India’s Defense Sensor Ecosystem

Unlocking domestic capabilities through technology, policy, and ecosystem development

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Executive summary (1/2)

India’s defense electronics spend is $5–$6 billion today and growing at 12%–16% annually, driven by the rising share of capital outlay within the defense budget, platform modernization, and rising electronics content across defense platforms. Within this, India’s defense sensor market, estimated at ~$1–$1.5 billion today, is projected to reach $3.5–$4 billion by 2030, driven by the mission criticality of sensor systems across defense platforms and India’s accelerating indigenization push. Despite this growth momentum, India’s sensor ecosystem is highly import-dependent, with ~80% of demand met through imports, creating supply, control, and sovereignty risks across mission-critical defense systems.

The sensor landscape spans four physical phenomena domains: electromagnetic; mechanical; static fields; and chemical, biological, radiological, and nuclear (CBRN), with electromagnetic and mechanical sensing accounting for ~95% of market value and carrying the highest military relevance. Within electromagnetic sensing, electro-optical and infrared (EO/IR) and radio frequency (RF) sensors are central to surveillance, detection, and targeting across all three services. Within mechanical sensing, inertial and pressure sensors are most heavily used by the Indian Air Force and Navy for navigation, stabilization, and platform monitoring, while acoustic sensors are particularly critical for naval undersea detection.

The sensor value chain consists of fabrication, packaging, and module assembly. India currently holds limited commercial capabilities across fabrication and packaging stages, with Defense Research and Development Organization (DRDO) labs leading research and development (R&D) and design intellectual property (IP). Fabrication represents nearly 100% import dependency, while packaging remains at ~80%–90%. Both stages lack commercial-scale domestic capability, with DRDO labs leading R&D and design IP across compound semiconductor, complementary metal-oxide-semiconductor (CMOS), micro electromechanical system (MEMS), and advanced semiconductor materials. Module assembly has ~50%–60% import dependency, with emerging commercial capability across RF sensor modules.

Executive summary (2/2)

India can potentially capture ~$1 billion of domestic defense sensor demand by 2030 (~30% share of market), anchored in high-impact initiatives such as localizing packaging and module assembly, scaling domestic players, and strengthening R&D-to-commercialization pathways. India's existing defense procurement framework—DAP 2020 and Positive Indigenization Lists (PILs)—provides a foundation but is lacking sensor-specific targeting that could enable a scaled domestic sensor industry.

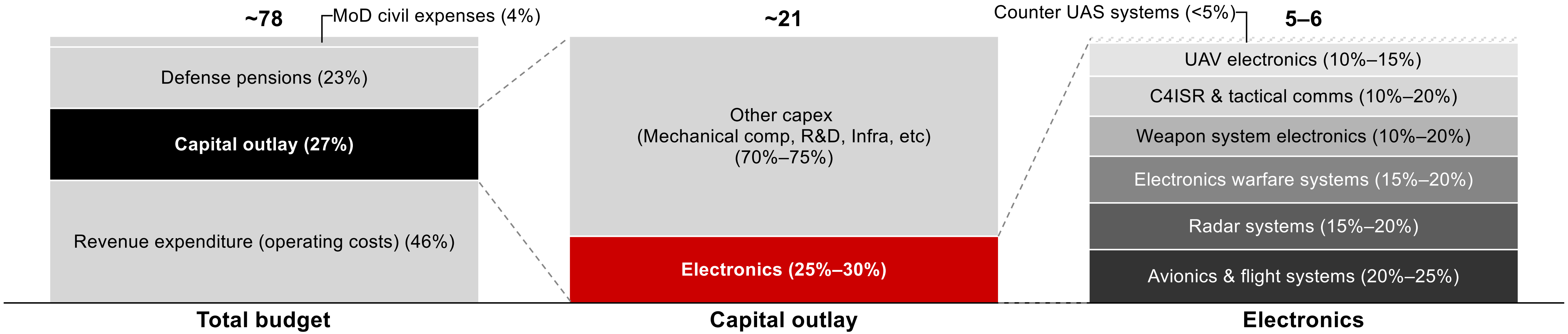
Six key enablers emerge as potentially critical to building a scaled and self-reliant sensor ecosystem:

- National Sensor Roadmap defining priority sensor categories, capability milestones, lead agencies, and timelines through 2035 to provide strategic direction
- Sensor-specific production-linked incentive (PLI) offering turnover-linked incentives to promote indigenous sensor production, with additional support for exports, to address production incentive gap
- Transfer of Technology (ToT) framework enabling transfer of design IP and manufacturing expertise, with export rights in original equipment manufacturers' (OEMs) existing global markets, to incentivize industry participation
- National Sensor Qualification Framework (NSQF), backed by domestic testing infrastructure, to enable military-grade certification and potentially build export credibility
- Sensor exports cell driving export support, market access, end-use certification, and Free Trade Agreement (FTA) navigation for Indian sensor manufacturers
- Strategic fab partnerships in semiconductor fabrication (compound semi, MEMS, infrared [IR] detectors), enabled by co-investment incentives and anchor demand, potentially addressing the upstream capability gap

A roadmap can potentially translate India's ambition into three sequential stages: building domestic assembly and packaging capabilities, scaling upstream inputs, and progressing toward end-to-end capability. In the Foundation phase (fiscal 2026 through fiscal 2028), India could prioritize early localization of module assembly in priority sensor categories while initiating domestic packaging capability and strategic fab partnerships. In the Scale-Up phase (fiscal 2028 through fiscal 2031), domestic packaging could mature across priority sensors, enabling potentially ~$1 billion of domestic value capture by fiscal 2030 and early module exports in mature categories. In the Leadership phase (fiscal 2032 through fiscal 2035), India could potentially progress toward end-to-end sensor value-chain sovereignty, with substantially lower import reliance and commercial-scale indigenous production of critical inputs such as focal plane arrays (FPAs), monolithic microwave integrated circuits (MMICs), and MEMS.

Figure 1: Defense electronics spend: $5–$6B spend today with increasing capital outlay and rising electronics share driving strong growth (12%–16% 5Y CAGR)

India defense budget[1] FY 2026 ($B)

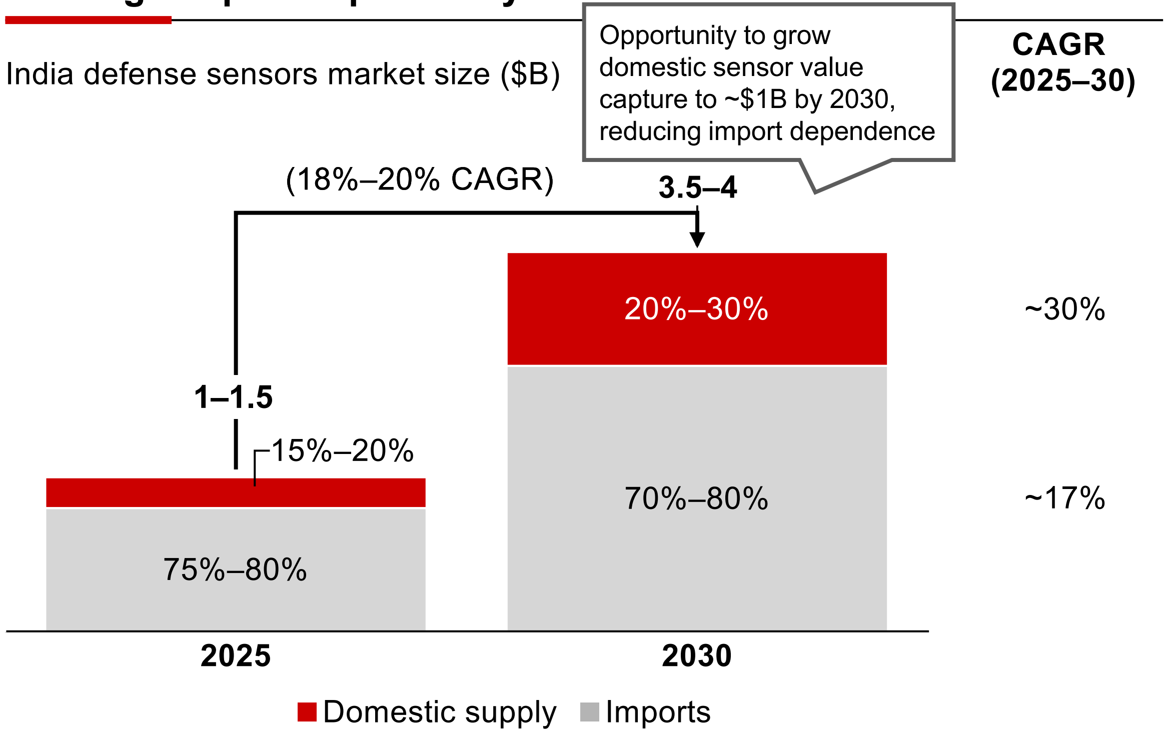


	Total budget	Capital outlay	Electronics
Growth CAGR (FY 2025-30)	**~8%**	**~10%**	**12%–16%**
Growth drivers	**Driven by rising defense capital outlay, self-reliance push (Atmanirbhar) mandating indigenous content, and export momentum** (~30x growth in a decade)	**Deliberate shift toward capital spend** (share rising from ~27% to ~30%+ by FY 2030) to address modernization backlog and complete **large-ticket platform acquisitions**	**Rising electronics intensity per platform, network-centric warfare transition (C4ISR[2], Electronics Warfare [EW], radar)**, and **emerging UAV[3] and counter-UAS[4] demand**

Note: 1 USD = 87 INR used as exchange rate; (1) Announced budget; (2) C4ISR is Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance; (3) UAV is unmanned aerial vehicle; (4) UAS is unmanned aircraft system
Sources: India Ministry of Defense (MoD); Press Information Bureau; expert inputs; Bain analysis

Figure 2: Defense sensors spend is a $1–$1.5B market and growing rapidly, but mission-critical use cases and import dependence create a potential need for strategic localization

India's defense sensor market[1] is a $1–$1.5B opportunity today, with high import dependency



High mission criticality and supply/IP control risks highlight potential need for domestic sensor capabilities

Mission-critical role

- **Mission-critical electronic systems** (e.g., radar, sonar, electronic warfare) representing up to 30%–60% of cost of advanced military platforms
- **Limited number of nations** (US, France) **dominate global defense exports,** creating concentrated supply for mission-critical defense applications

India growth drivers

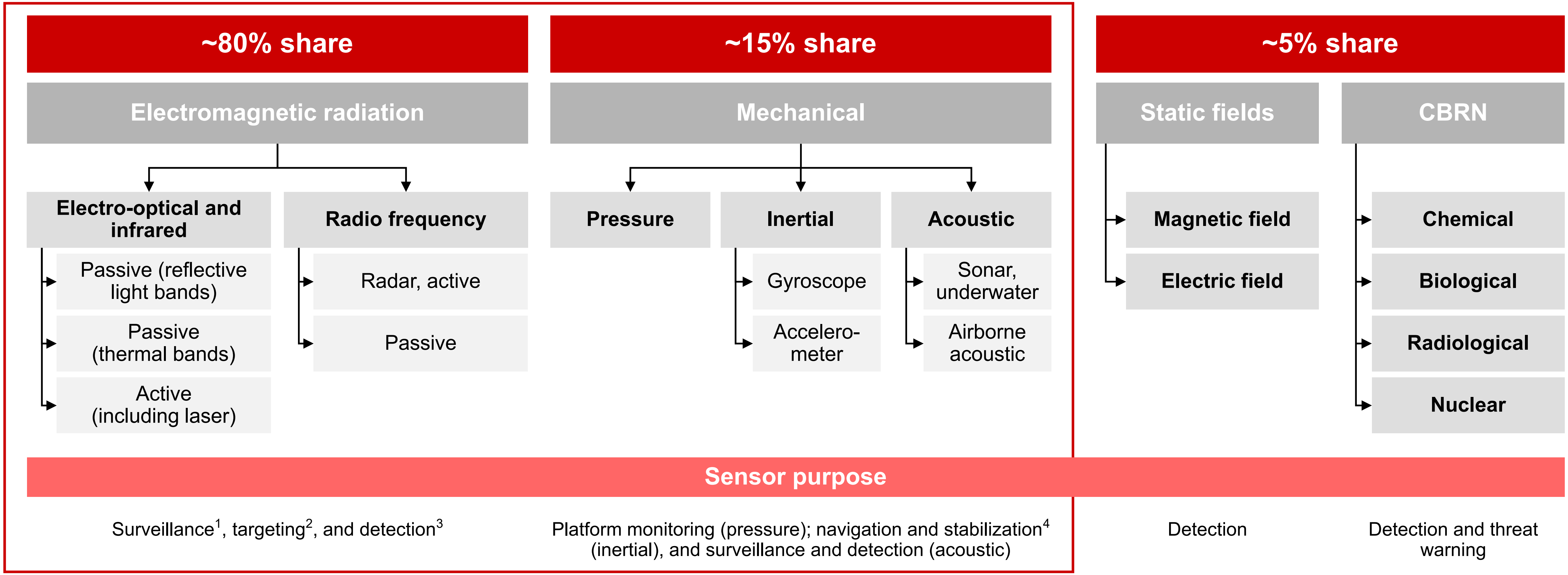
- **Strong indigenization push from Indian government** (Positive Indigenization Lists, Defense Acquisition Procedure)
- **Higher defense allocation by Indian government in FY 2027 (~$90 billion[2])** with ~15% increase over previous year

Key risks

- **National security risk from import dependency**, with mission-critical sensors exposed to export controls, supply disruptions, and long lead times
- **Foreign-owned design IP and software in mission-critical systems,** limiting sovereign control and creating control risk in operational deployment

Note: (1) Defense sensor market includes total value of sensor module, including sensor component (sensor chip), sensor packaging, and assembly of entire sensor module (including cost of other components part of sensor module); (2) 1 USD = 87 INR used as exchange rate
Sources: Literature search; secondary sources; expert inputs; Bain analysis

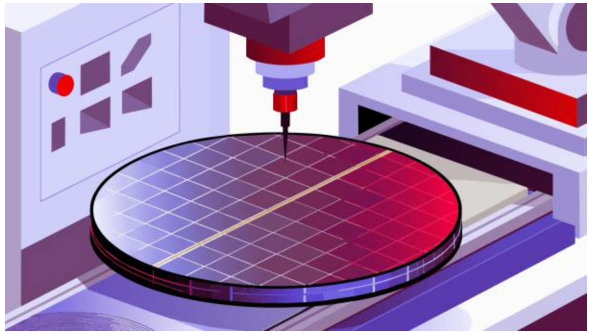
Figure 3: Sensors are divided into four physical phenomena domains, with electromagnetic and mechanical sensing dominating the market



Note: (1) Surveillance refers to observing/monitoring (e.g., search radars, listening sonars); (2) Targeting involves locating and engaging specific targets (e.g., heat-seeking missile locators, gunshots); (3) Detection includes identifying presence of threats (missile warning, sonar detection); (4) Stabilization refers to keeping platforms/weapons steady (gyroscope-based steadying of sights and guns)
Sources: Expert inputs; *A Sensor Classification Scheme* (IEEE), Sensor and Processing Community of Interest (US Department of Defense), Bain analysis

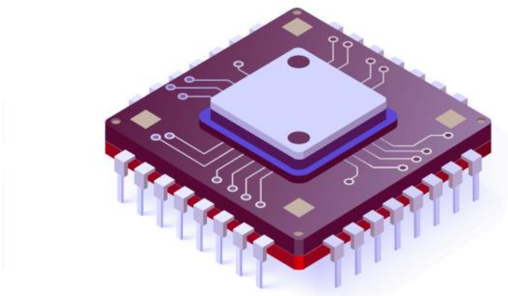
Figure 4: Sensor production flows through three sequential stages, building from wafer fabrication to a fully integrated module

Fabrication



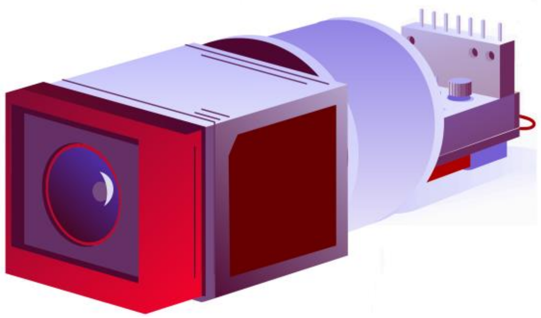
- **Sensing element fabricated on a wafer** using lithography, deposition, and etching, with **additional process steps depending on sensor type** (e.g., epitaxy for IR and RF compound semiconductors; micro-machining for MEMS)
- **Readout electronics either fabricated as separate Si[1] ASIC[2]** in a Si fab (e.g., Readout Integrated Circuit [ROIC] for IR cooled, readout ASIC for mechanical sensors) or **built on the same die** (e.g., EO/IR uncooled sensors)

Packaging



- **Multiple dies of different materials combined based on sensor type** (e.g., IR detector bonded to Si ROIC via indium bumps, MEMS co-packaged with Si ASIC)
- **Combined sensing transducer and readout dies placed in protective package with sensor-appropriate environment** (e.g., IR-transparent window for IR, hermetic cavity for MEMS inertial, port for MEMS pressure/acoustic)
- Hermetic seal and electrical interconnects formed via wire or flip-chip bonding

Sensor module assembly



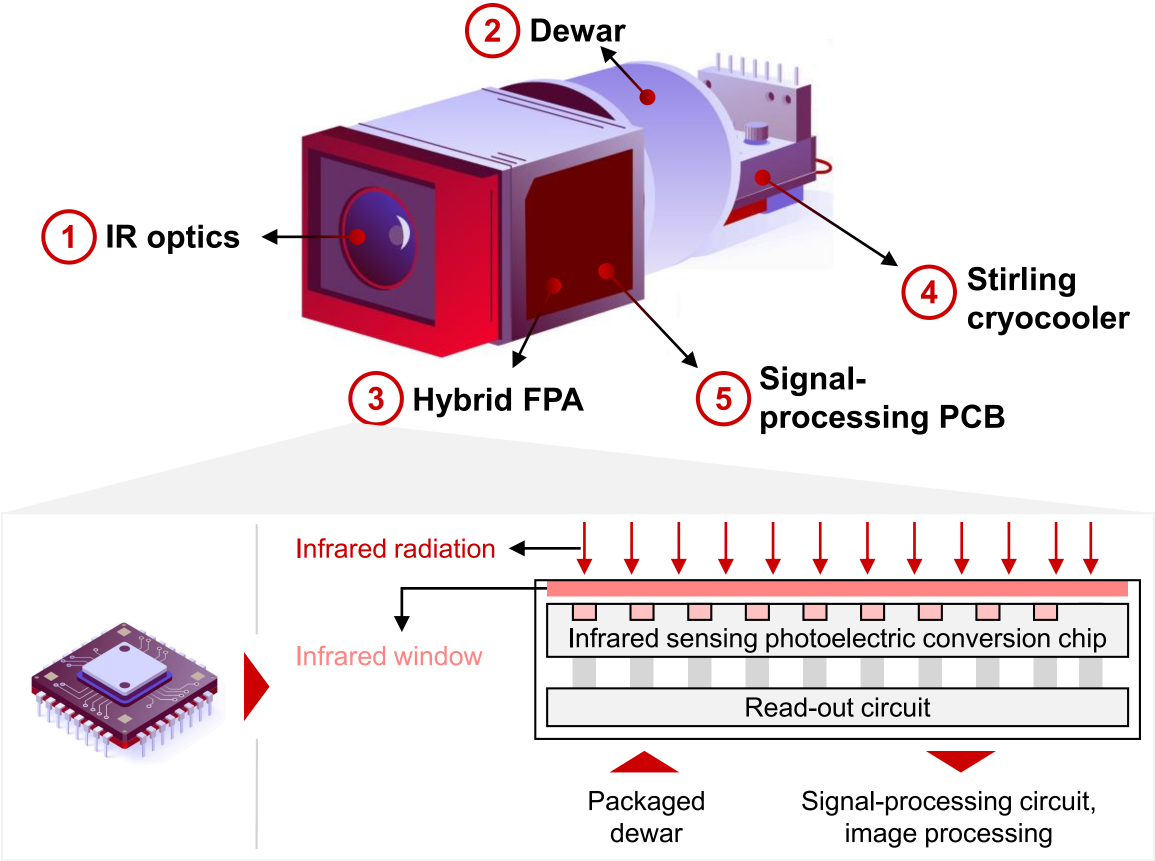
- **Packaged sensor dies assembled with signal-processing electronics, control circuitry, power/heat management, and sensor-specific components on a common PCB[3] to form a sensor module** (e.g., optical lens for EO/IR sensors, integrated gyroscope-accelerometer assemblies for inertial sensor [IMUs], and multiple MMICs mounted on thermally managed PCBs for RF sensors [T/R modules])

Note: (1) Si is silicon; (2) ASIC is application-specific integrated circuit; (3) PCB is printed circuit board
Sources: Literature search; expert inputs

/ILLUSTRATIVE

Figure 5: IR Sensor module has 5 key elements: optics, dewar (sealed vacuum housing), hybrid detector FPA, cryocooler, and signal-processing PCB

Sensor module teardown: IR cooled module



	Component	Description
1	**IR optics**	Directs incoming IR radiation onto the sensing die using specialty IR materials (germanium, silicon, chalcogenide lens), as ordinary glass blocks IR
2	**Dewar** (sealed vacuum housing)	Hermetic vacuum enclosure with an IR-transparent window, allowing IR radiation to reach the sensing die while maintaining vacuum for thermal insulation
3	**Hybrid FPA** (focal plane array)	Sensing element of the module where detector die (HgCdTe or InSb) converts IR photons into electrical charge and the bonded Si ROIC reads each pixel's charge as an electrical signal
4	**Stirling cryocooler**	Cylindrical mechanical cooler that chills the FPA to cryogenic temperatures, eliminating thermal noise from narrow-bandgap IR detector materials at room temperature
5	**Signal-processing PCB**	Onboard electronics driving the cryocooler, performing nonuniformity correction (critical due to varying IR pixel responses), and processing FPA output into a thermal video stream

Sources: Literature search; expert inputs; Global Sensor Technology (GSTiR)

Figure 6: EO/IR, RF sensors are used across all services; pressure and inertial have highest usage in IAF, followed by Navy, while acoustic sensing is primarily Navy-led

Sensor specificity of policy: Low, Medium, High

	Sensor type	Purpose[1]	Army (Battle Tanks, Infantry Fighting Vehicle)	Navy (Frigates, Destroyers, Submarines)	Air Force (Fighter Jets, Aircraft, Helicopters)
Electromagnetic	EO/IR	Surveillance and targeting	Daylight and night-vision sights on rifles/vehicles, thermal sights for long-range vision	Periscope/thermal cameras on masts and submarines for surveillance; IR detectors for sea-skimming missiles	EO/IR targeting/recon pods on aircraft and unmanned aerial vehicles (UAVs); heat-seeking air-to-air missiles tracking jet exhaust
Electromagnetic	RF	Detection and targeting	Radars tracking incoming shells; air-defense radars detecting aircraft and drones; jammers disrupting enemy comms	Search radars for full air and sea picture; fire-control radars for precise gun and missile targeting	Fighter nose radar for target detection, missile guidance; synthetic aperture radar on recon aircraft and UAVs for all-weather ground imaging
Mechanical	Pressure	Platform monitoring	Barometric fuses detonating munitions at set heights; engine and hydraulic pressure monitored in vehicles	Depth sensing for submarine operating depth; hull and hydraulic pressure checks across ship systems	Air-data sensors providing altitude and airspeed; cabin and hydraulic pressure checks
Mechanical	Inertial	Navigation and stabilization	Stabilizing rockets/missiles on heading and steadying sights on moving vehicles	Navigation unit for GPS[2]-denied environment; steadying guns against ship roll	Stabilizing aircraft and missiles on heading; accelerometers for navigation and weapons guidance
Mechanical	Acoustic	Detection and surveillance	Gunshot and sniper locators pinpointing fire by sound; ground sensors detecting vehicle and border movement	Hull-mounted, towed-array, and dipping sonar for submarine detection across active and passive modes	Sonobuoys deployed from maritime patrol aircraft for airborne submarine detection

Note: (1) Surveillance refers to observing/monitoring (e.g., search radars, listening sonars); targeting involves locating and engaging specific targets (e.g., heat-seeking missile locators, gunshots); detection includes identifying presence of threats (e.g., missile warning, sonar detection); stabilization refers to keeping platforms/weapons steady (e.g., gyroscope-based steadying of sights and guns); (2) GPS is global positioning system
Source: Literature search

Figure 7: Under the Atmanirbhar Bharat vision, India has established a coordinated policy framework to accelerate indigenous defense manufacturing

Procurement and indigenization

Defense Acquisition Procedure (DAP)

MoD's[1] acquisition framework to prioritize procurement of Indian-designed, developed, and manufactured defense equipment under Make in India initiative

Positive Indigenization Lists (PIL)

MoD notified import substitution lists to phase out imports across more than 5,000 defense items and create sustained demand for indigenous manufacturers under Atmanirbhar Bharat vision

Manufacturing incentives

India Semiconductor Mission (ISM)

MeitY's[2] flagship semiconductor program (launched in 2021) to build domestic manufacturing capabilities through ~INR 76,000 crore of fiscal incentives across silicon fabs, compound semiconductors, OSAT[3]/ATMP,[4] and display

Electronics Components Manufacturing Scheme (ECMS)

MeitY's incentive scheme (launched in 2025) to strengthen India's electronics component manufacturing ecosystem through capex- and turnover-linked incentives across strategic component categories

Innovation and R&D

Innovations for Defense Excellence (iDEX)

MoD's flagship innovation platform to accelerate indigenous defense technology development through funding, incubation, and prototyping support

Technology Development Fund (TDF) scheme

DRDO's grant program to support the development of indigenous defense and dual-use technologies through collaborative R&D with industry, start-ups, and academia

Ecosystem enablers

Defense corridors

Government of India (GoI)-designated defense manufacturing corridors in UP[5] and TN[6] (each attracting more than INR 10,000 crore investment) to build domestic production capacity and support export growth

FDI[7] reform for Defense

To attract foreign OEM investment and domestic partnerships, GoI's FDI policy for defense raised limits to 74% (automatic route) and 100% (government route)

Offset policy

MoD's policy requiring foreign vendors to invest back more than 30% of contract value in India, including purchase from domestic manufacturers, investments, tech transfers

Notes: (1) MoD is Ministry of Defense; (2) MeitY is Ministry of Electronics and Information Technology; (3) OSAT is outsourced semiconductor assembly and test; (4) ATMP is assembly, testing, marking, and packaging; (5) UP is Uttar Pradesh; (6) TN is Tamil Nadu; (7) FDI is foreign direct investment
Sources: Research reports; literature search; Press Information Bureau

Figure 8: DRDO labs lead R&D and design IP across sensor value chain; however, India remains heavily import dependent in upstream fabrication and packaging stages

	Fabrication	Packaging	Sensor module assembly[1]
Market size, share (%) 2025	**$650–$700M** (45%–50%)	**$150–$200M** (10%–15%)	**$500–$550M** (35%–40%)
Import dependency	**~100%**	**80%–90%**	**50%–60%**
Current capabilities in India	• **No commercial production in India; R&D, design IP led by DRDO labs** • **Solid State Physics Laboratory (SSPL):** specializing in advanced materials (e.g., CZT, HgCdTe, ZnTe, SiC, GaN on SiC), sensor devices and systems, RF/microwave, IR imaging and cryocooler, and frontier tech (e.g., quantum sensors) • **Other labs include:** Semi-Conductor Laboratory (SCL), Gallium Arsenide Enabling Technology Centre (GAETEC), Research Centre Imarat (RCI), Semiconductor Technology & Applied Research Center (STARC)	• **Capabilities at sub-commercial scale currently; DRDO labs leading R&D and design IP** for high-reliability sensor packaging across compound semi, IR FPAs, MEMS • **DRDO labs:** STARC (MEMS foundry), GAETEC (MMIC foundry)	• **Emerging commercial capability across RF sensor modules (T/R modules);** limited capability for EO/IR, MEMS, and inertial navigation modules with **R&D and IP design support from DRDO labs** • **DRDO labs:** Instruments Research & Development Establishment (IRDE), Electronics & Radar Development Establishment (LRDE) • **Industry presence:** BEL, Astra Microwave, Centum, Data Patterns
Global supply ecosystem	• Global supply concentrated in US and EU, followed by Asia-Pacific; select leading players vertically integrated across sensor value chain		

Notes: (1) Sensor module assembly also includes cost of non-sensor components part of sensor module
Sources: Literature search; expert inputs, Bain analysis

Figure 9: India can potentially achieve ~$1B in domestic defense sensor value capture by 2030 through coordinated supply-side and ecosystem interventions

Ambition FY 2030

India's defense sensor ecosystem by 2030: a potentially $3.5–$4B market with ~$1B in domestic value capture, indigenous manufacturing capabilities, globally competitive players, and a robust innovation-to-commercialization engine

Potentially $3.5–$4B defense sensor market by 2030, driven by increased defense spend

Defense sensor demand to potentially grow at ~20% CAGR,[1] reaching $3.5–$4B by 2030, driven by rising defense capex and higher electronics content from modernization programs

~30% domestic share of market, driving higher self-reliance

Domestic value capture to potentially increase to ~30%, generating ~$1B in local value addition through localization of critical sensor modules

Sensor packaging and module assembly indigenized

EMS[2] players build scale in sensor packaging and module assembly, creating indigenous manufacturing capacity for critical sensor categories, incl. EO/ IR and MEMS inertial/ pressure sensors

Globally competitive Indian sensor players

Indian players achieve global leadership in RF sensors (T/R modules) and scale manufacturing in EO/IR FPA modules, competing on quality, cost, and reliability

Robust R&D-to-commercialization ecosystem

Prototype funding and offtake mechanisms enable continuous lab-to-market commercialization of DRDO IP, supported by deeper industry-academia collaboration

Note (1) CAGR is compound annual growth rate; (2) EMS is electronics manufacturing services
Source: Bain analysis

Figure 10: 4 potentially critical success factors for India's defense sensor ecosystem

1 Apex body as ecosystem integrator	2 Strategic indigenization of sensor manufacturing	3 Export-led competitiveness	4 Leveraging industrial ecosystem
Potentially critical success factors for India			
Central government apex body to align **defense strategy, R&D priorities, funding allocation, and private sector engagement**	**Indigenization of advanced multi-sensor systems** alongside **scaled production of cost-competitive sensors,** supported by differentiated supply chains	**Export competitiveness** enabled by **globally recognized standards and independent testing,** improving market access and attracting private investment	**Existing capabilities** (EMS, design, precision manufacturing) **within India's private sector** to accelerate sensor capability development
Examples from global ecosystems			
Dedicated apex bodies coordinating defense strategy, tech development, and industry participation (e.g., South Korea's ADD[1])	**Distinct supply chains for advanced and cost-competitive sensors** (e.g., US manufacturing ecosystem for integrated sensor systems and low-cost drone production)	**Shift from import reliance to global export leadership** (e.g., South Korea's rise as a leading defense exporter)	**Strong industrial participation** driving defense ecosystem growth (e.g., South Korea's chaebols)

Note: (1) ADD is Agency for Defense Development (South Korea)
Source: Expert reports

Figure 11: India has built a broad defense policy foundation, but sensors have yet to emerge as a scaled, targeted priority

Sensor specificity of policy Low Medium High

	Policy	Description	Sensor coverage
MoD	**Defense acquisition procedure** (DAP 2020)	• **Policy framework** defining procurement guidelines • **"Buy" categories focused on procuring existing equipment and "Make" categories supporting new equipment**, with MoD funding/assured offtake • **iDEX[1] for start-ups/MSMEs[2]** (grants up to INR 25 crore per project) and **partnership model pairing Indian private primes with foreign OEMs**	Limited sensor-specific provisions/carve-outs; impact on sensor ecosystem is indirect, via indigenization content thresholds and Make routes Limited dedicated sensor funding stream—iDEX grants and Make-II routes are equipment-agnostic, with sensors competing alongside other defense electronics
MoD	**Positive Indigenization Lists** (PIL) *effective 2020 onward*	• **MoD's import substitution mechanism mandating** indigenous procurement of specified defense items • **Consists of ~5,500 items across DMA[3]- and DDP[4]-issued lists** for system, subsystem, and component indigenization	Select sensor systems (e.g., radars, sonars, EW system) and modules (e.g., T/R module) covered in DMA and DDP; limited inclusion of dies (e.g., GaN, GaAs, SiC)
MeitY	**India Semiconductor Mission** (ISM)	• **MeitY's flagship semiconductor program under Atmanirbhar Bharat/Make in India; INR 76,000 crore to build fab, ATMP/OSAT, and semiconductor design through fiscal incentives**	Coverage of silicon fab, compound semiconductors (including MEMS), and ATMP/OSAT; however, there is limited offtake for defense sensor applications
MeitY	**Electronics Components Manufacturing Scheme** (ECMS)	• **MeitY scheme** to build electronics component manufacturing ecosystem by promoting domestic value addition; advances Atmanirbhar Bharat in electronics supply chain • **Provides turnover- and capex-linked incentives** across sub-assemblies, bare components (PCBs, capacitors, connectors) and capital equipment	No dedicated sensor category; sensor modules eligible under electromechanical category, but there has been limited offtake to date

Note: (1) iDEX is Innovations for Defense Excellence; (2) MSMEs are micro, small, and medium enterprises; (3) DMA is Department of Military Affairs; (4) DDP is Department of Defense Production
Sources: Literature search; expert inputs

Figure 12: 6 key enablers emerge as potentially most critical to strengthening India's sensor ecosystem

Structural gaps in sensor ecosystem

Lack of sensor-specific focus: Sensors subsumed within broader platform and electronics initiatives, with limited sensor-specific carve-outs

Fragmented ecosystem support: Support spread across initiatives, limiting prioritization of sensor technologies and critical subsystem components

Limited scale-up support infrastructure: Insufficient funding and coordination to transition sensor capabilities from prototype to qualified production

Potential focus areas to grow India's sensor ecosystem

Sensor roadmap	**National sensor roadmap** setting priority segments, milestones, and indigenization timelines through 2035, aligning industry, research, and government stakeholders
PLI (Production-linked incentive)	**Sensor-specific PLI offering turnover-linked incentives** to promote indigenous production, with additional support for exports
ToT framework	**ToT terms enabling transfer of design IP and manufacturing expertise,** with export rights into OEMs' existing global markets to incentivize Indian industry participation
NSQF (National Sensor Qualification Framework)	**Sensor-specific qualification and certification framework**, backed by domestic testing infrastructure to enable military-grade certification and build export credibility
Exports cell	**Sensor exports cell** driving export support, market access, end-use certification, and FTA navigation for Indian sensor manufacturers
Strategic fab partnerships	**Global partnerships in semiconductor fabrication** (e.g., compound semi, MEMS, IR detectors) through co-investment incentives and DPSU[1] anchor commitments

Note: (1) DPSU is Defense Public Sector Undertaking
Source: Expert inputs, Bain analysis

Figure 13: A sensor roadmap with packaging and module assembly localization in the near term, with fabrication and full value chain sovereignty as the long-term ambition

2035 vision | A globally competitive Indian defense sensor ecosystem with end-to-end indigenous capability across the value chain

	Foundation FY 2026–2028	Scale-Up FY 2028–2031	Leadership FY 2032–2035
Objective	**Localization of module assembly** across priority sensors; emerging domestic packaging capability	**Domestic packaging scaling across priority sensors; ~$1B in domestic value capture by FY 2030;** emerging module exports in mature categories	**End-to-end sensor value chain sovereignty** across priority sensor categories
Industry ecosystem	**Indigenous demand emerges** across defense majors and primes for sensor categories **Sensor start-ups, MSMEs, and electronics players** enter the sensor value chain	Indian players **invest in advanced packaging; global OEMs increasingly license to Indian players** **Indian module exports begin in mature categories** (T/R modules, EO/IR optics)	**Global OEMs increasingly co-locate manufacturing, including for fab** in India **Indian players scale module exports to international defense customers**
Capabilities and technology	**Module assembly across other major sensor categories** (e.g., EO/IR, mechanical sensors) First domestic packaging lines operational for T/R modules	**Module assembly matures** across priority sensor categories **Packaging maturing** across RF modules, with EO/IR capability building **Pilot-scale fabrication for sensor inputs** (FPAs, MMICs) operational through global partnerships	**Commercial-scale indigenous production of critical sensor inputs** (FPAs, MMICs, MEMS) through scaled fab partnerships **Public-private frontier R&D labs operational for SWIR, photonics, and new materials** **Sovereign IP** in priority sensor categories
Key enablers	**National Sensor Roadmap, sensor-specific PLI, ToT framework, strategic fab partnerships** initiated for compound semi (GaN, GaAs), MEMS	**Sensor exports cell, NSQF-aligned** qualification and certification operational	Standards and certification leadership through mutual-recognition pacts
Expected outcomes	**Localization of module assembly for priority sensors; initial packaging capacity operational**	**~$1B domestic value capture** (~30% of demand) **Packaging localization maturing** (RF-led, EO/IR advancing); module assembly mature in key categories	**Import reliance significantly reduced** through establishment of self-reliant, end-to-end sensor capabilities for priority categories

Sources: Literature search; expert inputs, Bain analysis

Select terms used in the report (1/3)

1	**Sensor**	Device that converts physical input (light, heat, motion, pressure, RF energy, sound) into an electrical signal that can be processed and read by downstream electronics
2	**Sensor module**	A finished, functional sensing unit consisting of the sensing die, supporting electronics, sensing aid (optics, antenna, port), and external interfaces, ready to be integrated into a defense platform
3	**Transducer**	The element within a sensor that performs the actual physical conversion (e.g., a silicon photodiode converts photons to current; a piezoresistor converts strain to resistance change)
4	**Die**	A small piece of semiconductor wafer containing a complete circuit or sensing element; multiple dies are produced from one wafer and then individually packaged
5	**Wafer**	A thin, polished disc of single-crystal semiconductor material (typically 100–300 mm diameter) on which sensing structures and circuits are fabricated; diced into dies after fabrication
6	**Silicon (Si)**	Standard semiconductor material; used in EO image sensors, ROICs, ASICs, and MEMS sensor dies; abundant and supported by a mature global fab ecosystem
7	**Indium Gallium Arsenide (InGaAs)**	Compound semiconductor for SWIR detection; grown epitaxially on InP substrate; used in SWIR cameras, laser rangefinders, fiber-optic comms
8	**Indium Antimonide (InSb)**	Compound semiconductor for Mid-Wave Infrared (MWIR) detection with very narrow bandgap; requires cryogenic cooling; used in fighter Infrared Search and Tracks (IRSTs), missile seekers, weapon sights
9	**Mercury Cadmium Telluride (HgCdTe/MCT)**	Compound semiconductor with tunable bandgap for MWIR and Long-Wave Infrared (LWIR) detection; grown epitaxially on CdZnTe substrate; high-performing IR detector material used in advanced thermal imaging
10	**Vanadium Oxide (VOx)**	Material used in uncooled microbolometers for LWIR detection; deposited as a thin film on top of CMOS/ROIC substrate; resistance changes with temperature when infrared radiation is absorbed
11	**Gallium Arsenide (GaAs)**	Compound semiconductor with high electron mobility; used in RF MMICs for low-noise amplifiers (LNAs) and lower-power applications; grown epitaxially on GaAs
12	**Gallium Nitride (GaN)**	Wide-bandgap compound semiconductor used in RF MMICs for high-power amplifiers in radar T/R modules; usually grown epitaxially on SiC substrate
13	**Silicon Carbide (SiC)**	Wide-bandgap substrate material used as base for GaN epitaxy in RF MMICs; chosen for its excellent thermal conductivity managing heat from high-power transistors
14	**Cadmium Zinc Telluride (CdZnTe/CZT)**	Specialty substrate material used as the base for HgCdTe epitaxy in IR cooled detectors; expensive and supply-constrained substrate

Select terms used in the report (2/3)

15	**Piezoresistive/capacitive (MEMS readout)**	Two ways MEMS sensors convert mechanical deformation into electrical signal: piezoresistive (strain in the MEMS structure changing resistance of silicon piezoresistors) and capacitive (deformation changes the gap between electrodes, changing capacitance)
16	**PZT (lead zirconate titanate)**	Piezoelectric ceramic used as active transducers material in sonar and ultrasound; generates voltage when mechanically stressed by sound waves; produced by sintering
17	**Indium Phosphide (InP)**	Compound semiconductor substrate commonly used as the base for InGaAs epitaxy in SWIR detectors; also used for very-high-frequency RF MMICs and telecom lasers
18	**Epitaxy**	Process of growing a thin, defect-free crystalline layer of one material on top of a matched substrate; used to fabricate compound semiconductor sensing layers (e.g., HgCdTe on CdZnTe, GaN on SiC); requires precise control of composition to define performance characteristics
19	**Sacrificial etch**	Sub-step within surface micromachining where an underlying material is selectively removed to release a suspended structure, allowing it to physically move and respond to inputs
20	**Detector die**	Semiconductor chip that performs the actual sensing in sensors; similar to an EO/IR sensor, it consists of an array of light-sensitive pixels (photodiodes) on a single piece of semiconductor (Si for EO, InGaAs/InSb/HgCdTe for IR)
21	**Focal Plane Array (FPA)**	The 2D array of detector pixels at the focal plane of an EO/IR optical system; the term often refers to the complete sensing chip, including detector die and ROIC bonded together as one functional unit
22	**ROIC (Readout Integrated Circuit)**	Type of integrated circuit (IC) (typically CMOS-based chip) that reads each pixel's signal from the detector die, amplifies it, and outputs an ordered electrical signal for image processing; built monolithically with the detector for EO and bonded separately for cooled IR
23	**Hybrid FPA**	An FPA where the detector die (compound semiconductor) and the ROIC (silicon) are fabricated on separate wafers and bonded together via indium bumps; standard architecture for cooled IR detectors
24	**Application-Specific Integrated Circuit (ASIC)**	Custom-designed chip optimized for specific function (vs. general computing); it typically performs key actions with sensors interface, including signal amplification, conditioning, and digital conversion
25	**Monolithic Microwave Integrated Circuit (MMIC)**	Type of IC containing active, passive, and interconnect components and designed to operate at frequencies from hundreds of MHz to hundreds of GHz; widely used for high-frequency communication; typically fabricated on III-V compound substrates such as GaAs, InP, and GaN

Select terms used in the report (3/3)

26	**Micro Electro Mechanical System (MEMS)**	Class of sensors that combine miniature mechanical structures (diaphragms, proof masses, vibrating beams) with electronic readout on a single silicon die; used in pressure, inertial, and acoustic sensors
27	**Die attach**	Packaging step where a bare die is mechanically and thermally bonded to its package base or substrate; uses high-conductivity solder, conductive epoxy, or sintered silver depending on heat dissipation needs
28	**Wire bonding**	Packaging step where thin gold/aluminum wires (25–50 μm) make electrical connections between die's top-surface pads and package's external leads or other dies
29	**Flip-chip bonding**	Packaging method where a die is flipped face down and connected to its substrate or another die via tiny solder or metal bumps on the die's surface; used for high-density connections and higher RF performance than wire bonding
30	**Indium bumps**	Tiny indium metal spheres used to bond a compound semiconductor detector die to its silicon ROIC pixel-by-pixel; the critical hybridization step in cooled IR FPA manufacturing, with one bump per pixel
31	**Hermetic sealing**	Packaging step that creates a moisture- and gas-tight enclosure around a sensitive die; required for cooled IR (vacuum), MEMS inertial (controlled pressure), and RF MMICs (humidity-sensitive GaN)
32	**Cryocooler (Stirling cooler)**	Miniature mechanical refrigeration unit using the Stirling cycle to chill a cooled IR FPA to 77–150 K; required because narrow-bandgap IR detectors generate spurious thermal noise at room temperature
33	**Dewar**	Sealed vacuum housing enclosing cooled IR FPA, with IR-transparent window allowing IR radiation to reach the detector while preventing heat ingress/condensation
34	**IR window**	Specialty transparent material (germanium, silicon, etc.) used in IR optics/dewars to allow IR radiation to pass while blocking other wavelengths; ordinary glass blocks IR
35	**Transmit-Receive Module (T/R Module)**	A hermetically packaged subassembly combining multiple MMIC dies (power amplifier, LNA, phase shifter, switch, control IC) that performs both transmit and receive functions in an active electronically scanned array (AESA) radar; hundreds tiled together form a radar antenna
36	**Inertial Measurement Unit (IMU)**	A sensor module that combines three MEMS gyroscopes and three MEMS accelerometers (one per axis) with a microcontroller for sensor fusion to produce six-axis motion sensing for navigation and platform stabilization
37	**SWIR/MWIR/LWIR**	Short-, mid-, and long-wave infrared bands covering ~1–3 μm, 3–5 μm, and 8–12 μm, respectively; each band requires different detector materials and is used for different defense applications (SWIR for laser range-finding, MWIR for hot-engine tracking, LWIR for thermal imaging of warm bodies)
38	**Synthetic Aperture Radar (SAR)**	Active data collection technique where multiple shorter antennas are used to stimulate larger antennas by emitting energy pulse and recording the amount of energy reflected after it interacts with the surface

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