From Technologies to IP Business Intelligence

SAMPLE

Imaging Radar for Autonomous Systems

Patent Landscape Analysis

September 2025

KnowMade
Patent & Technology Intelligence

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ONE-HOUR PRESENTATION

The author of the report is available to address any questions you may have.

A **one-hour online presentation** of the report is included with your purchase. This session offers the opportunity for a direct interaction with the author, including a presentation of the results and a dedicated Q&A session.

Feel free to contact the author to schedule a meeting.

Contact us

KNOWMADE is a technology intelligence and IP strategy consulting company specializing in the analysis of patents and scientific publications. We assist innovative companies, investors, and research organizations in understanding the competitive landscape, anticipating technological trends, identifying opportunities and risks, improving their R&D, and shaping effective IP strategies. Our highly qualified analysts transform patent information and scientific literature into actionable insights to support decision-making in R&D, innovation, investment, and intellectual property.

INTRODUCTION
Context of the report

This report provides a detailed analysis of the global patent landscape for **imaging radar technologies applied to autonomous systems**. Based on more than **10,600 identified patent families (inventions)**, including selected over **2,800 core inventions**, the study captures the strong acceleration of innovation in this field over the past decade. The increase in patent activity is closely tied to the growing demand for high-resolution, real-time perception solutions across a wide range of autonomous platforms.

Imaging radar technologies analyzed in this report cover **six high-impact domains: terrestrial, aerial, marine, space, robotics, and defense**. Among these, **terrestrial applications** remain the most active and mature area in terms of both volume and technical complexity. Patent filings related to **advanced driver-assistance systems (ADAS),** Level 2 to Level 4 autonomous driving, and robotaxi platforms account for a significant share of the dataset. This reflects the urgency of equipping vehicles with robust sensing capabilities able to operate under adverse weather, poor lighting, and dynamic road conditions. Key industrial players such as **Intel-Mobileye**, **Bosch**, **Magna**, **Huawei-Yinwang**, **Waymo**, and **General Motors** have built extensive and diversified patent portfolios centered on terrestrial imaging radar use cases.

A major driver of recent innovation is the shift toward **4D imaging radar**, which enables simultaneous measurement of range, velocity, azimuth, and elevation. This advancement allows radar systems to produce dense point clouds and support complex perception tasks such as object classification, free-space detection, and scene reconstruction. Since 2018, patenting activity in 4D radar has intensified, with a growing number of inventions covering antenna configurations, beamforming methods, calibration procedures, radar-SLAM, and deep learning–based radar interpretation. As a result, 4D radar is becoming a core technology in next-generation perception architectures, especially for road-based autonomous platforms.

To analyze the technological content of the patent landscape, this report segments the inventions into **five progressive technical layers**. The foundational layer includes signal generation and spatial sampling techniques such as FMCW, MIMO, and beamforming. The second layer focuses on radar system platforms, including hardware modules, SoCs, and 4D radar integration. The third layer addresses imaging and calibration processes, including synthetic aperture radar (SAR), ISAR, and radar-camera alignment. The fourth layer covers perception and mapping functions, such as radar-based SLAM, object tracking, and scene modeling. Finally, the fifth layer encompasses AI enhancement and sensor fusion, including deep learning networks, radar-vision fusion frameworks, and multi-sensor decision making. Most of the leading IP holders show activity across several of these layers, indicating a strong trend toward full-stack radar system development.

From a geographical perspective, the **United States** and **China** lead the global radar IP landscape. The U.S. remains strong due to early innovation by automotive OEMs and technology providers, while China has shown the fastest growth since 2022, fueled by both incumbent players and emerging radar startups. **Europe** maintains a steady presence, particularly through Tier-1 automotive suppliers. The competitive IP environment is shaped by a mix of large multinational corporations and smaller, highly focused technology firms. While established players such as **Bosch**, **Intel-Mobileye**, and **GM** continue to invest heavily, newer entrants like **Arbe Robotics**, **Uhnder**, **Cheng-Tech**, **Zadar** and **Geometrical-PAL** are building specialized patent portfolios around 4D radar chip design, signal processing, and perception software.

In conclusion, terrestrial imaging radar stands as the primary engine of innovation and IP development in the autonomous systems space. The convergence of radar hardware, signal processing, and AI-based perception is reshaping the technical landscape, with 4D imaging radar emerging as a central technology. As the field continues to evolve, patenting strategies will play a key role in defining competitive advantage, technological leadership, and barriers to entry in both automotive and broader autonomous domains.

INTRODUCTION
Scope of the report

We have selected and analyzed more than **22,200 patents and patent applications** published worldwide up to **May 2025**, representing more than **10,600 patent families** (inventions) relevant to the scope of this report. Among them, more than **2,800 patent families** have been identified as **core inventions**, showing a stronger relevance to the imaging radar domain.

The patent search strategy has been implemented using advanced search equations in the patent database and by a cautious patent selection performed by the analyst to get the most out of the corpus.

More details are available in METHODOLOGY part.

Inventions related to **Imaging Radar for Autonomous Systems** have been selected as follows:

Included	Excluded
➤ Patents claiming fundamental techniques, architectures and signal processing applied to imaging radar (e.g., FMCW, MIMO, beamforming, range-Doppler processing).	➤ Inventions describing only non-imaging radar, e.g., long-range radar (LRR) or short-range radar (SRR) without angle/elevation resolution.
➤ Inventions describing imaging radar hardware platforms, such as integrated radar SoCs, RFICs, analog front-ends (AFE), and automotive-grade chipsets.	➤ Patents specific to optical, LiDAR, Sonar or ultrasonic sensing unless they directly contribute to radar performance.
➤ Imaging radar related inventions applied to multi-sensor fusion, such as camera-radar or lidar-radar fusion for autonomous navigation.	➤ Radar applications in fields unrelated to imaging for autonomous systems, such as meteorology, aviation traffic control, industrial logistics, unless clearly cross-deployable.
➤ AI-based imaging radar processing: deep learning networks for object classification, denoising, super-resolution, etc.	➤ Component-level patents not explicitly targeting imaging radar integration or radar signal generation.
➤ Imaging radar software stacks for SLAM, mapping, obstacle detection, and motion tracking in dynamic environments.	➤ General AI/ML algorithms not dedicated to radar signal enhancement or radar-based perception tasks.
➤ Automotive and non-automotive autonomous applications of imaging radar, including robotics, aerial, marine, space, and defense use cases.	

INTRODUCTION
Objectives of the report

The report aims to provide a comprehensive view of the **imaging radar for autonomous systems patent landscape** along **6 applications** and **5 technical layers**

Imaging radar for autonomous systems analyzed in this report extend far beyond traditional automotive use. The patent dataset reveals active deployment across **six high-impact domains**:

➢ **Terrestrial**: ADAS, autonomous vehicles (L2–L4+) , robotaxi, etc.

➢ **Aerial**: Airborne platforms like aircrafts, UAVs, and helicopters, etc.

➢ **Marine**: Surface and underwater sensing via ships, AUVs, and autonomous marine vessels.

➢ **Space**: Satellite-borne and space vehicle sensing, etc.

➢ **Robotics**: Articulated robots, AGVs, and indoor navigation in industrial or warehouse settings.

➢ **Defense**: Military systems for surveillance, targeting, and perimeter security.

This report structures the imaging radar patent landscape along **five progressive technical layers**, reflecting the typical technology development and deployment pipeline, from foundational signal architecture to intelligent fusion for autonomy. These layers represent both functional hierarchy and innovation hotspots in radar systems.

Waveform & Architecture	Radar System Platforms	Imaging & Calibration	Perception & Mapping	AI Enhancement & Sensor Fusion

More in details, the patent landscape analysis provides an overview of **imaging radar for autonomous systems**:

• To present **global IP trends** (time evolution of patent filings, geographical evolution of patent filings, etc.).

• To identify the **main IP players** and the **IP newcomers** in the different segments of application and technology;

• To determine the status of their **patenting activity** (active / inactive) and their **dynamics** (ramping up, slowing down, steady);

• To identify **notable patents** and targeted applications and technologies.

• To reveal **IP collaborations** (joint co-owned patents, sub-brands, joint ventures, etc).

In addition, the report includes **IP profiles**, which provide a comparison and an overview of the patent portfolios and the recent patenting activity of **General Motors**, **Bosch**, **Huawei-Yinwang**, **Intel-Mobileye**, **Magna** and **Alphabet-Waymo**.

INTRODUCTION
Reading guide: find the right information in the report

Report sections

Your concern

Information you get

	TECHNOLOGY *For R&D teams, engineers, scientists*	**IP** *For IP teams, patent attorneys*	**MARKET** *For executives, business developers*	**PLAYER** *Zoom in a competitor / partner*
PATENT LANDSCAPE OVERVIEW • **Ranking of players** (enforceability, current activity, geo/tech coverage, prior-art contribution, etc.) • **Patent filings dynamics per player** • **IP collaborations** (co-filings, IPR transfers) • **Patent litigation/oppositions**	Innovators	Main patent owners IP risks/opportunities	Ecosystem (competitors, newcomers, partners, clients) Main trends IP vs Market	IP position vs Market position Player relationships (collaborations/ dependencies)
SEGMENTS ANALYSIS • **Patent filings dynamics per segment** • **IP leaders per segment** (enforceability, current activity, blocking potential) • **Notable patents per segment** • **Recent patenting activity per segment**	Technology trends Technology mapping	Blocking players IP risks/opportunities in each segment (FTO, litigation, licensing)	Benchmarking Markets of interest Future developments	IP position and level of investment in each segment Key IP developments
IP PROFILE OF KEY PLAYERS • **Patent portfolio summary** (portfolio size, IP activity evolution, patents legal status, geo/tech coverage, strengths/weaknesses, etc.) • **Key patents** • **Recent patenting activity**	Current R&D activities Technology roadmap	Blocking patents Geo/Tech coverage Link between patents and products	Future products Potential partners Potential targets	R&D investment level Key inventions Current IP activities Strengths / Weaknesses

KnowMade

INTRODUCTION
Excel database

This report includes an extensive **Excel database** with the **10,600+ patent families** (inventions) analyzed in this study. This useful patent database allows for multicriteria searches and includes patent publication numbers, **hyperlinks to an updated online database** (original documents, legal status, etc.), priority date, title, abstract, patent assignees, patent's current legal status, and **segments** (six application domains, five technology layers with 11 technique segments.), and **core inventions**.

Patent information
Publication numbers, title, abstract, patent assignees, priority dates, etc., and hyperlinks to an updated online database (original documents, current legal status, etc.)

Segments in which the patents are classified.
- Application domains: terrestrial, aerial, robotics, space, marine, defense
- Technology: FMCW, MIMO, Beamforming, 4D imaging radar, SAR, ISAR, calibration, point cloud, SLAM, tracking, AI and sensor fusion

PATENT LANDSCAPE OVERVIEW
General trends, main patent assignees and new entrants

SAMPLE
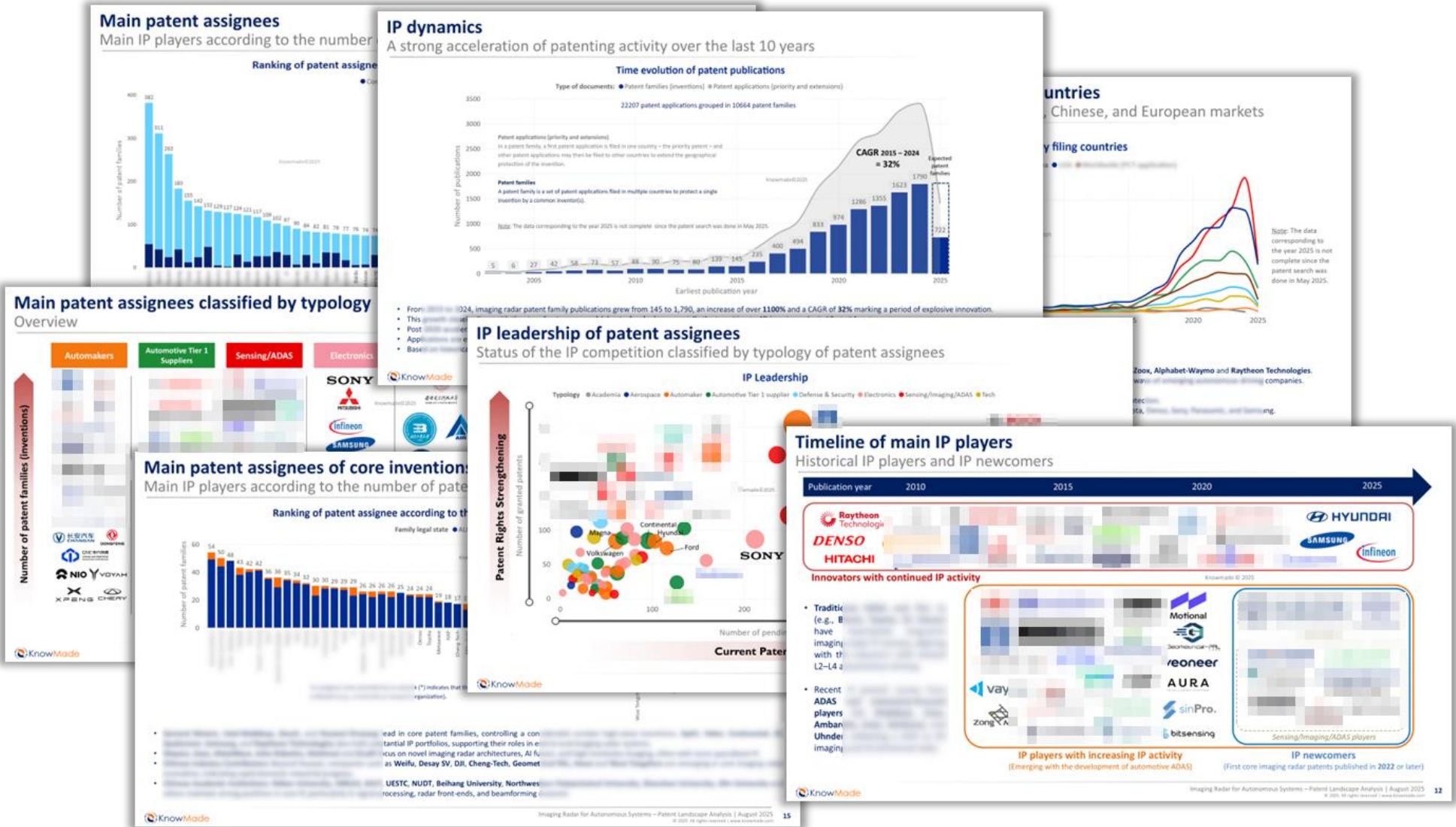
PATENT LANDSCAPE OVERVIEW
IP leaders, IP strategies, IP collaborations, licensing agreement, litigations
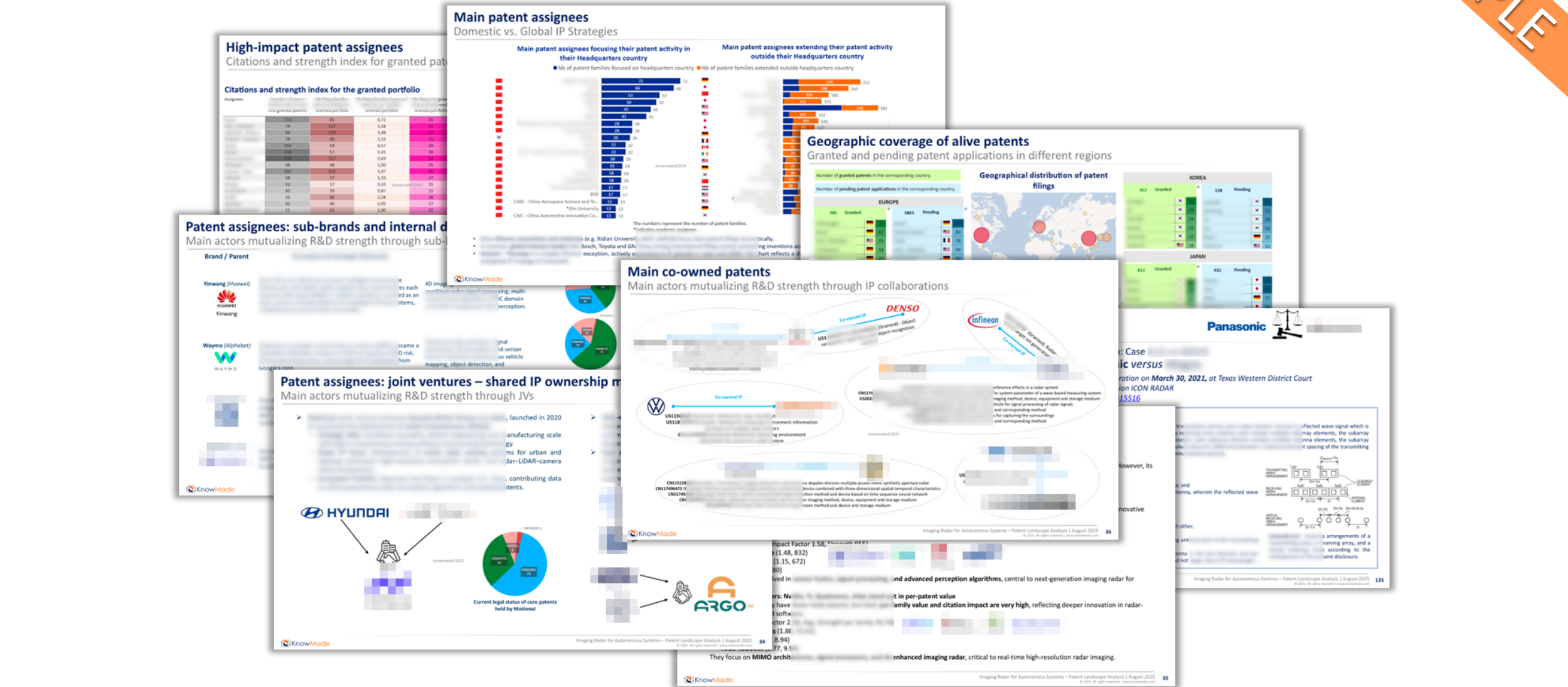
PATENT SEGMENTATION
Patent Categorization by Technical Layers and Deployment Scenarios

The patents selected for this report have been categorized into 6 application domains and 5 technology layers comprising 11 technique segments

Waveform & Architecture	Radar System Platforms	Imaging & Calibration	Perception & Mapping	AI Enhancement & Sensor Fusion

TECHNOLOGY

Foundational Layer

FMCW Radar: Foundational for range and velocity measurement

MIMO Radar: Enhance angular resolution using antenna arrays

Radar Beamforming: Allow directional control and multi-target tracking

System Layer

4D Imaging Radar:
- Integrates FMCW, MIMO, Beamforming
- Outputs range, azimuth, elevation, and Doppler
- Backbone of modern high-performance radar systems

Support Layer

SAR / ISAR: Synthetic and inverse aperture imaging

Radar Calibration: Essential for multi-sensor and ego-alignment

Mid-layer Processing

Point Cloud Processing: Filters, clusters, structures radar data

Dynamic Radar Tracking: Learns object motion over time

SLAM / Mapping: Localizes vehicle and builds maps

Application Layer

AI-Enhanced Imaging: Deep learning for denoising and recognition

Fusion of Camera and Lidar: Leverages complementary strengths

APPLICATIONS

Terrestrial | Aerial | Marine | Space | Robotics | Defense

FOCUS ON TARGETED APPLICATIONS
IP dynamics, main patent assignees, IP leaders, and notable patents by segment
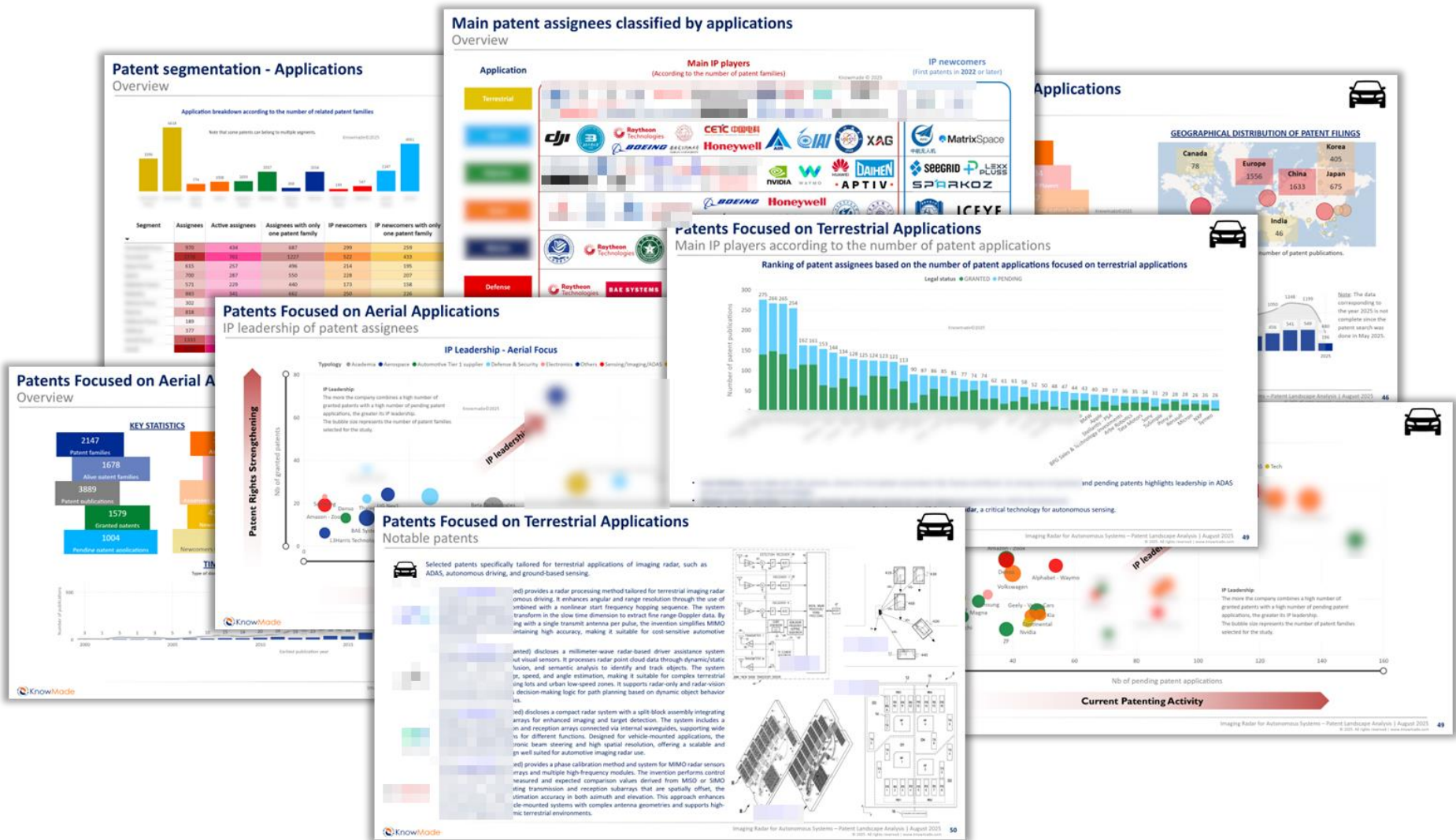
The categories to which each patent belongs are available in the Excel file provided with the report

FOCUS ON TECHNICAL SEGMENTS
IP dynamics, main patent assignees, IP leaders, and notable patents by segment

The categories to which each patent belongs are available in the Excel file provided with the report
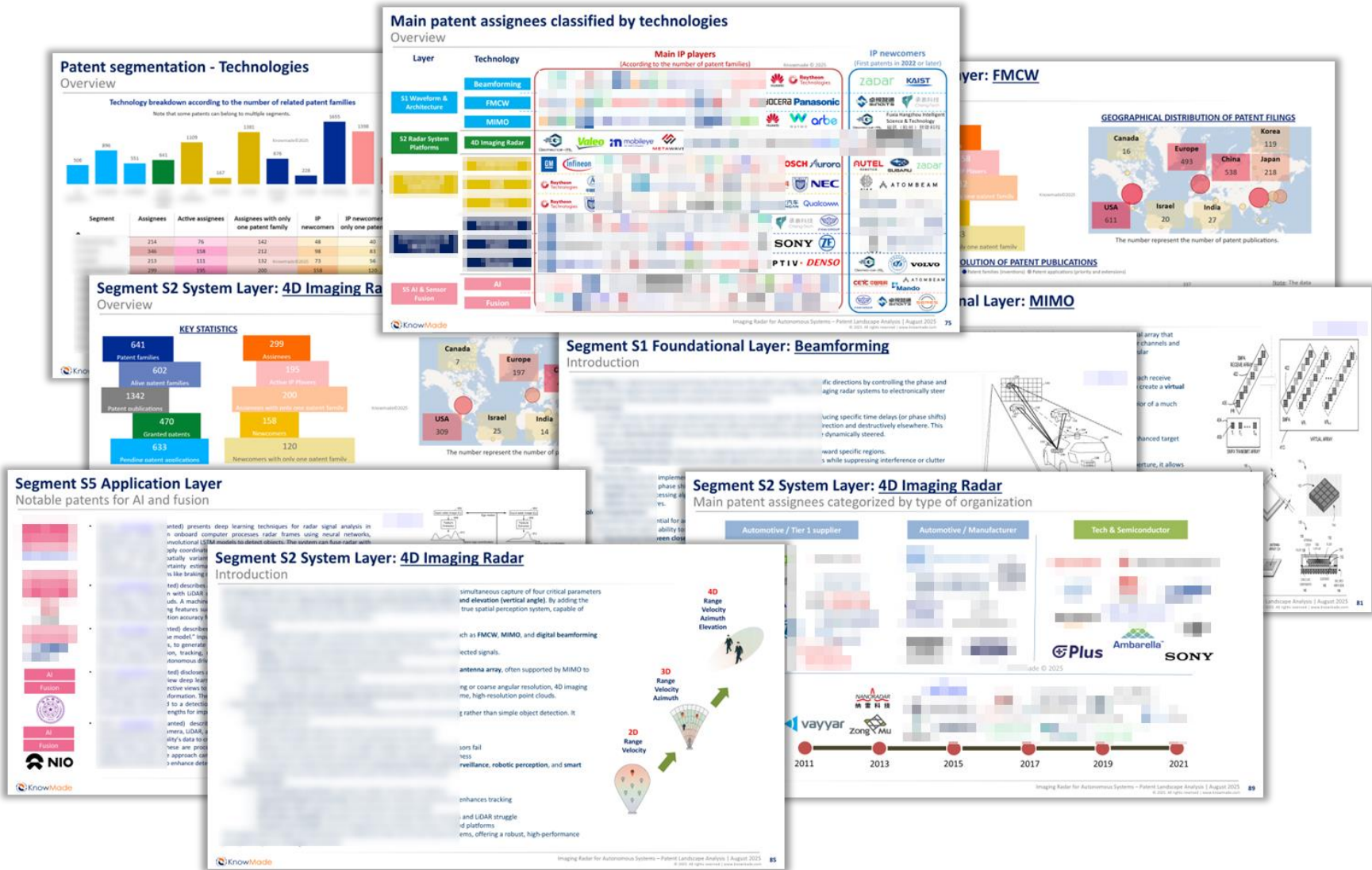
IP PROFILE OF PLAYERS
IP portfolio summary, IP strategy, key patents and recent patenting activity

This report includes detailed profiles of **General Motors**, **Intel-Mobileye**, **Bosch**, **Huawei-Yinwang**, **Magna** and **Alphabet-Waymo**, covering patent portfolio dynamics, notable granted and pending patents, legal status and global coverage.

IP Profile

➤ Imaging radar patent portfolio overview

➤ Notable granted patents

➤ Notable pending patent applications

ORDER FORM

Imaging Radar for Autonomous Systems

Patent Landscape Analysis – September 2025

Ref.:KM25002

SHIP TO

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_____

Job Title:

_____

Company:

_____

Address:

_____

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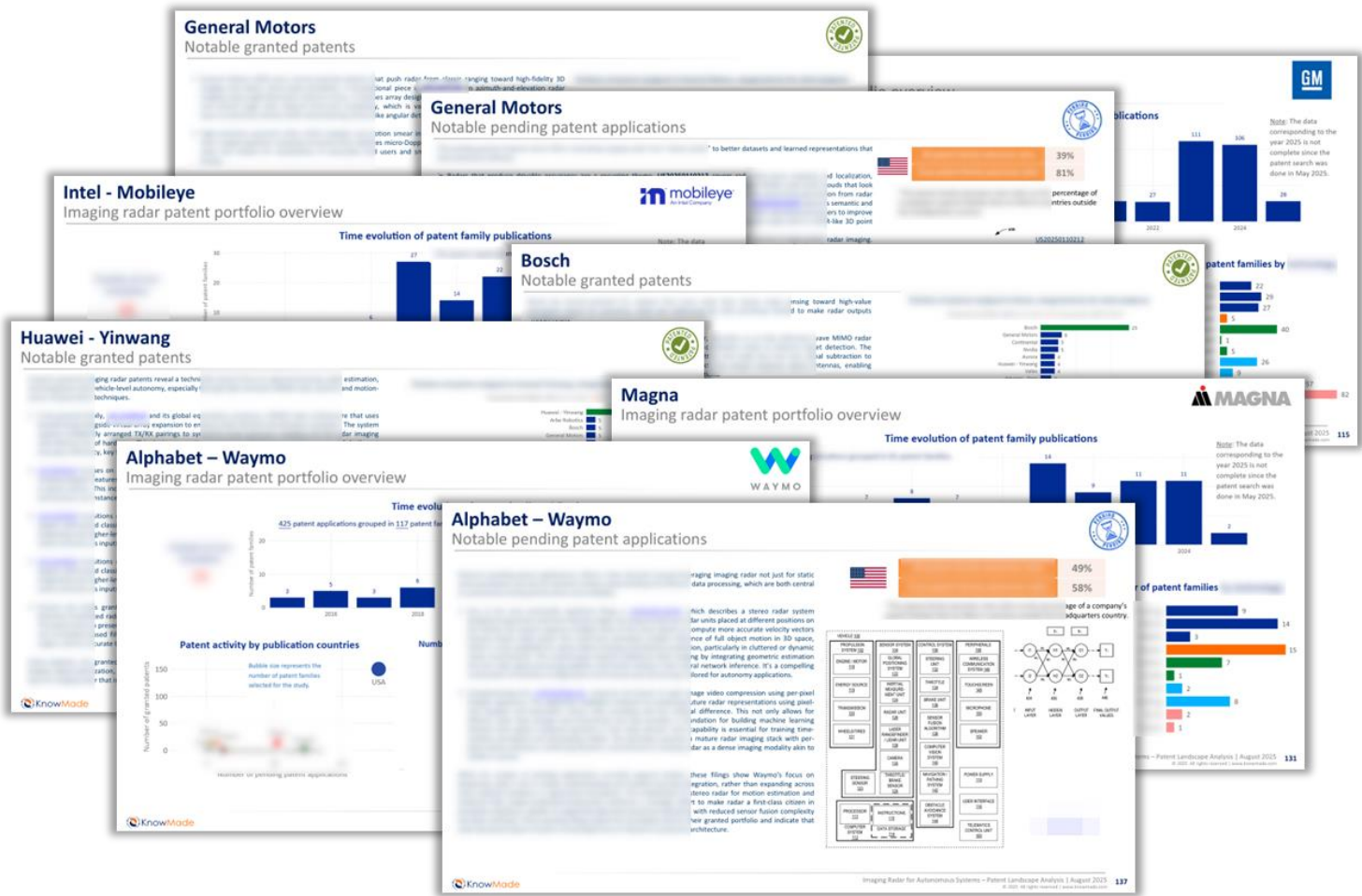To pay your invoice using a check, please mail your check to the following address**:**

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b) any claim attributable to errors, omissions or other inaccuracies in the Product or interpretations thereof.

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Patent your inventions
Assert your patents
and defend your position
Evaluate the IP risks

Understand, anticipate and evaluate the competitive landscape and current technology developments

Improve your R&D
and innovation strategy
Identify and get access
to external innovation

YOUR NEEDS

Intellectual Property

Innovation Strategy

OUR SOLUTIONS

Prior art search
Freedom-to-operate analysis
Patent invalidation
Evidence of use

Patent landscape
Monitoring service
Patent portfolio analysis
Patent valuation

Technology scouting
Scientific literature analysis
Technology review

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WHAT INFORMATION CAN YOU GET ?

INTELLECTUAL PROPERTY

For IP teams,
patent attorneys

➢ Risks and opportunities
  (FTO, litigations, licensing)
➢ Key patents
➢ Link between patents and products
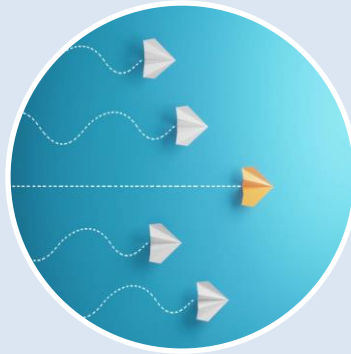
TECHNOLOGY

For R&D teams,
engineers, scientists

➢ R&D activities
➢ Technological roadmap
➢ Position on the supply chain

MARKET

For executives,
business developers

➢ Identify competitors
➢ Compare IP with market position
➢ Evaluate the level of investment
➢ Future products & target markets

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Format
- PDF file with analyses.
- Excel file with data.
- Access to the analyst.

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- Stand alone report
- Patent landscape.
- Overview on IP dynamics, trends and players.
- Competitor, technology and strategy analysis.
- Benchmark of patent portfolios.
- Key IP players & key patents.

Format
- PDF file with analyses.
- Excel file with patent data.

MONITORS
(multi-client product)

To track the latest R&D developments and IP activities, and to be sensitive to weak signals

- Annual subscription
- Patent monitoring service.
- Quarterly updated patent data and technology trends.
- Current R&D and IP activities.
- Early detect weak signals, opportunities and risks.
- Open discussion with analyst.

Format
- PDF file with analyses.
- Excel file with patent data.
- Direct access to the analyst.

INSIGHTS
(free article & webinar)

To get unique information about industry and technology

- Analyst point of view about industry news (product release, M&A, start-up, fund-raising, etc.) from a patent perspective.

Format
- KnowMade website

MAIN FIELDS OF EXPERTISE

SEMICONDUCTORS

- Materials & Substrates
- Power electronics
- RF & Wireless datacom
- MEMS, Sensing & Imaging
- Photonics, Lighting & Display
- Memory
- Packaging

HEALTHCARE

- New therapeutic tools
- Medical diagnostics
- Medical devices and imaging
- Drug discovery and delivery

ENERGY

- Batteries
- Fuel-cells
- Solar PV
- Power management

AGRI-FOOD

- Food processing & formulation
- Vegan food
- Next-gen packaging
- Microbiology

KnowMade

SEMICONDUCTORS
Expertise

Power electronics
- Wide bandgap semiconductors
- Power devices and IC
- Power modules
- Power applications

RF & Wireless communications
- RF substrate & epiwafers
- RF devices (SAW, BAW, PA/LNA, etc.), RFIC, MMIC
- RF front-end module, RF packaging
- MIMO, beamforming, carrier aggregation
- 5G & 6G networks, Radar, mm-waves, microwaves, THz

MEMS, Sensing & Imaging
- MEMS sensors and actuators
- 3D imaging and sensing (ToF, CIS, thermal imaging, LiDAR, imaging Radar, event-based camera, etc.)
- AI/ML, sensor data fusion

Memory
- SRAM, DRAM, flash
- 3D-stacked memories
- Emerging non-volatile memories (MRAM, PCM, RRAM, etc.)
- Embedded NVM

SEMICONDUCTORS
from materials and devices to circuits, packaging and modules/systems

Photonics, Lighting & Display
- Optoelectronics & optical components (LED, OLED, laser, optical transceivers, waveguides, metasurfaces, etc.)
- Photonic crystal, photonic IC, silicon photonics
- Optical communications, AR/VR, quantum

Advanced packaging
- Fan-Out WLP/PLP, 2.5D/3D IC
- SiP, SoC, Chiplets
- TSV, μbumps, interposer, interconnect bridge, hybrid bonding

Materials & Substrates
- Compound semiconductors
- Engineered substrates
- Epiwafers

KnowMade

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Patent & Technology Intelligence

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