-to-air missile systems.

Country	Notable SAMs	Characteristics
USSR	S-75 (SA-2), S-125, S-200	Deployed widely; S-75 shot down U-2 spy plane in 1960
USA	MIM-23 HAWK, Nike Hercules	Mobile, high-altitude, semi-active radar
France	Crotale	Short-range, mobile, radar-guided
Israel	Barak 1 (1980s)	Naval point defense SAM

As the Cold War intensified, both superpowers expanded their SAM arsenals. The U.S. developed mobile systems like the MIM-23 HAWK to support ground forces, while the Soviets fielded a family of mobile and long-range systems such as the S-125, S-200, and Buk series. These systems were exported widely to allies and client states, becoming a crucial element of global air defense doctrines.

By the 1980s and 1990s, SAM technology advanced to include phased-array radars, multi-target tracking, and the ability to engage not just aircraft but also cruise and ballistic missiles. Systems like the U.S. Patriot (which gained fame during the Gulf War) and Russia's S-300 series represented the new generation of high-performance SAMs. These platforms offered layered defense capabilities and higher accuracy through improved radar and guidance systems.

In the 21st century, the development of SAMs has focused on greater mobility, digital integration, and network-centric warfare. Modern systems like the Russian S-400, U.S. THAAD and NASAMS, Israel's Iron Dome and David's Sling, and the India-Israel jointly developed Barak 8/MRSAM represent the cutting edge of missile defense technology. These systems incorporate active electronically scanned array (AESA) radars, active seekers, and real-time integration with satellite and drone-based surveillance networks. They are capable of intercepting a wide range of threats, including low-RCS aircraft, UAVs, cruise missiles, and short-range ballistic missiles.

COUNTRY	SYSTEM	HIGHLIGHTS
USA	Patriot (PAC-2, PAC-3)	Medium-long range, anti-missile roles
Russia	S-300, Buk-M1	Phased-array radar, mobile
China	HQ-9	Modeled after S-300, long-range
India-Israel	Barak 8 / MRSAM	AESA radar, active guidance, 70–100 km range

System	Countries	Key Features
S-400 Triumf	Russia	Long-range (400 km), multi-target, radar-resistant
THAAD	USA	Intercepts ballistic missiles in terminal phase
NASAMS	USA/Norway	Uses AIM-120 AMRAAM, mobile, modular
Iron Dome	Israel	Short-range, cost-effective anti-rocket system
Akash & Akash-NG	India	Indigenous, medium-range, active seeker (NG)

Today, SAMs are an essential component of national air defense strategies, providing multi-layered protection for cities, military installations, and mobile forces. Their evolution mirrors the broader history of military technology—driven by the need to counter emerging threats with increasing speed, precision, and reliability.

Types of Surface-to-Air Missiles

Type	Range	Purpose	Examples
VSHORAD (Very Short-Range)	<5 km	Point defense, MANPADS	FIM-92 Stinger, Igla, QW-2
SHORAD (Short-Range)	5–30 km	Low-altitude aircraft & UAVs	Crotale, Pantsir-S1, Akash Mk-I
MR-SAM (Medium-Range)	30–100 km	Intercepts fighters, cruise missiles	Barak 8, Buk-M3
LR-SAM (Long-Range)	100–300+ km	Multi-layer defense, high-altitude	S-300, HQ-9, Barak ER, Patriot
ABM Systems	200–1000+ km	Anti-ballistic missile role	THAAD, S-400, Arrow 2/3

Key Features of Modern SAM Systems

Feature	Description
Radar Integration	AESA/PESA radars for 3D tracking, target acquisition
Seeker Types	Command guidance, semi-active, active radar seekers, IR seekers
Mobility	From fixed installations to fully mobile, truck- or tank-based systems
Kill Mechanism	Proximity fuze with fragmentation, hit-to-kill (PAC-3, THAAD)
C4ISR Capability	Integrated with command networks for coordinated response
Multi-target Engagement	Track and engage multiple targets simultaneously
Interoperability	NATO or regional compatibility in modern systems (e.g., NASAMS, SAMP/T)

Development of India's SAM

India's journey in the development of surface-to-air missile (SAM) systems began in the post-independence era, driven by the need to secure its vast airspace against emerging regional threats. In the early decades, India relied heavily on imported air defense systems, particularly from the Soviet Union, which supplied India with SAM systems such as the SA-2 Guideline (S-75 Dvina) and later the Kvadrat (SA-6 Gainful) in the 1970s. These systems were used to establish static and mobile air defense units for the Indian Air Force and Army.

The vision to develop an indigenous SAM system began to take shape in the 1980s, when India recognized the strategic necessity of self-reliance in missile technologies. This was formally realized through the launch of the Integrated Guided Missile Development Programme (IGMDP) in 1983, led by Dr. A.P.J. Abdul Kalam, under the aegis of the Defence Research and Development Organisation (DRDO). The IGMDP aimed to develop a family of missiles, including Agni (ballistic missile), Prithvi (SRBM), Nag (anti-tank missile), Trishul (short-range SAM), and Akash (medium-range SAM).

India's first indigenous SAM development under IGMDP was the Trishul missile, envisioned as a quick-reaction short-range system with a range of around 12 km. It was intended for use by all three services—Army, Navy, and Air Force. However, due to technological challenges in achieving reliable guidance and tracking systems (especially in sea-skimming scenarios for naval use), the project suffered delays and was ultimately shelved in the early 2000s after limited user trials.

Parallel to Trishul, DRDO began developing the Akash missile system, a medium-range SAM capable of engaging multiple aerial threats including fighter aircraft, helicopters, UAVs, and cruise missiles. Akash was based on ramjet propulsion technology, giving it the capability to maintain high speeds (Mach 2.5) throughout its flight. The system was designed to be mobile and could be deployed by both the Indian Air Force and Army. Its fire-control radar, Rajendra, was developed by BEL and LRDE, and featured phased-array tracking capability.

Despite initial delays and skepticism from users, the Akash system gained momentum in the 2000s, especially after the cancellation of foreign deals like the Israeli SPYDER system due to political and budgetary reasons. The indigenous system saw major support during Dr. V.K. Saraswat's tenure at DRDO and was eventually inducted into the Indian Air Force in 2009 and the Indian Army in 2015. Akash has evolved into Akash Mk-II (range up to 40 km) and Akash-NG (70–80 km), featuring improved range, active radar seekers, and canister-based launch systems.

India's SAM development was also influenced and assisted through **select collaborations and technology insights**, particularly:

- **Russia:** Through legacy systems (SA-6, SA-8) and defense cooperation, providing early exposure to radar-guided SAM operations.
- **Israel:** In the 2000s, India entered into a strategic collaboration with Israel Aerospace Industries (IAI) for the Barak 8 / MRSAM program, which significantly advanced India's capabilities in AESA radar, active seekers, and integrated command systems. This system has been inducted by the Indian Navy, Air Force, and Army.

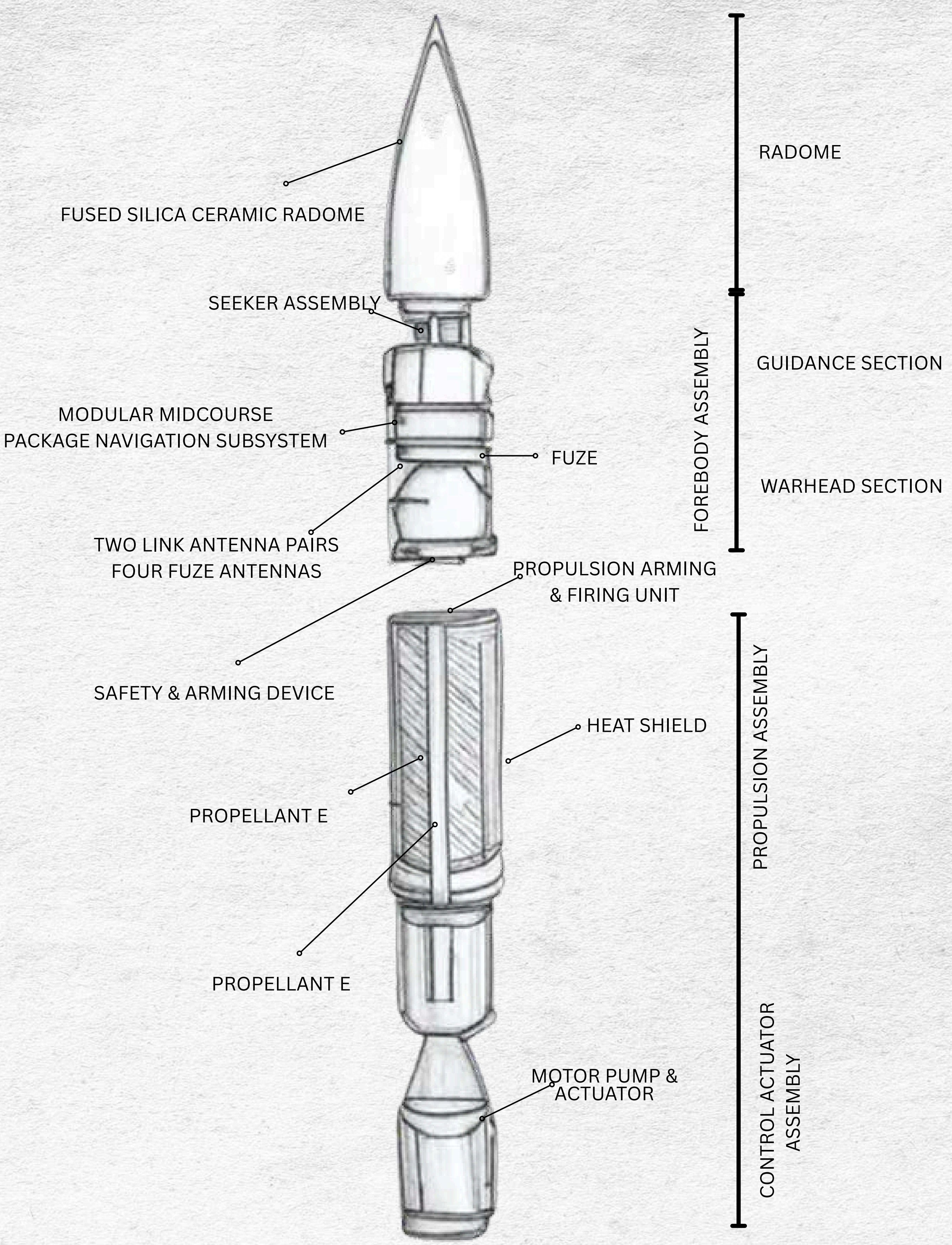
From early reliance on Soviet systems to the successful operationalization of Akash and MRSAM systems, India has now positioned itself as a SAM-exporting nation, with the Akash system being offered to countries in Southeast Asia and Africa.

ORGANIZATION	HIGHLIGHTS
DRDO	Lead developer of Akash, Rajendra radar, Trishul
Bharat Electronics Ltd (BEL)	Radar and C2 systems
Bharat Dynamics Ltd (BDL)	Missile production and assembly
Russia	Supplied initial SAMs; knowledge foundation
Israel Aerospace Industries (IAI)	Co-development of Barak 8 (MRSAM)
Indian Armed Forces	User trials, feedback, operational validation

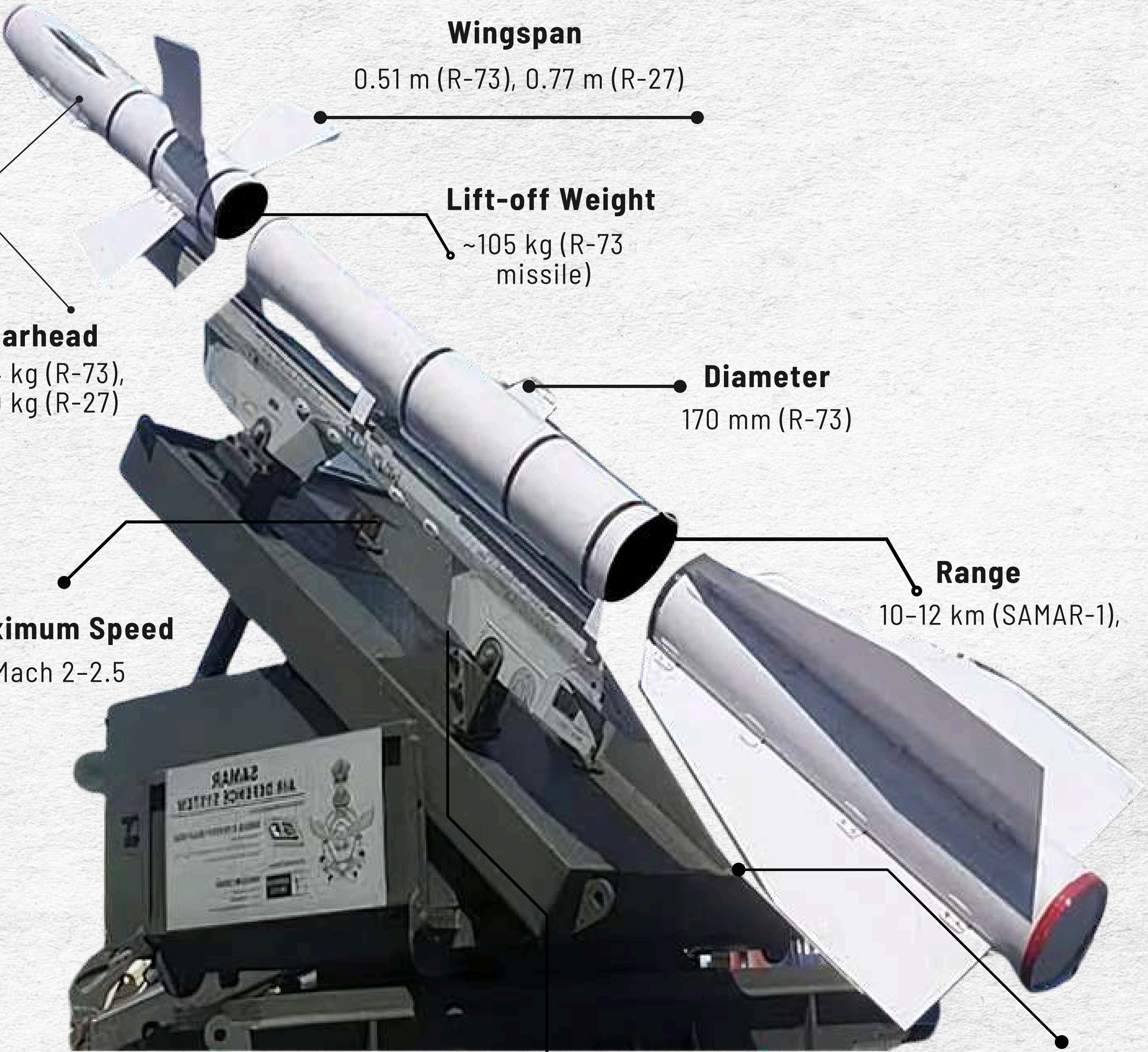
INDIA's

MISSILE SYSTEMS

COMPONENTS


RADOME
FUSED SILICA CERAMIC RADOME
SEEKER ASSEMBLY
GUIDANCE SECTION
FOREBODY ASSEMBLY
MODULAR MIDCOURSE
PACKAGE NAVIGATION SUBSYSTEM
FUZE
WARHEAD SECTION
TWO LINK ANTENNA PAIRS
FOUR FUZE ANTENNAS
PROPULSION ARMING
& FIRING UNIT
SAFETY & ARMING DEVICE
HEAT SHIELD
PROPULSION ASSEMBLY
PROPELLANT E
PROPELLANT E
MOTOR PUMP &
ACTUATOR
CONTROL ACTUATOR
ASSEMBLY

SAMAR Air Defence System



Wingspan
0.51 m (R-73), 0.77 m (R-27)

Lift-off Weight
~105 kg (R-73 missile)

Warhead
7.4 kg (R-73), 39 kg (R-27)

Diameter
170 mm (R-73)

Range
10-12 km (SAMAR-1),

Maximum Speed
Mach 2-2.5

Price/Battery
$8 million

Flight Altitude
Effective up to 5,000 meters

SAMAR Air Defence System

About

The SAMAR Air Defence System (Surface to Air Missile for Assured Retaliation) is a next-generation, all-weather, mobile short-range air defence platform. Developed by the Indian Air Force in collaboration with private industry, SAMAR is engineered to neutralize low-flying threats-fighter jets, UAVs, helicopters, and loitering munitions-at close ranges. Leveraging repurposed air-to-air missiles, it offers a unique blend of cost-effectiveness, rapid deployment, and operational versatility, making it an ideal solution for nations seeking affordable yet potent point defence capabilities .

Strategic Benefits

Mobility: Road-mobile, twin-turret launchers for rapid deployment and repositioning

Cost-Effectiveness: Repurposes expired air-to-air missiles, drastically reducing acquisition costs

Modular System: Can be integrated with existing radars and command networks

Export Control Compliance: No ITAR restrictions; ideal for non-aligned and developing countries

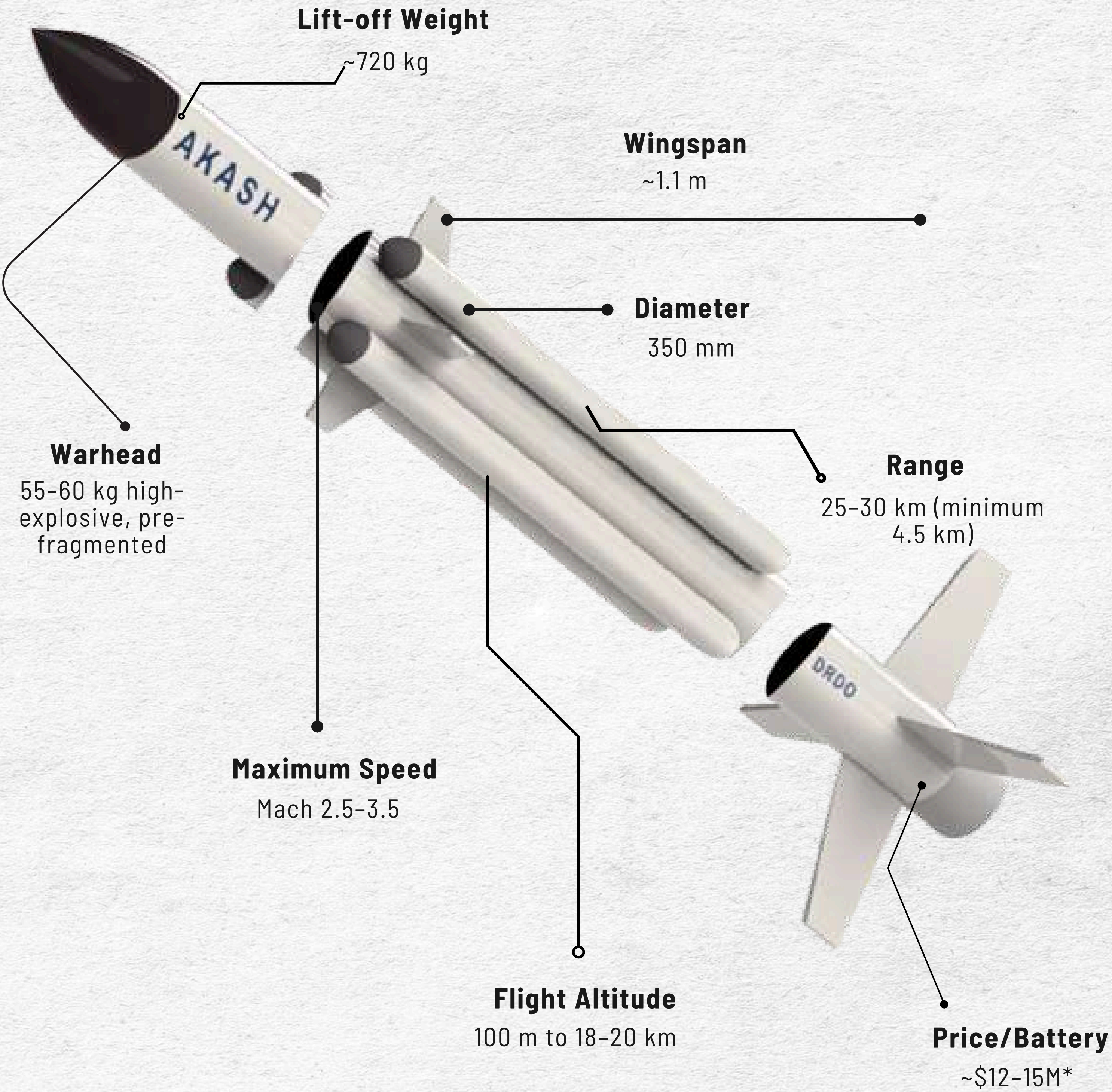
Dual Guidance Capability: Infrared and radar options for countering diverse threats

Rapid Response: Designed for quick reaction to pop-up threats and saturation attacks

Designation

- The SAMAR system is designed to intercept and destroy low-flying aerial threats such as fighter jets, helicopters, UAVs, and loitering munitions.
- It can be launched from road-mobile, twin-turret launchers, allowing for flexible, rapid deployment and high survivability.
- Capable of both single and salvo launch modes for adaptive threat engagement.

Akash Air Defence System



Akash Air Defence System

About

Akash, India's indigenous, all-weather, mobile, medium-range surface-to-air missile (SAM) system, developed by DRDO and produced by Bharat Dynamics Limited, defends against diverse aerial threats, including fighter jets, cruise missiles, UAVs, and helicopters. With a 25-30 km range, it employs advanced Rajendra radar and command guidance for precise multi-target engagement. Deployed by the Indian Air Force and Army, Akash ensures robust air defense with rapid response, high mobility, and the ability to operate in challenging environments.

Strategic Benefits

Mobility: Tracked/wheeled launchers for rapid deployment.

Cost-Effectiveness: Indigenous production reduces costs.

Modular System: Integrates with various radars and command networks.

Export Control: ITAR-free, suitable for export.

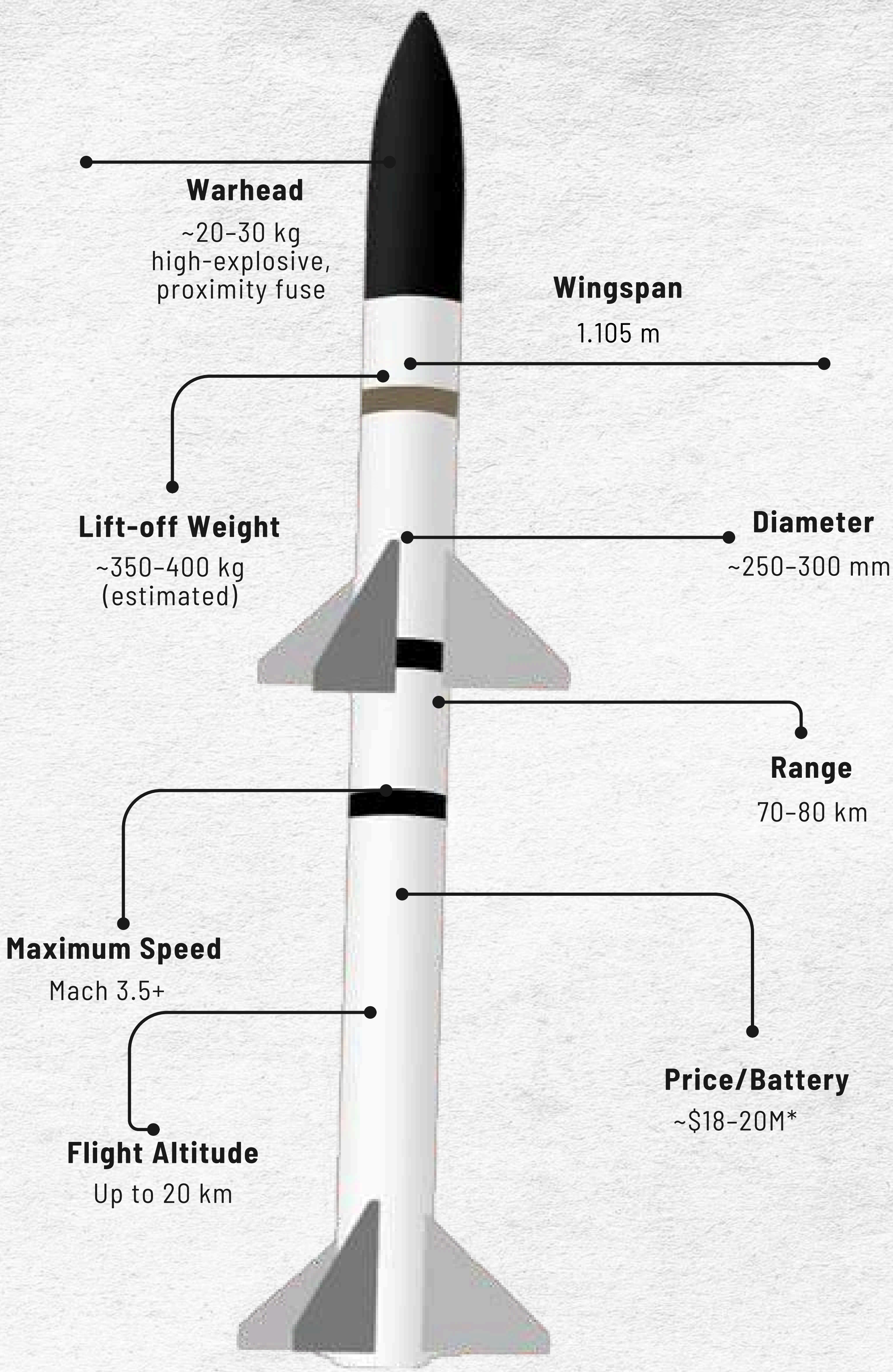
Multi-Target Engagement: Simultaneous tracking and engagement.

Rapid Response: Designed for quick reaction to pop-up threats.

Designation

- Intercepts and destroys a wide range of aerial threats (fighters, UAVs, cruise missiles, helicopters).
- Can be deployed from road-mobile launchers for rapid movement and high survivability.
- Capable of both single and salvo launch modes.

Akash Ng Air Defence System



Akash NG Air Defence System

About

Akash-NG, an advanced version of the Akash SAM system, offers enhanced range, higher kill probability, and improved survivability. It features a lighter missile, an active radar seeker, and a reduced ground footprint, making it ideal for modern, high-mobility air defence operations. Designed to counter advanced aerial threats, Akash-NG ensures rapid deployment and superior performance, strengthening air defence capabilities with cutting-edge technology tailored for dynamic battlefield scenarios.

Strategic Benefits

Mobility: Lighter, more compact system for rapid repositioning.

Cost-Effectiveness: Indigenous, with improved lifecycle costs.

Modular System: Integrates with modern radars and C4I networks.

Export Control: ITAR-free, ideal for global markets.

Multi-Target Engagement: Fire-and-forget, better ECCM, and higher accuracy.

Rapid Response: Optimized for quick reaction and saturation attack scenarios.

Designation

- Intercepts and destroys a wide range of aerial threats (fighters, UAVs, cruise missiles, helicopters).
- Can be deployed from road-mobile launchers for rapid movement and high survivability.
- Capable of both single and salvo launch modes.

MR-SAM (Barak-8)

Warhead
60 kg pre-fragmented, proximity fuse

Wingspan
.94m

Diameter
225 mm (missile), 540 mm (booster)

Lift-off Weight
~275-276 kg

Range
70-100 km

Maximum Speed
Mach 2

Price/Battery
~$25-30M*

Flight Altitude
Effective up to 16-20 km

 JUNE 2025

MR-SAM (Barak-8)

About

The MR-SAM (Barak-8), a cutting-edge medium-range air defence system, was co-developed by India's DRDO and Israel's IAI. This mobile, all-weather system neutralizes diverse aerial threats, including fighter jets, helicopters, UAVs, cruise missiles, and guided bombs. Equipped with advanced radar and interceptors, it ensures robust protection. Operational across the Indian Army, Air Force, and Navy, the Barak-8 enhances India's defence capabilities with its high precision and versatility in countering modern aerial challenges.

Strategic Benefits

Mobility: Highly mobile, road-mobile vertical launchers for rapid deployment and repositioning.

Cost-Effectiveness: Jointly developed; produced in India under Make in India.

Modular System: Integrates with multifunctional AESA radars and command networks.

Export Control: ITAR-free (Indian version), suitable for export**.**

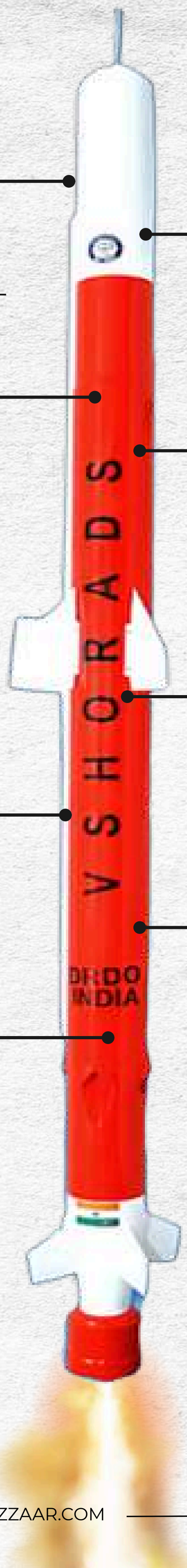
Multi-Target Engagement: Command and active radar seeker for effective electronic counter-countermeasures.

Rapid Response: Quick reaction time, effective against pop-up and saturation attacks.

Designation

- Intercepts and destroys a wide range of aerial threats (fighters, UAVs, cruise missiles, helicopters).
- Deployable from road-mobile, vertical launchers for fast movement and high survivability.
- Capable of both single and salvo launch modes for adaptive threat engagement.

VSHORAD Missile System



Warhead

~2.5 kg high-explosive, pre-fragmented

Wingspan

32 cm

Lift-off Weight

~20 kg

Diameter

90 m

Range

0.5-6 km

Maximum Speed

Mach 1.5-2

Price/Battery

~$3-4 million

Flight Altitude

10-3500 m

VSHORAD Missile System

About

The VSHORAD, developed by DRDO for the Indian Army and Air Force, is a man-portable, all-weather missile system designed to counter low-flying threats like fighter jets, helicopters, UAVs, and loitering munitions. Featuring rapid reaction, high mobility, and advanced guidance, it replaces the outdated Igla-M systems. As a vital component of India's layered air defence, VSHORAD enhances battlefield survivability and operational flexibility, ensuring effective protection against evolving aerial threats in modern warfare scenarios.

Strategic Benefits

Mobility: Man-portable and can be quickly repositioned by small teams or mounted on vehicles.

Cost-Effectiveness: Indigenous production, replacing expensive imports and legacy systems.

Modular System: Can be integrated with existing surveillance radars and command networks.

Export Control: ITAR-free; suitable for export to non-aligned and developing countries.

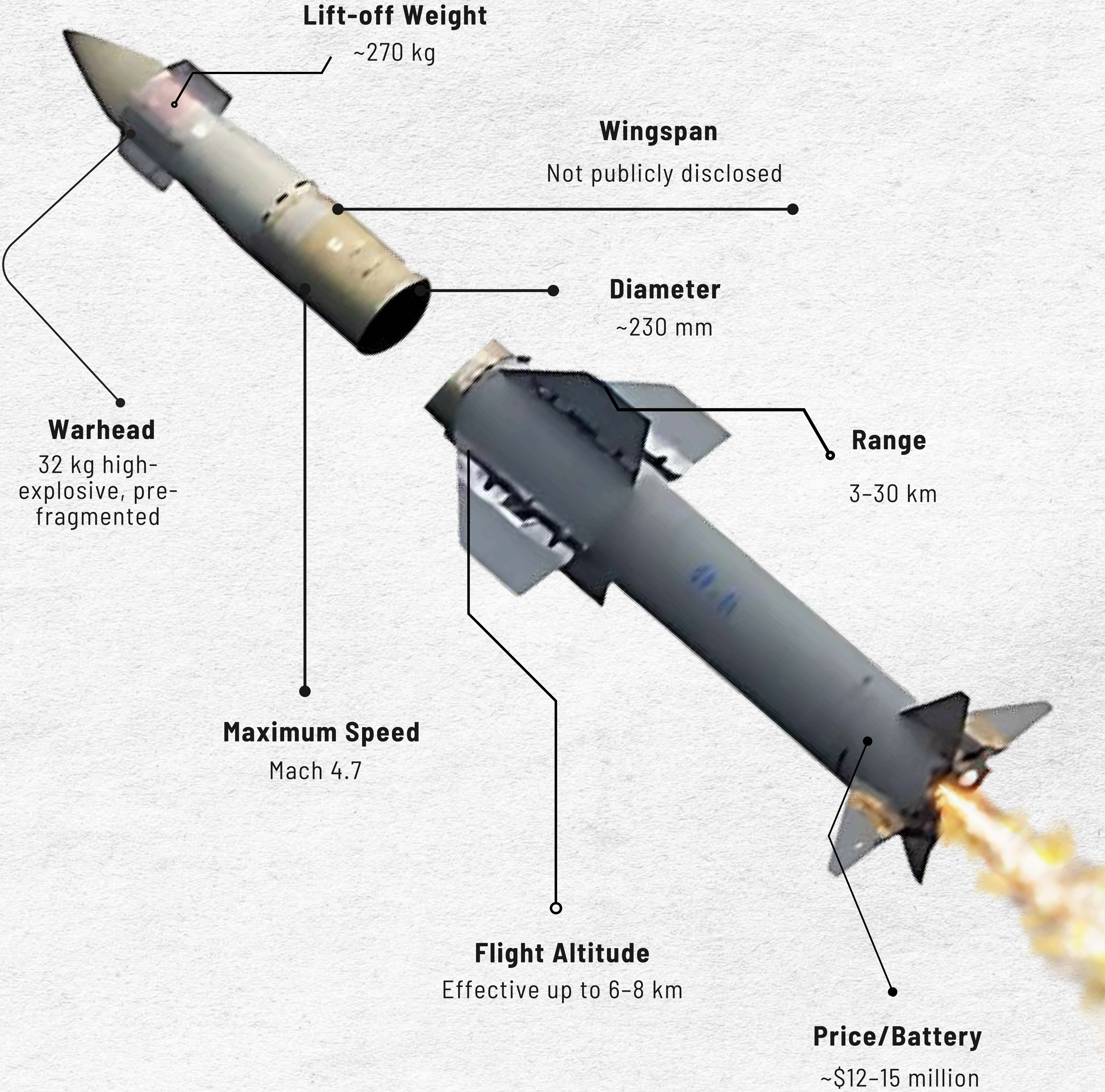
Multi-Target Engagement: Imaging infrared seeker with advanced ECCM

Rapid Response: Designed for quick reaction to pop-up threats and saturation attacks.

Designation

- Designed to intercept and destroy low-flying aerial threats: fighter jets, helicopters, UAVs, loitering munitions.
- Can be launched from shoulder, tripod, or light vehicle for rapid deployment and high survivability.
- Capable of both single and salvo launch modes (with multiple operators

QRSAM


Lift-off Weight
~270 kg
Wingspan
Not publicly disclosed
Diameter
~230 mm
Warhead
32 kg high-explosive, pre-fragmented
Range
3-30 km
Maximum Speed
Mach 4.7
Flight Altitude
Effective up to 6-8 km
Price/Battery
~$12–15 million

QRSAM

About

The QRSAM (Quick Reaction Surface-to-Air Missile), developed by DRDO for the Indian Army, is an all-weather, mobile, short-range air defence system. Designed for point/area defence, it counters low-flying threats like aircraft, helicopters, UAVs, and cruise missiles. Fully automated, highly mobile, and equipped with advanced tracking, QRSAM engages multiple targets simultaneously. It enhances India's layered air defence with rapid response capabilities, ensuring robust protection against diverse aerial threats in dynamic battlefield scenarios.

Strategic Benefits

Mobility: Highly mobile; all components mounted on 8x8 high-mobility vehicles for rapid deployment and repositioning.

Cost-Effectiveness: Indigenous system ; reduces import dependency and lifecycle costs.

Modular System: Integrates with indigenous AESA radars and command networks.

Export Control: ITAR-free; suitable for export to friendly nations.

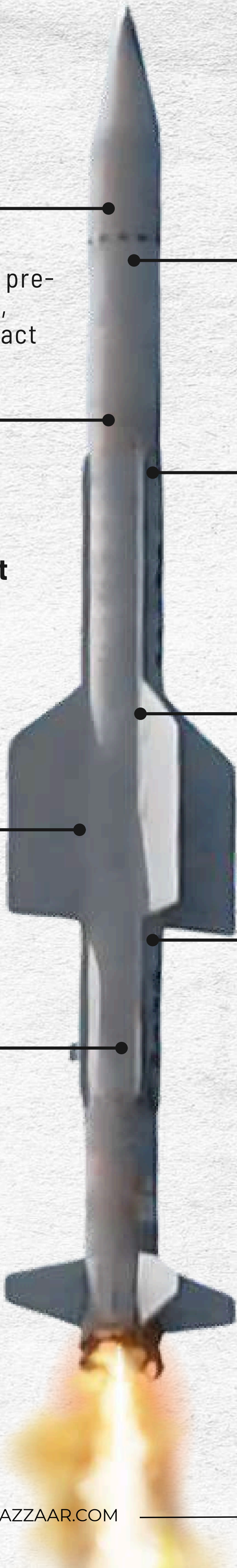
Multi-Target Engagement: Active radar seeker for terminal phase, inertial navigation for mid-course.

Rapid Response: Designed for quick reaction to pop-up and saturation attacks; shoot-on-the-move capability.

Designation

- Designed to intercept and destroy low- and medium-altitude aerial threats (fighter jets, helicopters, UAVs, cruise missiles).
- Can be launched from road-mobile, canister-based launchers for rapid deployment and high survivability.
- Capable of both single and salvo launch modes for adaptive threat engagement.

VL-SRSAM System



VL-SRSAM System

About

The VL-SRSAM, developed by DRDO for the Indian Navy and Air Force, is a quick-reaction, vertically launched surface-to-air missile system. It offers 360° protection against diverse aerial threats, including fighter jets, helicopters, UAVs, and sea-skimming anti-ship missiles. Designed to replace the Barak-1 missiles on naval warships, it is also being adapted for airbase defense, enhancing India's indigenous defense capabilities with versatile, rapid-response air defense.

Strategic Benefits

Mobility: Highly mobile; can be deployed on naval warships or truck-mounted for airbase defense.

Cost-Effectiveness: Fully indigenous system; reduces import dependency and lifecycle costs

Modular System: Integrates with indigenous AESA radars, weapon control systems, and command networks.

Export Control: ITAR-free; suitable for export to friendly nations.

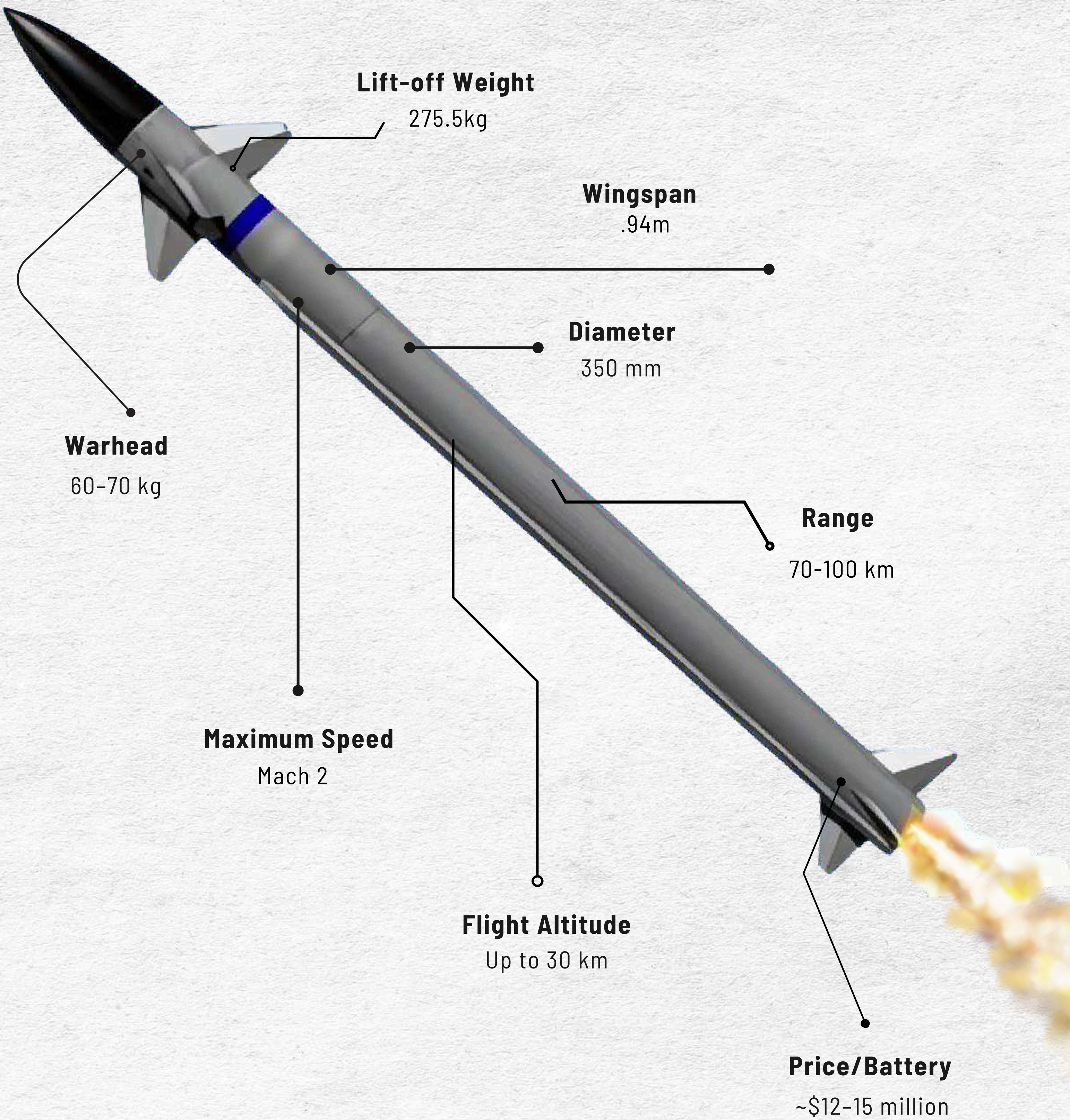
Multi-Target Engagement: Active radar seeker for terminal phase, inertial navigation for mid-course.

Rapid Response: Designed for quick reaction to pop-up and saturation attacks; vertical launch allows 360° coverage and rapid engagement.

Designation

- Designed to intercept and destroy low- and medium-altitude aerial threats (fighter jets, helicopters, UAVs, cruise missiles).
- Can be launched from road-mobile, canister-based launchers for rapid deployment and high survivability.
- Capable of both single and salvo launch modes for adaptive threat engagement.

LR-SAM System



LR-SAM System

About

The LR-SAM (also known as Barak-8 ER or XRSAM) is a next-generation, all-weather, long-range air defence system co-developed by India's DRDO and Israel Aerospace Industries (IAI). Designed to neutralize high-altitude aerial threats such as fighter jets, strategic bombers, AWACS, ballistic missiles, and stealth aircraft at extended ranges, it serves as India's premier strategic air defence shield. The system is operational with the Indian Navy, Air Force, and Army, and is a cornerstone of India's multi-layered defence network.

Strategic Benefits

Mobility: Shipborne VLS and road-mobile TEL (Transporter-Erector-Launcher) for rapid repositioning.

Cost-Effectiveness: Joint Indo-Israeli development reduces lifecycle costs; 70% indigenous components.

Modular System: Integrates with existing radars (e.g., Rohini, Ashwin) and command networks.

Export Control: ITAR-free (Indian variant); exported to Azerbaijan, Vietnam, and Morocco.

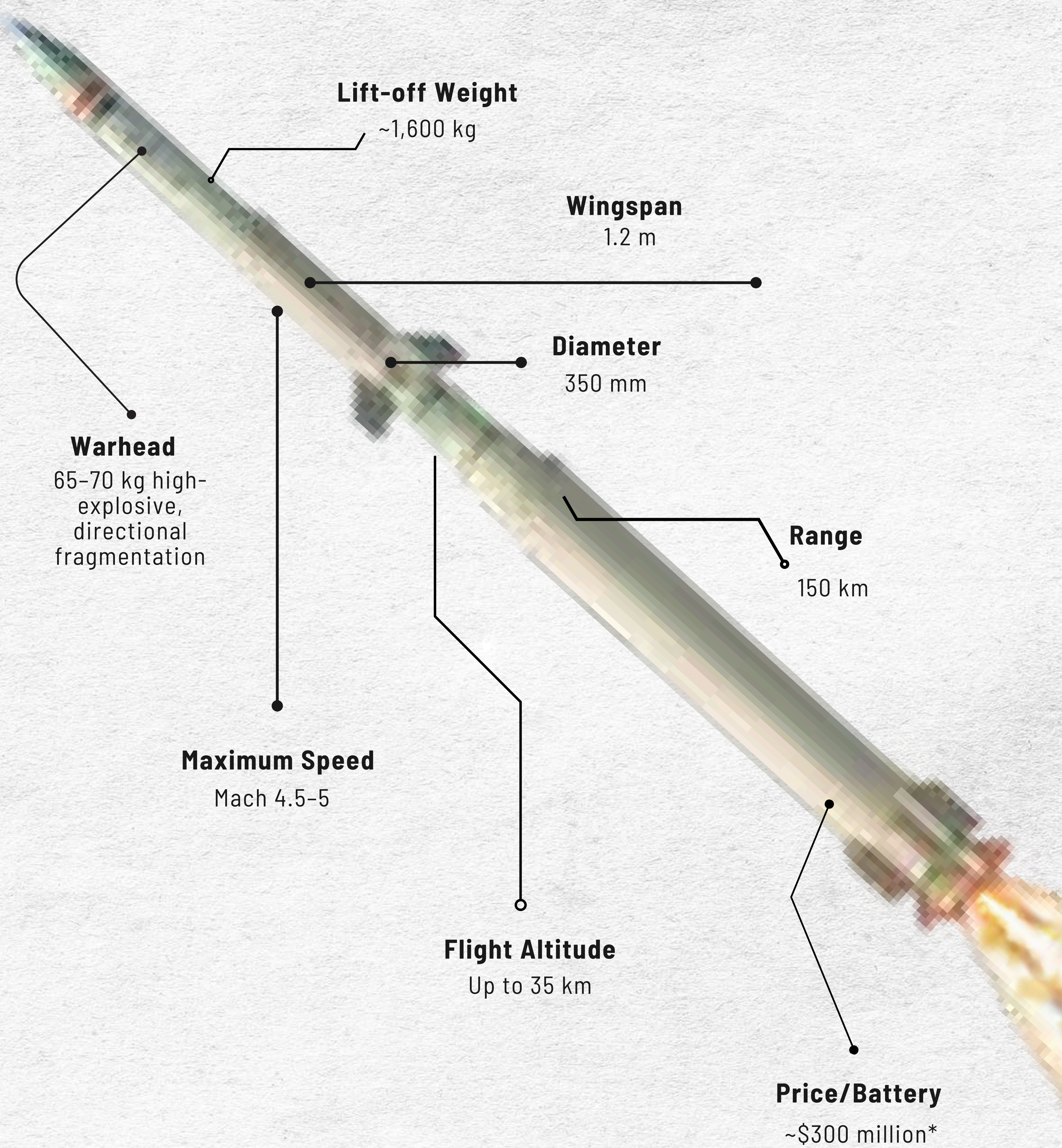
Multi-Target Engagement: Active radar + inertial navigation for high accuracy in electronic warfare environments.

Rapid Response: Reaction time <10 seconds; intercepts ballistic missiles in terminal phase.

Designation

- Intercepts and destroys high-altitude, long-range threats: strategic bombers, AWACS, ballistic missiles, stealth aircraft, and hypersonic glide vehicles.
- Deployed on naval warships (destroyers, frigates) and land-based mobile launchers for rapid deployment.
- Capable of single and salvo launches for saturation attacks.

ER-SAM System



ER-SAM System

About

The ER-SAM, an advanced variant of the Barak-8 missile system, is jointly developed by India's DRDO and Israel Aerospace Industries. It provides enhanced long-range air defense capabilities, neutralizing aerial threats like fighter jets, ballistic missiles, cruise missiles, and stealth aircraft. Deployable on naval vessels and land-based platforms, it offers extended reach and superior interception compared to the baseline LR-SAM, strengthening India's defense against a wide range of sophisticated airborne threats with improved precision and versatility.

Strategic Benefits

Mobility: Shipborne VLS and road-mobile TEL (Transporter-Erector-Launcher) for rapid repositioning.

Cost-Effectiveness: Joint Indo-Israeli development reduces lifecycle costs; 70% indigenous components.

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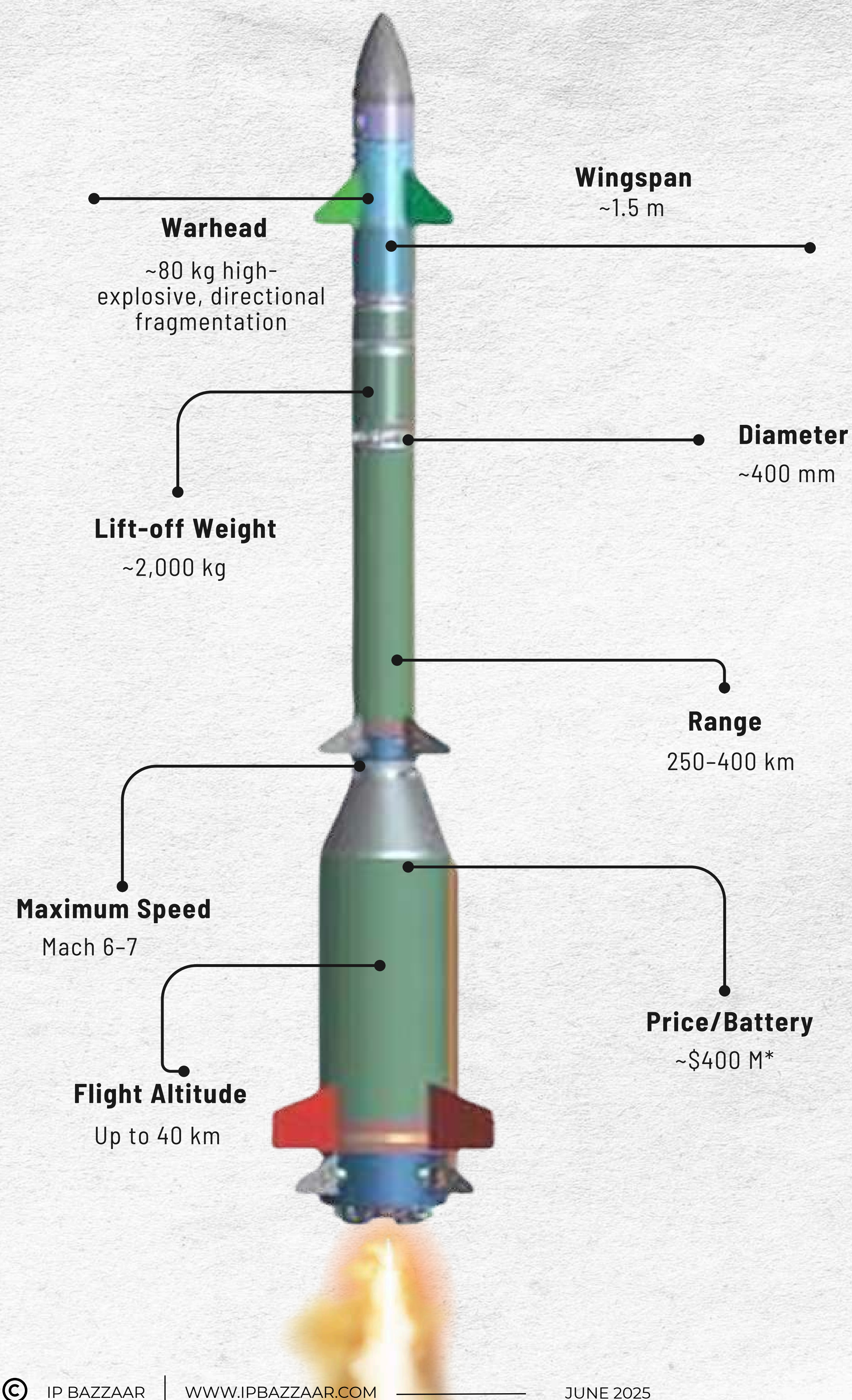
- Deployed on naval warships (destroyers, frigates) and land-based mobile launchers for rapid deployment.
- Capable of single and salvo launches for saturation attacks.

XR-SAM SYSTEM



XR-SAM SYSTEM

About

XR-SAM is India's next-generation, indigenous, all-weather, extra-long-range air defence system under advanced development by DRDO. It is designed to bridge the capability gap between the MR-SAM/ER-SAM (Barak-8 family) and the Russian S-400, providing layered defence against a wide spectrum of aerial threats including fighter jets, AWACS, bombers, cruise missiles, and ballistic missiles. XR-SAM is expected to offer interception ranges of up to 400 km, making it a strategic asset for India's air defence network.

Strategic Benefits

Mobility: Road-mobile TEL and planned shipborne VLS for flexible deployment and rapid repositioning.

Cost-Effectiveness: Indigenous development reduces lifecycle costs and import dependency; high indigenous content.

Modular System: Integrates with India's IACCS and advanced multi-function radars for networked, layered defence.

Export Control: ITAR-free; designed for Indian requirements, future export potential.

Multi-Target Engagement: Active radar + inertial navigation for high accuracy in complex, jammed environments.

Rapid Response: Reaction time <10 seconds; capable of intercepting high-speed, low-RCS, and maneuvering targets.

Designation

- Intercepts and destroys high-altitude, extra-long-range threats: strategic bombers, AWACS, ballistic missiles, cruise missiles, stealth aircraft, and hypersonic glide vehicles.
- Deployable on land-based mobile launchers and, in future, large naval platforms for rapid, strategic area defence.
- Capable of single and salvo launches for saturation attacks.

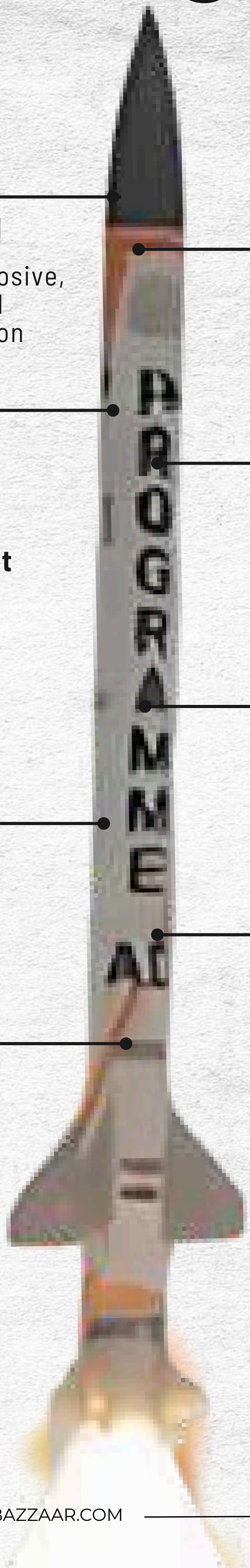
Advanced Air Defence (AAD) System

Wingspan
Not publicly disclosed

Warhead
30 kg high-explosive, directional fragmentation

Diameter
~420 mm

Lift-off Weight
~1,000 kg



Range
150km-200km

Maximum Speed
Mach 4.5

Price/Battery
~$150 M*

Flight Altitude
15-30 km

Advanced Air Defence (AAD) System

About

Advanced Air Defence (AAD) is India's indigenously developed endo-atmospheric ballistic missile interceptor, forming the lower layer of India's two-tier Ballistic Missile Defence (BMD) program. Designed to intercept and destroy incoming ballistic missiles at lower altitudes (within the atmosphere), it complements the Prithvi Air Defence (PAD) system to provide a layered defence shield for Indian cities and strategic assets.

Strategic Benefits

Mobility: Road-mobile launchers allow flexible, rapid repositioning to protect high-value targets.

Cost-Effectiveness: Indigenous development reduces dependency on foreign BMD solutions.

Modular System: Integrates with India's BMD command-and-control and long-range tracking radars.

Export Control: ITAR-free; designed for Indian requirements.

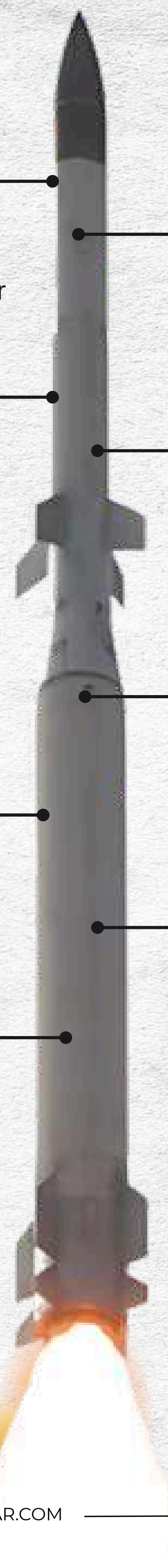
Multi-Target Engagement: Inertial and active radar homing for high accuracy against maneuvering targets.

Rapid Response: Reaction time <30 seconds; intercepts targets at high speed and altitude.

Designation

- Intercepts and destroys incoming enemy ballistic missiles in the endo-atmospheric region (within the atmosphere).
- Deployed on road-mobile launchers for flexible, rapid deployment to protect cities and strategic assets.
- Works in tandem with Prithvi Air Defence (PAD) for layered interception (AAD for lower altitude, PAD for higher altitude).

AD-1 Missile (Advanced Defence-1) System



Wingspan
Not publicly disclosed

Warhead
kinetic kill or fragmentation, as per BMD standards

Diameter
Not publicly disclosed

Lift-off Weight
not been officially disclosed

Range
1,000–5,000 km

Maximum Speed
Mach 6.5

Price/Battery
~$300–$400M*

Flight Altitude
Up to ~100 km

AD-1 Missile (Advanced Defence-1) System

About

The AD-1 Missile is India's advanced long-range interceptor missile developed by DRDO as part of Phase-II of the Indian Ballistic Missile Defence (BMD) Programme. Designed for both low exo-atmospheric and endo-atmospheric interception, AD-1 is capable of neutralizing ballistic missiles with ranges up to 5,000 km, as well as providing limited capability against hypersonic glide vehicles (HGVs) and enemy aircraft. The missile is a critical component in enhancing India's multi-layered defence against long-range and emerging threats .

Strategic Benefits

Mobility: Road-mobile launchers allow for rapid repositioning and flexible deployment.

Cost-Effectiveness: Indigenous development reduces reliance on foreign systems and lifecycle costs.

Modular System: Integrates with India's BMD command-and-control network and advanced radars.

Export Control: ITAR-free; designed for Indian strategic needs.

Multi-Target Engagement: Capable of intercepting both ballistic missiles and aircraft, with limited anti-HGV capability**.**

Rapid Response: Mach 6.5 speed ensures engagement with high-speed and maneuvering threats.

Designation

- Intercepts and destroys incoming ballistic missiles (up to 5,000 km range) in both exo-atmospheric (low altitude) and endo-atmospheric regions.
- Limited capability against hypersonic glide vehicles (HGVs) during the terminal phase of flight.
- Can engage enemy aircraft at various altitudes, providing additional air defence flexibility.
- Deployed on road-mobile launchers for rapid, flexible deployment to protect strategic assets.

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RFID APPLICATIONS

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- Asset & Inventory Management (Weapons, high-grade equipment)
- Maintenance & Lifecycle Management (Uniforms, tools & aircraft components)
- Physical fitness & Readiness tests tracking (Racetracks & other tests tracking)

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GLOBAL AGENCIES INVOLVED IN DEVELOPMENT OF SAM SYSTEMS

UNITED STATES

The United States has long been a global leader in missile defense technologies, with several major defense contractors contributing to SAM development. Raytheon Technologies is a primary developer of systems like the Patriot missile system, the widely used NASAMS (in collaboration with Norway’s Kongsberg), and the naval Standard Missile (SM) series. Lockheed Martin is another key player, responsible for advanced systems like THAAD (Terminal High Altitude Area Defense) and the PAC-3 interceptor, which enhances the Patriot’s missile-kill capabilities. Northrop Grumman supports these systems through development of radar and command-and-control systems. The U.S. Army and Missile Defense Agency (MDA) oversee the research, strategic planning, and deployment of SAM and missile defense systems across the country and allied bases.

RUSSIA

Russia has a long and sophisticated history in air defense, having developed layered and highly mobile SAM systems under the Soviet Union and beyond. The Almaz-Antey Concern, a state-owned defense conglomerate, is responsible for the design and production of nearly all of Russia’s major SAM systems, including the S-300, S-400, and the next-generation S-500, as well as shorter-range systems like the Buk, Tor, and Pantsir. These systems are known for their high speed, extended range, and multi-target capabilities. The Russian Ministry of Defence plays a central role in defining operational requirements and directing system deployment.

FRANCE AND EUROPEAN PARTNERS

In Europe, MBDA, a joint missile company with operations in France, Italy, Germany, and the UK, is the main entity involved in SAM development. France has developed systems like the VL MICA for short- to medium-range defense, and jointly with Italy, the ASTER 15/30 family of missiles, which form the backbone of the SAMP/T air defense system. Thales Group supports these systems by providing advanced fire control radars and networked command solutions.

ISRAEL

Israel is recognized for pioneering multi-layered air defense systems, driven by the country's need to defend against a wide spectrum of threats. Israel Aerospace Industries (IAI), in collaboration with DRDO India, co-developed the Barak 8 (MRSAM) system. IAI also leads the Arrow program for ballistic missile defense. Rafael Advanced Defense Systems is the key developer of the world-renowned Iron Dome, which intercepts short-range rockets, and David's Sling, which covers the medium- to long-range threat spectrum. Elta Systems, a subsidiary of IAI, provides AESA radars critical for guidance and tracking in many of these systems.

INDIA

India’s SAM development is led by the Defence Research and Development Organisation (DRDO). The DRDO initiated SAM programs such as Trishul (now retired), Akash, and its upgraded version Akash-NG, and has worked with Israel to develop the Barak 8/MRSAM system. Bharat Dynamics Limited (BDL) handles production and integration of missiles, while Bharat Electronics Limited (BEL) develops radars, fire control, and communication systems. These efforts are part of India's broader goal of defense self-reliance under the “Atmanirbhar Bharat” initiative.

CHINA

China has rapidly expanded its air defense capabilities, largely through its two major aerospace conglomerates. China Aerospace Science and Industry Corporation (CASIC) and China Aerospace Science and Technology Corporation (CASC) are responsible for systems like the HQ-6, HQ-9, and HQ-22, many of which are inspired by or reverse-engineered from Russian technology. These systems now feature indigenous advancements, including phased-array radars and advanced seekers. The People’s Liberation Army (PLA) closely oversees system deployment and doctrinal integration.

GERMANY

Germany contributes to SAM development mainly through Diehl Defence, which produces the IRIS-T SL/SLM, a mobile short- to medium-range air defense system with infrared guidance. MBDA Germany also collaborates on broader European projects like MEADS (Medium Extended Air Defense System), which is designed for NATO interoperability and modern battlefield integration.

ITALY

Italy, through MBDA Italy, plays a prominent role in the ASTER missile family and the SAMP/T air defense system, developed in partnership with France. Leonardo, another major Italian defense contractor, develops radar and electronic systems that integrate with missile batteries for target detection and engagement.

NORWAY

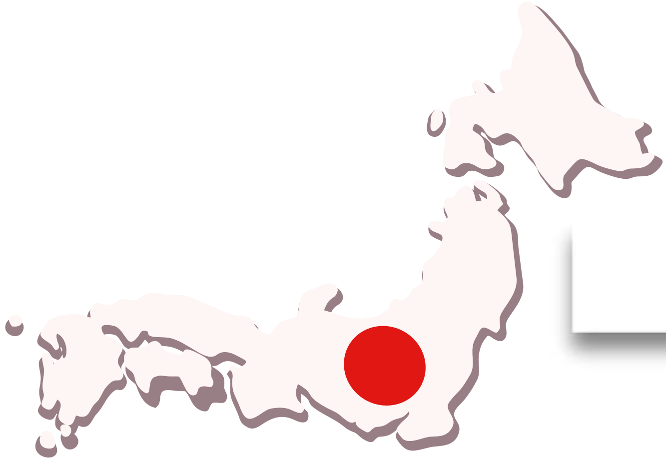
Norway's Kongsberg Defence & Aerospace has gained global recognition for its role in co-developing the NASAMS system with Raytheon. NASAMS integrates the AIM-120 AMRAAM air-to-air missile into a ground-launched platform, offering a modular and mobile medium-range solution. It has been adopted by many countries, including the United States (for homeland defense), Australia, and Ukraine.

TURKEY

Turkey's defense industry, led by Roketsan and ASELSAN, has made strides in developing indigenous SAM systems such as Hisar-A (short-range) and Hisar-O (medium-range). They are also working on Siper, a long-range air defense system aimed at reducing dependence on foreign systems like the Russian S-400. These efforts are part of Turkey's broader push for defense autonomy.

SOUTH KOREA

LIG Nex1 and Hanwha Systems are South Korea's main developers of SAM systems. The Cheongung (KM-SAM) is a medium-range system developed with Russian assistance and incorporates AESA radar and cold-launch vertical launch systems. South Korea is also developing L-SAM, a high-altitude system aimed at intercepting ballistic missiles, forming part of its three-layered missile shield strategy.



JAPAN

Japan's SAM programs are led by **Mitsubishi Heavy Industries** and **Mitsubishi Electric, responsible** for systems like the **Type 03 Chu-SAM**, designed for mobile medium-range defense. Japan also works with the U.S. on systems like the **SM-3**, which is deployed aboard Aegis-equipped ships for ballistic missile defense.

Patent Landscape

Total Patents: 2956

Patents Filed by Indian Applicants: 24

Total Patents Published in India: 99

DATE RANGE: *TILL 10 JUNE, 2025*

SOURCE: *QUESTEL ORBIT, PATENT LENS, GOOGLE PATENTS*

Top 10 COUNTRIES

CN	519
US	323
RU	303
EP	183
DE	121
GB	105
FR	99
KR	90
IL	74
IN	69

TOP 10

WORLDWIDE PLAYERS

78	RAYTHEON
61	JSC KBP INSTRUMENT DESIGN BUREAU
60	US NAVY
44	BOEING
34	BAE SYSTEMS INFORMATION & ELECTRONIC SYSTEMS INTEGRATION
33	BAE SYSTEMS
28	LOCKHEED MARTIN
28	NUAA - NANJING UNIVERSITY OF AERONAUTICS & ASTRONAUTICS
23	US ARMY
21	NATIONAL UNIVERSITY OF DEFENSE TECHNOLOGY

TOP
INDIAN APPLICANTS

BHARAT DYNAMICS
3

CHAIRMAN DEFENCE RESEARCH DEVELOPMENT ORGANISATION DRDO
1

BRAHMOS AEROSPACE PRIVATE
1

BRAHMOS AEROSPACE PVT
1

BHARAT ELECTRONICS
3

DIMENSION NXG PVT
1

DRDO - DEFENCE RESEARCH & DEVELOPMENT ORGANISATION
1

Top 10 Countries who Filed in India

INDIA	69
EUROPE	38
USA	37
GERMANY	28
FRANCE	27
ISREAL	26
UK	25
AUSTRALIA	19
CANADA	19
CHINA	19

TOP 10
PLAYERS IN INDIA

BAE SYSTEMS HAEGGLUNDS	04
HENSOLDT SENSORS	04
ISRAEL AEROSPACE INDUSTRIES	04
RAFAEL ADVANCED DEFENSE SYSTEMS	04
BAE SYSTEMS INFORMATION & ELECTRONIC SYSTEMS INTEGRATION	03
BHARAT DYNAMICS	03
BHARAT ELECTRONICS	03
LPU - LOVELY PROFESSIONAL UNIVERSITY	03
MBDA UK	03
VIASAT	03

Innovation trend for next 5 years

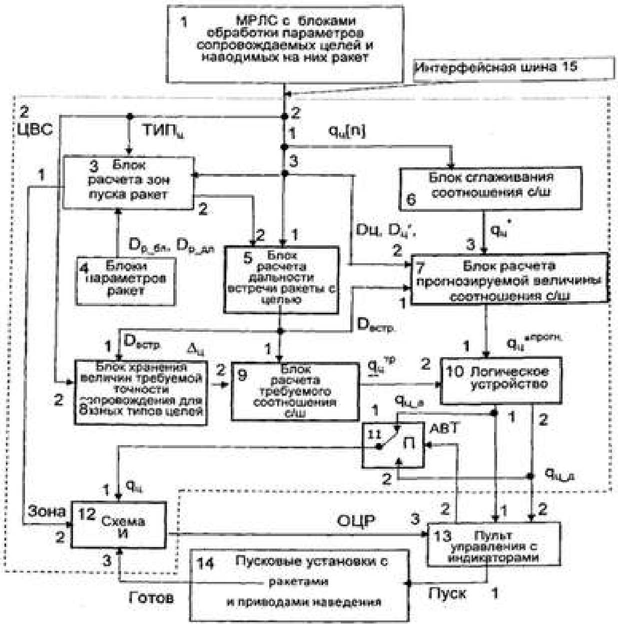
Notable Patents

RU2790339

METHOD FOR LAUNCHING A SURFACE-TO-AIR MISSILE AND SURFACE-TO-AIR MISSILE LAUNCH SYSTEM

ASSIGNEE

JSC KBP INSTRUMENT DESIGN BUREAU



TECH INTRO

This aviation technology enhances target detection, tracking, and missile guidance using advanced radar systems and signal processing. It optimizes launch precision by predicting signal-to-noise ratios, ensuring efficient engagement. By integrating dynamic threat assessment and adaptive targeting, the system maximizes accuracy and reliability.

TECH FEATURES

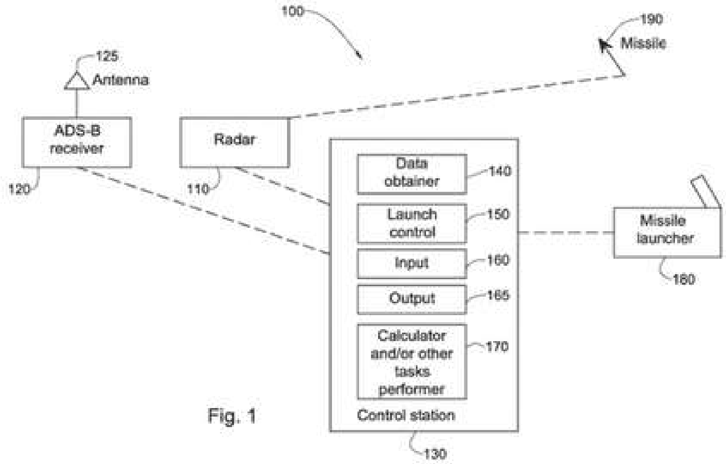
- Employs a discrete-time filter to dynamically smooth SNR fluctuations, ensuring robust target tracking under signal modulation.
- Computes predicted SNR at the missile-target intercept using real-time target kinematics and radar data.
- Derives required SNR via tracking error (Δc) and antenna pattern (θ) for high-precision missile guidance.
- Generates a confidence interval (Δq) for SNR to enable engagements against low-RCS, high-speed targets with modulated signals.
- Logic unit (LU) outputs dual signals for SNR threshold validation or confidence interval compliance, optimizing launch decisions.
- Calculates dynamic launch zones integrating missile parameters and multi-target type adaptability for maximized engagement envelopes.
- Determines intercept range (Dint) using a dedicated block, factoring in target velocity and radar-derived coordinates.
- Features a control panel with real-time SNR indicators (green/yellow) for autonomous or operator-driven volley fire decisions.

IL228789 B

MISSILE SYSTEM INCLUDING ADS-B RECEIVER

ASSIGNEE

ISRAEL AEROSPACE INDUSTRIES



TECH INTRO

This missile system integrates ADS-B, radar, and control mechanisms to assess airborne threats and make launch decisions with high precision. Designed for surface-to-air defense, it adapts to varying data availability for optimized threat response.

TECH FEATURES

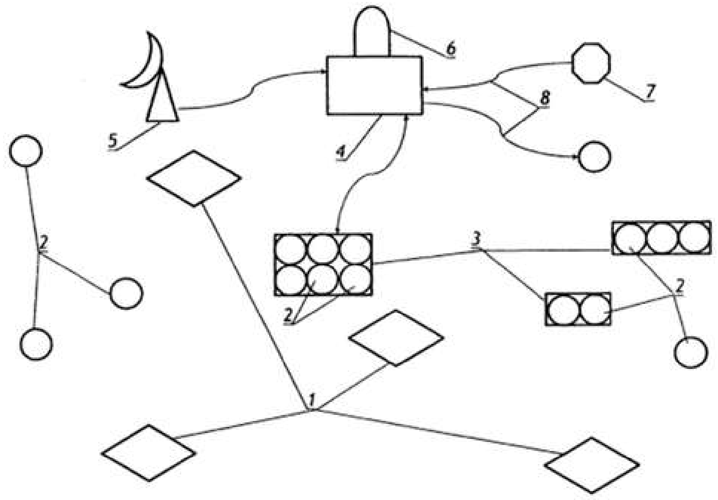
- Integrates ADS-B data with radar for precise target identification to avoid engaging non-hostile airborne entities.
- Evaluates trustworthiness of ADS-B identification to estimate hostile likelihood with high accuracy.
- Compares position data from ADS-B and radar to confirm entity correlation before launch decisions.
- Employs automated decision logic to refrain from launching if radar data is unavailable.
- Provides operator interface with hostility estimates for manual override in launch decisions.
- Uses threshold-based algorithms to halt launches if non-hostile likelihood exceeds predefined limits.
- Supports surface-to-air missile systems with real-time ADS-B receiver integration for enhanced targeting.
- Embeds computer-readable code for autonomous launch control on a secure, scalable platform.

RU2797976 C2

ANTI-AIRCRAFT MISSILE SYSTEM

ASSIGNEE

3RD CENTRAL RESEARCH INSTITUTE OF THE MINISTRY OF DEFENCE OF THE RUSSIAN FEDERATION



Фиг. 1

TECH INTRO

This short-range anti-aircraft missile system (SAM) is designed for air target elimination while ensuring high secrecy and crew safety. It integrates millimeter-range tracking radar, passive detection systems, and wired/wireless communication, enabling effective defense in low visibility and strong radio interference conditions.

TECH FEATURES

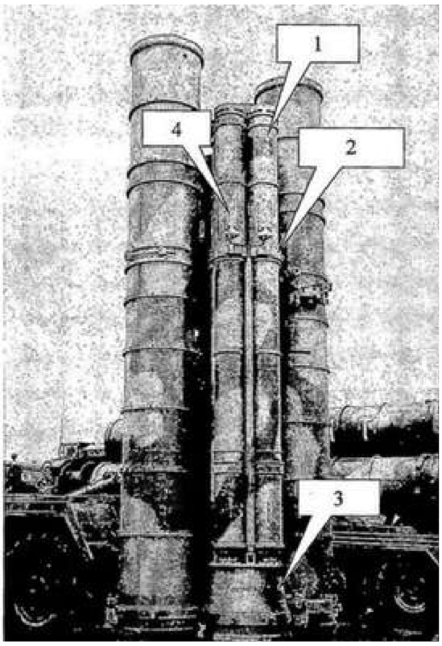
- Employs vertical-launch anti-aircraft missiles housed in modular containers for rapid deployment and enhanced engagement flexibility.
- Integrates launchers on remotely-controlled robotic chassis, enabling autonomous positioning in diverse terrains like ruins or ravines.
- Utilizes a passive radar with ground and air-based receivers on telescopic masts or tethered UAVs for stealthy target detection.
- Deploys a millimeter-wave radar for precise target tracking, positioned over 1000 m from the command module to reduce detectability.
- Incorporates an optoelectronic system for high-resolution low-altitude target tracking, enhancing accuracy in radio-silent conditions.
- Positions the command module 500-1000 m from launchers, ensuring crew safety and operational resilience against attacks.
- Facilitates wired and wireless communication between modules for robust, interference-resistant data exchange in contested environments.
- Features a computer system that autonomously prioritizes and assigns missiles to low-flying UAVs and cruise missiles for rapid response.

RU2809387 C1

9M96E2-2 CANISTER FOR SURFACE-TO-AIR GUIDED MISSILES

ASSIGNEE

ALMAZ ANTEY



TECH INTRO

This cassette-based anti-aircraft missile system enables compact storage and efficient deployment of up to four guided missiles per module. Designed with upper and lower fastening yokes, it allows secure attachment to transport containers, ensuring stable launch positioning. The integrated external connector facilitates multiplex data transmission, optimizing missile coordination and targeting precision. By supporting 9M96E(2) missiles in 35P6E and 40P6E complexes, it quadruples ammunition capacity, significantly enhancing operational readiness and firepower.

TECH FEATURES

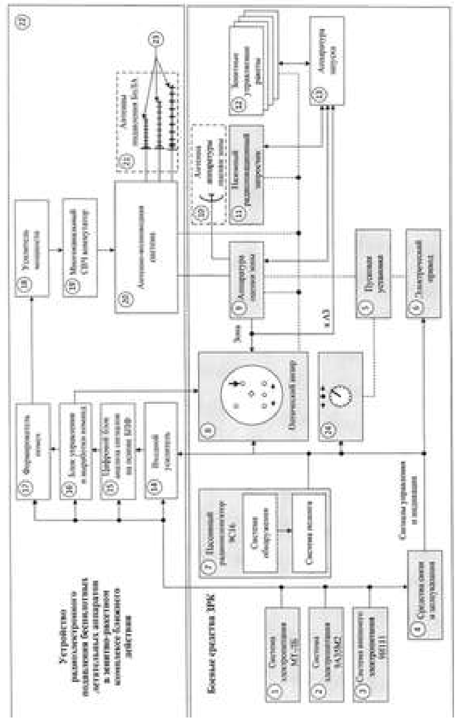
- Combines four 9M96E(2) missiles into a compact package matching the size of older missile containers for use in existing launchers.
- Uses matching yokes to fit the cassette perfectly into 5P85E/51P6E launchers designed for larger missiles.
- Includes a ground support to keep the cassette stable during missile launch.
- Aligns the cassette's center of mass with older missile containers for seamless launcher compatibility.
- Features a data splitter to send control signals to all four missiles at once.
- Assigns unique IDs to each missile using a simple jumper system for accurate targeting.
- Has a standard connector matching older missile systems for easy integration.
- Boosts missile capacity four times on existing launchers, increasing firepower.

RU2820537 C1

ELECTRONIC JAMMING DEVICE FOR UNMANNED AERIAL VEHICLES IN SHORT-RANGE ANTI-AIRCRAFT MISSILE SYSTEM

ASSIGNEE

FEDERAL STATE STATE MILITARY EDUCATIONAL INSTITUTION OF HIGHER EDUCATION MILITARY TRAINING & SCIENTIFIC CENTER OF THE NAVAL NAVY NAVAL ACADEMY NAMED AFMIRAL NURSERY CENTER NAVO NATIONAL ACADEMY FAMILY DISTRIBUTION CENTER NAVY NAVY ACADEMY NAMED ACADEMY CENTER



TECH INTRO

This electronic jamming device is designed for UAV suppression in coordination with short-range anti-aircraft missile systems. It uses Fourier-based digital signal analysis, power amplifiers, and directional electromagnetic fields to disrupt UAV control channels, enhancing air defense effectiveness.

TECH FEATURES

- Integrates a UAV suppression device into the 9A35M2 combat vehicle, housed in a missile container form factor for seamless launcher compatibility.
- Employs fast Fourier transform (FFT) in the digital signal analysis unit to identify UAV type and optimize interference parameters.
- Utilizes disk-element director antennas to generate circular/elliptical polarized electromagnetic fields, enhancing penetration through obstacles like foliage.
- Leverages combat vehicle power systems (MT-LB/9A35M2/9I111) to extend suppression mode duration, surpassing battery-powered anti-drone solutions.
- Incorporates a multi-channel microwave switch to dynamically route interference signals to multiple UAV control and geopositioning channels.
- Enhances targeting precision using the vehicle's electric servo drives and optical sight for accurate UAV suppression alignment.
- Determines UAV nationality via integration with the ground radar interrogator, enabling selective engagement of hostile targets.
- Combines active fire (missile) and passive electronic suppression, increasing hit probability against small, low-thermal UAVs.

IL285271 A

ASSIGNEE

BIRD AEROSYSTEMS

A DEVICE, SYSTEM, AND METHOD OF AIRCRAFT PROTECTION AND COUNTERMEASURES AGAINST MISSILES

TECH INTRO

The device uses a MANPAD Missile / AT Missile Optical Classification Unit to identify missiles as MANPAD or Anti-Tank via SWIR-based optical signals, analyzing velocity, backscattered signals, and rotation frequency. It triggers tailored laser-based jamming, with configurations like UV for MANPAD or Visible/NWIR/LWIR for AT missiles. A pre-jamming unit and IR receiver optimize jamming by assessing range, velocity, and roll-rate.

TECH FEATURES

- Utilizes a SWIR-based optical imager with a 1,400-3,000 nm band filter to capture missile-specific optical signals for precise tracking.
- Employs a SWIR signals processor to dynamically refine missile angular position using MAWS data and continuous SWIR signal analysis.
- Features a laser-based missile-jamming unit with internal/external emitters, delivering multi-wavelength laser beams via fiber optic links.
- Incorporates a dichroic mirror to split laser beams, directing a minor portion to a calibration unit for real-time emitter optimization.
- Includes a tunable piezoelectric lens to narrow SWIR beam-width, enhancing missile tracking accuracy under varying conditions.
- Uses a gimbaling unit with elevation/azimuth motors for real-time alignment of the jamming laser with the missile's precise position.
- Implements a pre-jamming backscattering inducer to analyze missile range/velocity/roll-rate, dynamically adjusting jamming parameters.
- Features a MANPAD/ATGM classifier using SWIR signal analysis to select tailored jamming patterns for missile type and guidance method.

CN119047335

GROUND-TO-AIR COMBAT EFFECT SIMULATION SYSTEM

ASSIGNEE

AVIC POWER SCIENCE & TECHNOLOGY ENGINEERING

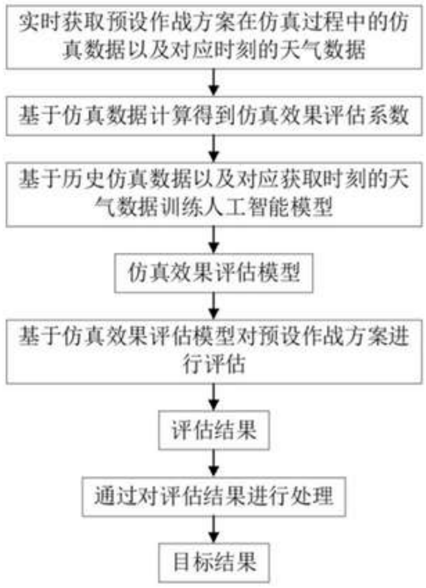


图2

TECH INTRO

The device uses a MANPAD Missile / AT Missile Optical Classification Unit to identify missiles as MANPAD or Anti-Tank via SWIR-based optical signals, analyzing velocity, backscattered signals, and rotation frequency. It triggers tailored laser-based jamming, with configurations like UV for MANPAD or Visible/NWIR/LWIR for AT missiles. A pre-jamming unit and IR receiver optimize jamming by assessing range, velocity, and roll-rate.

TECH FEATURES

- Employs a data acquisition module for real-time capture of ground-to-air combat simulation data and corresponding weather data, including personnel survival rates and radar target recognition.
- Utilizes a data analysis module to compute a simulation effect evaluation coefficient using weighted formulas integrating ground, air, and environmental assessment coefficients.
- Leverages a model training module with convolutional neural networks or deep belief networks to train on historical simulation and weather data for predictive modeling.
- Calculates ground assessment coefficient via a formula incorporating hyperbolic tangent and logarithmic functions of personnel survival, facility damage, and radar recognition rates.
- Determines air evaluation coefficient using an exponential decay model with logarithmic adjustments based on air personnel survival, facility damage, and radar performance.
- Computes environmental assessment coefficient by evaluating magnetic induction deviations from optimal radar operation values in ground and air combat zones.

US20250076000 A1

TARGET LEAD ESTIMATION BASED ON LAUNCHER SLEW

ASSIGNEE

BAE SYSTEMS INFORMATION & ELECTRONIC SYSTEMS INTEGRATION

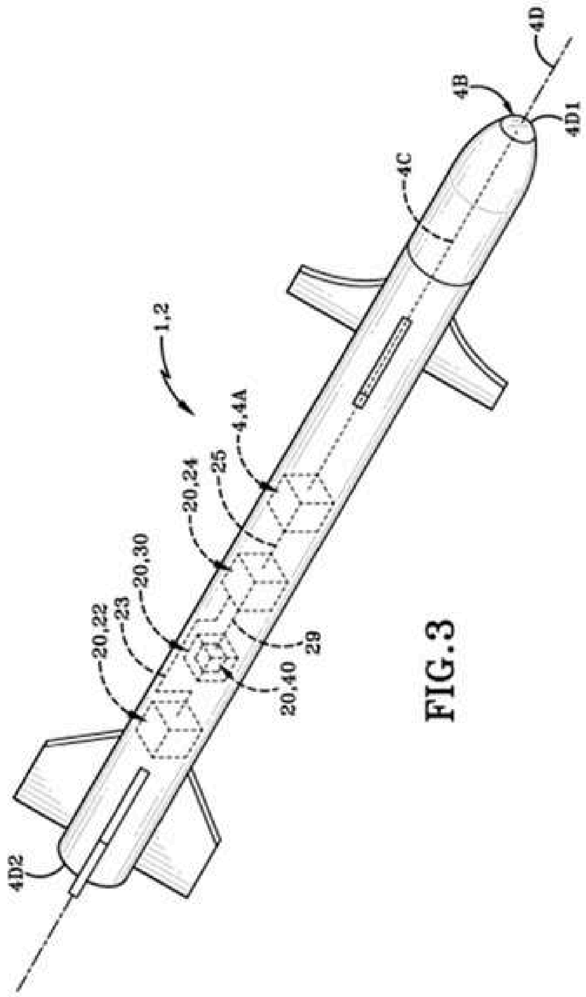


FIG.3

TECH INTRO

A portable launcher fires guided projectiles at aerial targets, using a projectile guidance kit and a target leading guidance kit. The latter dynamically adjusts the reticle for precise targeting.

TECH FEATURES

- Integrates an inertial measurement unit (IMU) to precisely track projectile slew from initial to translated positions within the portable launcher.
- Features a target lead estimation protocol executed by a processor to dynamically adjust the electronic sight reticle based on target speed and projectile movement.
- Employs a seeker device on the guided projectile to detect aerial target speed, enabling accurate lead position calculations.
- Includes a target locking function within the protocol to securely lock onto aerial targets detected by the seeker device.
- Utilizes a slew measuring function to quantify projectile orientation changes using real-time IMU data for precise guidance.
- Incorporates a lead position function to compute the lead target position by combining target speed and projectile slew data.
- Features a reticle adjustment function to dynamically reposition the electronic sight reticle to align with the calculated lead target position.
- Equips a transceiver for seamless communication between the target leading guidance kit and projectile guidance kit, enhancing coordination.

CN215298530 U

VERTICAL AND HORIZONTAL KILLING AREA MODEL DEVICE FOR GROUND-TO-AIR MISSILE

ASSIGNEE

AIR FORCE ENGINEERING UNIVERSITY OF PLA

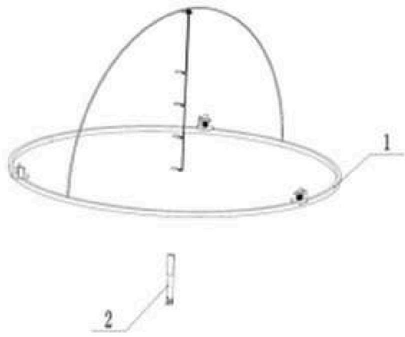


图1

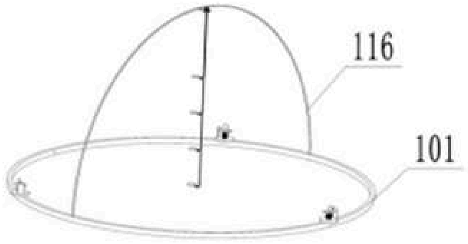


图2

TECH INTRO

This model device simulates the killing area of a surface-to-air missile using explosion air pressure detection. Equipped with lateral and vertical measuring devices, it evaluates blast effects through wind amplitude. An ejection system launches explosive columns to generate air waves for accurate simulation and assessment.

TECH FEATURES

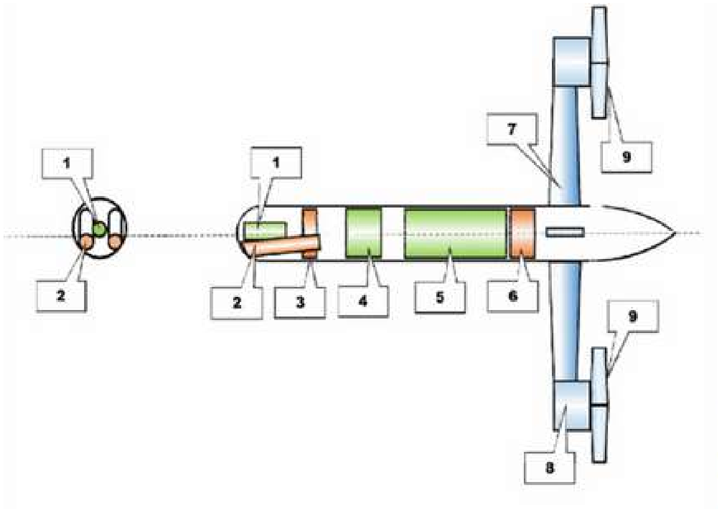
- Features a vertical ring with a lifting disc to precisely adjust the top plate height for simulating missile kill zones.
- Incorporates a sliding column with a rope collecting motor to dynamically control tightening rope tension via a rope clamping disc.
- Utilizes at least four sliding plates connected by tightening ropes to rope clamping discs for multi-axis kill zone modeling.
- Equips sliding plates with short rods and rotating springs to enable shaking plates for simulating missile impact dynamics.
- Includes a transverse ring with a moving spring and transverse plate to support an air disc for horizontal kill zone simulation.
- Employs an ejection column with a jacking spring to propel an air bomb for realistic missile trajectory emulation.
- Features a movable clamping plate on a sliding frame to securely hold and release the air bomb during ejection.
- Integrates a round buckle on the air bomb to ensure precise clamping and controlled release by the movable clamping plate.

RU2837930 C1

ANTI-AIRCRAFT GUIDED MISSILE

ASSIGNEE

MACHINE BUILDING DESIGN BUREAU FAKEL NAMED AFTER ACADEMICIAN P D GRUSHIN



TECH INTRO

This anti-aircraft guided missile features an X-shaped aerodynamic design with folding wing consoles for compact transport. Equipped with inertial guidance, optoelectronic homing, and trajectory correction, it ensures precision targeting. Its lightweight build allows deployment in both portable and group air defense systems.

TECH FEATURES

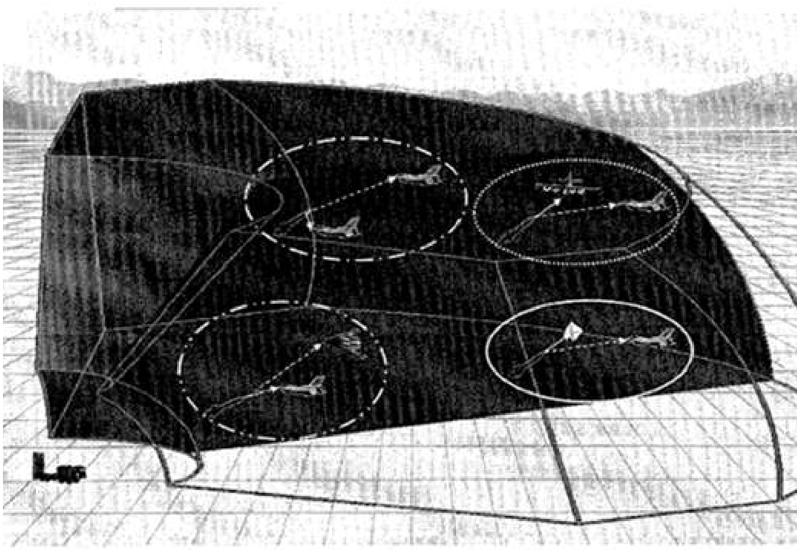
- Adopts an X-shaped aerodynamic scheme with non-rotating pushing propellers at wing console ends for enhanced maneuverability against mini-UAVs.
- Utilizes individually controlled electric motors to drive propellers, enabling precise flight path adjustments for low-speed target interception.
- Features rotatable wing consoles that fold along the missile body, optimizing storage in a compact transport and launch container.
- Integrates an inertial control system (ICS) paired with an optoelectronic homing head (OEGSN) for real-time trajectory correction based on target movement.
- Incorporates special software (SPO) supporting vertical and inclined launch modes, enhancing operational flexibility on the battlefield.
- Employs a remote fuse and safety actuator to ensure reliable detonation of the warhead against hovering or slow-moving UAVs.
- Reduces missile weight by 20-35 times compared to 9M33/9M331, allowing 3-5 missiles in a 10 kg fighter stowage for squad-level use.
- Achieves a 20-25 times cost reduction over traditional SAMs, leveraging serial quadcopter components for scalable production.

CN103940305 B

GROUND-TO-AIR MISSILE SHOOTING CONTROL METHOD AND CORRESPONDING GROUND-TO-AIR MISSILE WEAPON SYSTEM

ASSIGNEE

WANG WENPU



TECH INTRO

This fire control method enables target reassignment for launched surface-to-air missiles, optimizing engagement efficiency. It dynamically redirects missiles to higher-priority threats, reducing wasted launches and improving overall combat effectiveness. The system enhances real-time adaptability in battlefield conditions.

TECH FEATURES

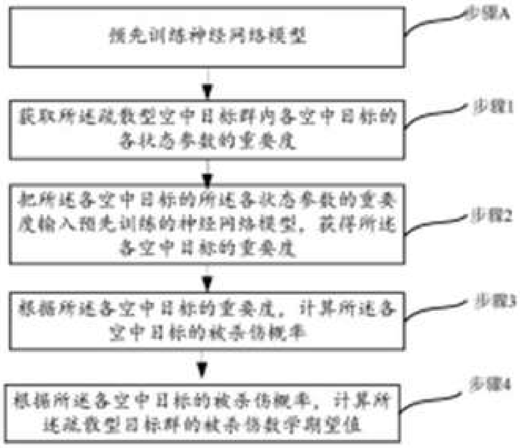
- Features a vertical ring with a lifting disc to precisely adjust the top plate height for simulating missile kill zones.
- Incorporates a sliding column with a rope collecting motor to dynamically control tightening rope tension via a rope clamping disc.
- Utilizes at least four sliding plates connected by tightening ropes to rope clamping discs for multi-axis kill zone modeling.
- Equips sliding plates with short rods and rotating springs to enable shaking plates for simulating missile impact dynamics.
- Includes a transverse ring with a moving spring and transverse plate to support an air disc for horizontal kill zone simulation.
- Employs an ejection column with a jacking spring to propel an air bomb for realistic missile trajectory emulation.
- Features a movable clamping plate on a sliding frame to securely hold and release the air bomb during ejection.
- Integrates a round buckle on the air bomb to ensure precise clamping and controlled release by the movable clamping plate.

CN114565278 A

GROUND-TO-AIR MISSILE WEAPON SYSTEM EVACUATION GROUP TARGET COMBAT EFFECTIVENESS EVALUATION METHOD

ASSIGNEE

AIR FORCE ENGINEERING UNIVERSITY OF PLA



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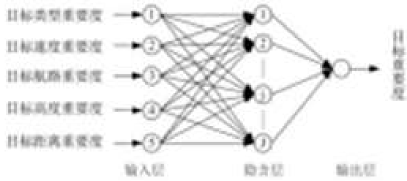


TECH INTRO

This invention introduces a method for assessing the combat effectiveness of aerial targets within an evacuation group of a surface-to-air missile system. By leveraging a pre-trained neural network and target state parameters, it accurately evaluates kill probabilities, offering a realistic and streamlined approach to battlefield analysis.

TECH FEATURES

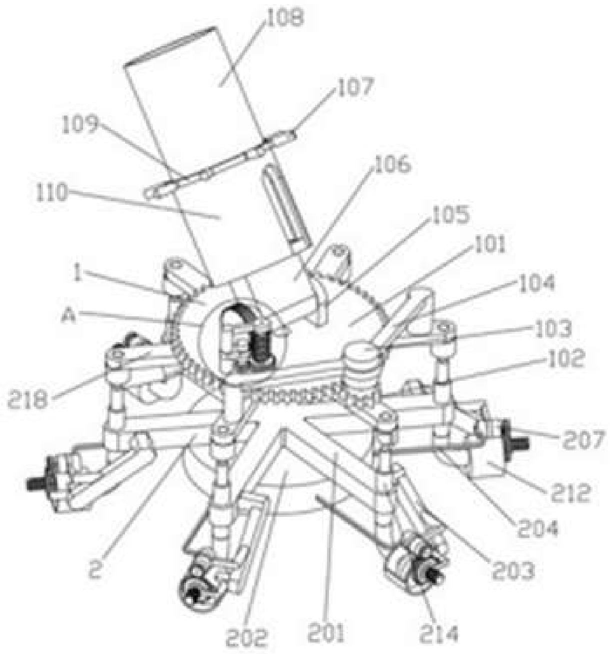
- Employs a BP neural network with a three-layer fully connected architecture to predict air target importance from state parameter inputs.
- Calculates target type importance (Tw) by categorizing air targets into four classes based on combat roles.
- Computes target speed importance (Vw) using a normalized formula dividing target speed by the maximum speed within the evacuation group.
- Determines route shortcut importance (Jw) via a formula normalizing the target's route shortcut against the group's maximum shortcut value.
- Evaluates target distance importance (Dw) by normalizing the distance to air defense points relative to the group's maximum distance.
- Derives killing probability (Pj) for each air target using a weighted sum of firepower unit assignments and target importance.
- Calculates the mathematical expectation (M(X)) of group destruction by summing individual killing probabilities across all targets.
- Trains the neural network using gradient descent to minimize error between historical data outputs and true target importance values.

CN112504011 B

GROUND-TO-AIR MISSILE WEAPON SYSTEM KILLING AREA CALCULATION MODEL SYSTEM

ASSIGNEE

AIR FORCE ENGINEERING UNIVERSITY OF PLA



TECH INTRO

This invention presents a killing area calculation model for ground-to-air missile systems, featuring an adjustment and balance module. It enhances missile launch precision by enabling control over elevation angle and launch force, while maintaining platform stability for improved target accuracy.

TECH FEATURES

- Stabilizes with six hydraulic pistons in pressure barrels for precise launch platform leveling on uneven terrain.
- Deploys via six telescopic tubes for compact storage and rapid operational height extension.
- Enables 360-degree targeting with a rotating base plate gear driven by a motorized system.
- Adjusts elevation precisely using a worm gear mechanism powered by an adjusting motor.
- Auto-levels via movable balls and blocks for multi-axial terrain compensation.
- Combines motorized aiming with manual handles for flexible targeting control.
- Operates autonomously with an onboard battery powering balance and adjustment motors.
- Features modular balance and adjustment units for easy maintenance and customization.

STRATEGIC RECOMMENDATIONS

1. INDIGENOUS INNOVATION ALIGNED WITH NATIONAL REQUIREMENTS

RECOMMENDATIONS:

- Prioritize the development of SAM systems through indigenous R&D frameworks, tailored to the country's operational and geographic requirements (e.g., high-altitude zones, coastal defense, dense urban centers).
- Promote collaboration between DRDO-like institutions, defense forces, academia, and private sector innovators to ensure mission-relevance and adaptability.
- Establish a National Missile Innovation Roadmap, driven by user-centric requirements and future threat assessments.

FUTURE SCOPE:

- Develop modular and scalable missile platforms that can be upgraded over time (e.g., plug-and-play seekers, AI-based targeting).
- Establish national centres of excellence for missile innovation, focusing on advanced materials, guidance systems, and simulation environments.
- Promote export-oriented variants of SAM systems customized for friendly foreign militaries under the umbrella of defense diplomacy.

2. CAPACITY BUILDING AND SKILL DEVELOPMENT

RECOMMENDATIONS:

- Implement structured programs for human capital development in missile technologies, with specialized training in aerodynamics, warhead design, radar systems, and embedded electronics.
- Encourage industry-academia consortia and dedicated defense skilling initiatives to build a talent pipeline aligned with long-term SAM requirements.
- Expand public-private manufacturing partnerships to meet both domestic and export demands efficiently.

FUTURE SCOPE:

- Develop defense technology parks or missile clusters with dedicated infrastructure and R&D labs.
- Establish graduate fellowships, innovation labs, and internships in defense research institutions to attract young talent.
- Create technology transfer and incubation frameworks to involve MSMEs and startups in sub-component development and digital integration.

3. INTEGRATION ACROSS LAND, AIR, AND MARITIME DOMAINS

RECOMMENDATIONS:

- Design SAM systems with interoperability at the core, enabling seamless deployment across land-based units, naval platforms, and mobile air-defense configurations.
- Promote development of unified command-and-control interfaces, compatible with multiple surveillance and targeting assets (AWACS, UAVs, satellites).
- Adopt a layered defense strategy, integrating short-, medium-, and long-range SAMs into a single operational architecture.

FUTURE SCOPE:

- Invest in AI-driven air defense networks for faster response, threat prioritization, and autonomous engagement decisions.
- Develop dual-role SAM platforms that can perform in both static and mobile combat environments.
- Enable real-time data fusion between tri-services, allowing coordinated threat engagement in contested environments.

4. SUPPLY CHAIN INNOVATION AND RESILIENCE

RECOMMENDATIONS:

- Localize critical technologies including seeker heads, propulsion systems, guidance kits, and warhead materials, reducing strategic dependency.
- Strengthen Tier-1 and Tier-2 defense supplier ecosystems by implementing standardized quality protocols, vendor development programs, and fiscal incentives.
- Integrate advanced digital supply chain tools for procurement tracking, inventory forecasting, and lifecycle management.

FUTURE SCOPE:

- Implement blockchain-enabled traceability and predictive analytics for missile system logistics and spare parts.
- Establish strategic manufacturing reserves and flexible production lines to ensure continuity in crisis situations.
- Promote public-private supply chain consortia focused on innovation in materials, component testing, and digital documentation systems.

5. NATIONAL POLICY FRAMEWORK FOR SAM DEVELOPMENT

RECOMMENDATIONS:

- Formulate a dedicated national policy for SAM system development, aligning it with the country's long-term air defense strategy.
- Set clear milestones for indigenization, procurement preferences for domestic systems,

and timelines for phased import substitution.

- Create a mission-mode program under the Ministry of Defence or a National Missile Development Authority to streamline decision-making and resource allocation.

FUTURE SCOPE:

- Establish an integrated policy ecosystem linking SAM development with the broader missile, aerospace, and cyber defense architecture.
- Use the policy as a platform to attract FDI in niche SAM sub-technologies, with strict IP ownership protocols.
- Integrate this policy with India's Defence Acquisition Procedure (DAP) and R&D funding frameworks.

6. EXPORT FACILITATION AND GLOBAL MARKET STRATEGY

RECOMMENDATIONS:

- Set up a Defence Export Facilitation Cell focused on SAM systems under DRDO, DPSUs, or Department of Defence Production.
- Identify potential export markets and align product variants with international specifications (e.g., NATO standards, ASEAN interoperability).
- Simplify and fast-track export clearances under the SCOMET list for non-sensitive, friendly-nation sales.

FUTURE SCOPE:

- Position India as a global supplier of modular, cost-effective SAM systems for developing countries.
- Leverage diplomatic defense corridors (e.g., IOR, Africa, Southeast Asia) for joint production and knowledge-sharing.
- Establish after-sales service hubs overseas to support lifecycle management of exported SAM systems.

7. STANDARDIZATION, CERTIFICATION, AND INTEROPERABILITY

RECOMMENDATIONS:

- Develop a centralized Surface-to-Air Missile Certification Authority, responsible for quality control, safety testing, and systems interoperability.
- Create design standards and compliance protocols for sub-systems, ensuring interchangeability and maintainability.
- Mandate interoperability with tri-services platforms and integrate with existing radar, UAV, and AEW&C assets.

FUTURE SCOPE:

- Promote plug-and-play SAM architectures, enabling integration across land, naval, and aerial defense units.
- Facilitate international certification programs for export readiness and collaborative development with friendly countries.
- Position India as a global center for SAM systems testing and certification for regional allies.

8. CYBERSECURITY AND ELECTRONIC WARFARE (EW) RESILIENCE

RECOMMENDATIONS:

- Integrate cybersecurity protocols at the design stage of SAM software, guidance systems, and communication modules.
- Develop anti-jamming, spoofing, and radar deception resistance capabilities within the C4ISR and C5ISR framework.
- Conduct cyber vulnerability assessments and red team simulations for operational systems.

FUTURE SCOPE:

- Establish Cyber-Resilient Missile Labs under DRDO or NTRO to test advanced threat scenarios.
- Collaborate with AI and quantum computing startups to enhance SAM system encryption and EW countermeasures.
- Embed cyber and EW training modules into defense skilling programs for system operators and integrators.

9. ENVIRONMENTAL AND TERRAIN ADAPTABILITY

RECOMMENDATIONS:

- Design missile systems and launchers to operate reliably in extreme environments—high-altitude areas, deserts, coastal zones, and jungles.
- Use climate-resistant materials, humidity-proof electronics, and anti-corrosion coatings for naval variants.
- Standardize containerized and air-mobile configurations for faster deployment.

FUTURE SCOPE:

- Develop a family of terrain-specific SAM variants, each optimized for different operational theatres (e.g., Arctic-ready or amphibious variants).
- Create mobile power and sensor platforms compatible with SAM systems for off-grid and high-altitude missions.
- Offer dual-use environmental tech innovations for export and civilian disaster management roles.

10. SIMULATION, WARGAMING, AND TESTING INFRASTRUCTURE

RECOMMENDATIONS:

- Establish high-fidelity missile simulation centers for modeling guidance accuracy, target dynamics, and countermeasure scenarios.
- Invest in digital twin infrastructure to replicate SAM system performance and maintenance diagnostics.
- Integrate AI-based wargaming platforms to simulate multi-layered air defense engagements.

FUTURE SCOPE:

- Enable predictive analytics and AI-assisted battlefield simulations to optimize engagement algorithms.
- Build joint-service simulation centers for collaborative training and real-time strategic decision modeling. Commercialize simulation
- technologies for use in civil aviation security and critical infrastructure protection.

11. STRATEGIC STOCKPILING AND PRODUCTION SURGE MECHANISMS

RECOMMENDATIONS:

- Maintain buffer inventories of SAM systems, critical spares, and raw materials through national missile stockpiles.
- Build modular and scalable production lines capable of surge output during emergency deployment.
- Develop tiered vendor ecosystems with ready-to-activate contingency contracts.

FUTURE SCOPE:

- Use AI and IoT-based logistics systems to monitor stockpile health, shelf-life, and replenishment cycles.
- Establish dual-use SAM component production zones that can serve both peacetime industry and wartime needs.
- Build SAM-specific defense logistics zones near strategic borders or naval bases for rapid operational readiness.

12. INSTITUTIONAL COORDINATION AND GOVERNANCE MECHANISMS

RECOMMENDATIONS:

- Form a National Council with representation from DRDO, Armed Forces, MoD, industry bodies, and academia.
- Hold biannual technology and capability review boards to assess gaps, update roadmaps, and align projects.
- Encourage joint capability development programs with industry, including milestone-linked co-investment schemes.

FUTURE SCOPE:

- Position National Council as a nodal authority for cross-sectoral convergence—linking SAM with cyber, space, and AI domains.
- Promote institutional twinning programs with international missile agencies for knowledge transfer and standards harmonization.
- Develop an open innovation platform for academia and startups to contribute to focused missile subdomains (e.g., seekers, micro-propulsion, sensors).

CONCLUSION

The successful national Surface-to-Air Missile (SAM) program transcends technical innovation and production, requiring a strategic ecosystem of robust policy frameworks, coordinated institutions, advanced infrastructure, and proactive international outreach. By integrating these "Other Strategic Suggestions"—clear policies incentivizing private investment, dedicated agencies fostering collaboration, state-of-the-art testing and supply chain networks, and alliances for technology sharing and export—alongside the four foundational pillars of research, manufacturing, testing, and deployment, nations can establish resilient, scalable, and globally competitive SAM ecosystems. This holistic approach, grounded in self-reliance, bolstered by industry partnerships, and oriented toward future conflict preparedness, not only fortifies national defense but also elevates a country's country's standing as a technological and economic leader in the global defense landscape, ensuring security and competitiveness in an increasingly complex geopolitical environment.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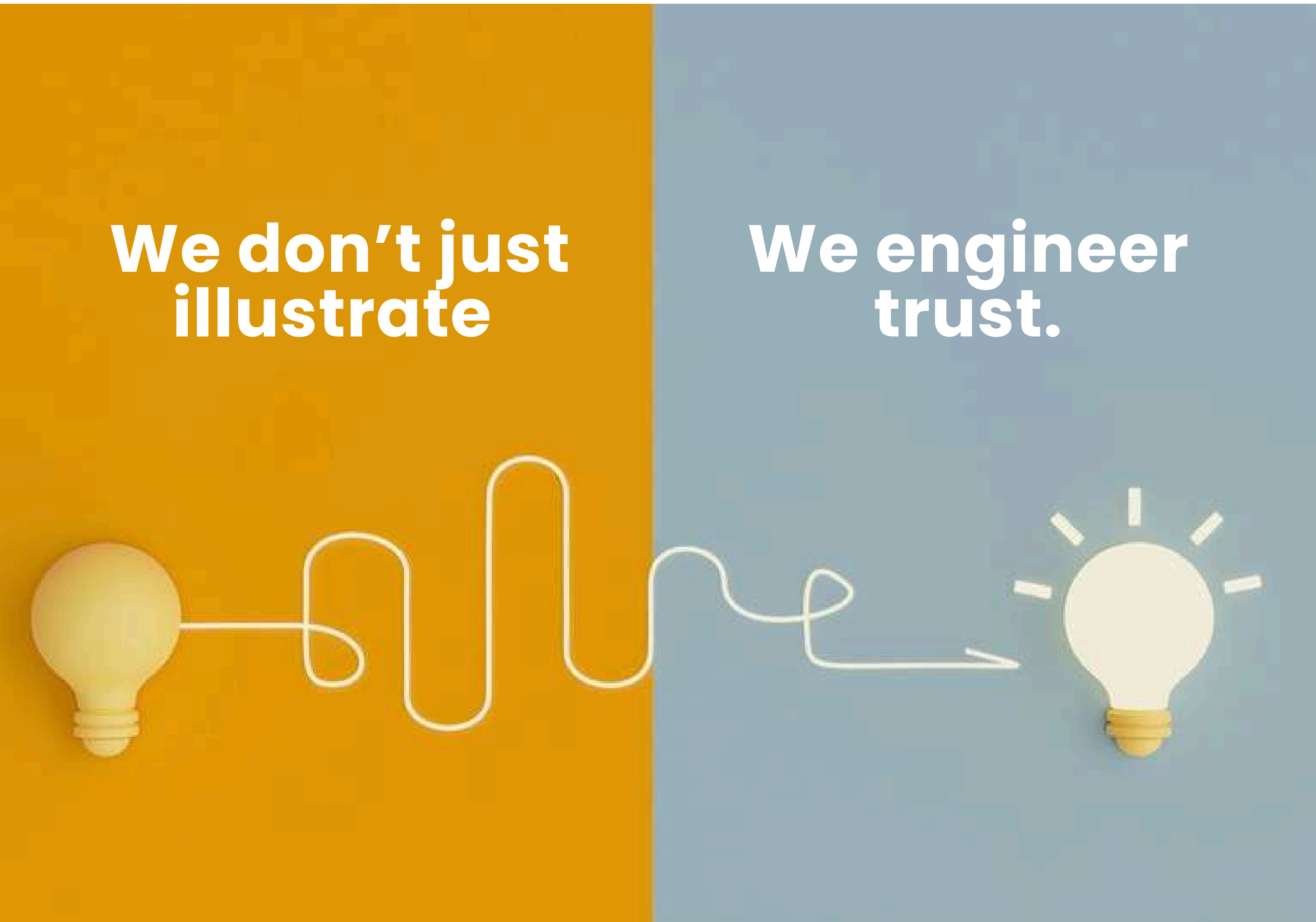
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The Centre for Joint Warfare Studies (CENJOWS) was established on 27 August 2007, at the initiative of the Ministry of Defence, and is registered under The Societies Registration Act 1860. The centre aims to transcend sectoral and departmental legacies, fostering a holistic examination of joint warfare and synergy issues. CENJOWS serves as a vital interface between stakeholders, including the government, public and private sectors, academia, NGOs, and civil society. It facilitates independent and unbiased debates and discussions to identify the best possible alternatives.

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