From Technologies to Market

Opportunities for sensors in the IoT applications:

What are the real growth drivers?

MEF 2015
MEMS Engineer Forum

Presentation
MEMS Engineer Forum – Tokyo 2015

YOLE Développement

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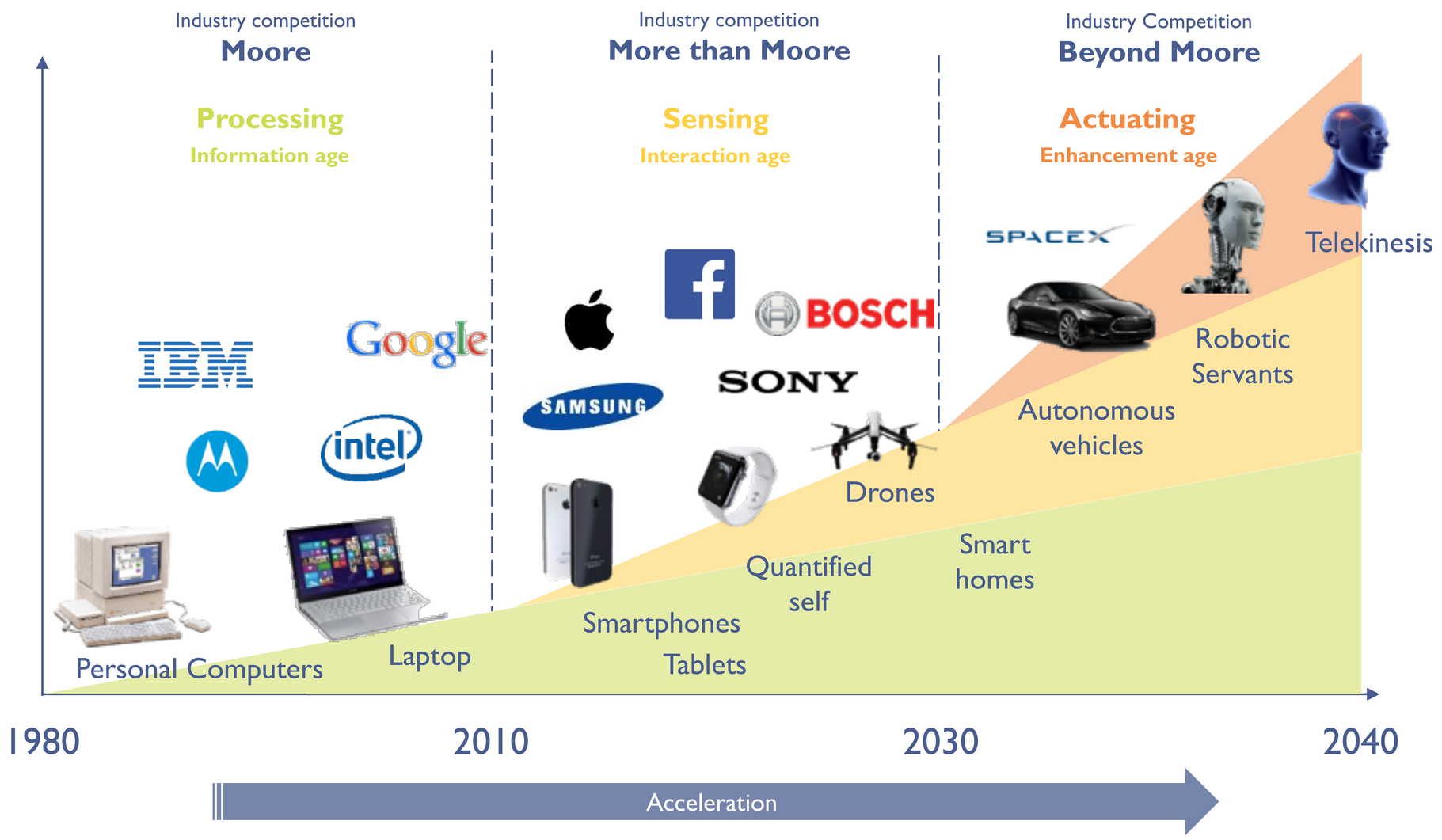
Internet of Things

MEMS & SENSORS ROADMAP

From More than Moore towards Beyond Law

MEMS & Sensors enable key functionalities …

Current battleground of the industry



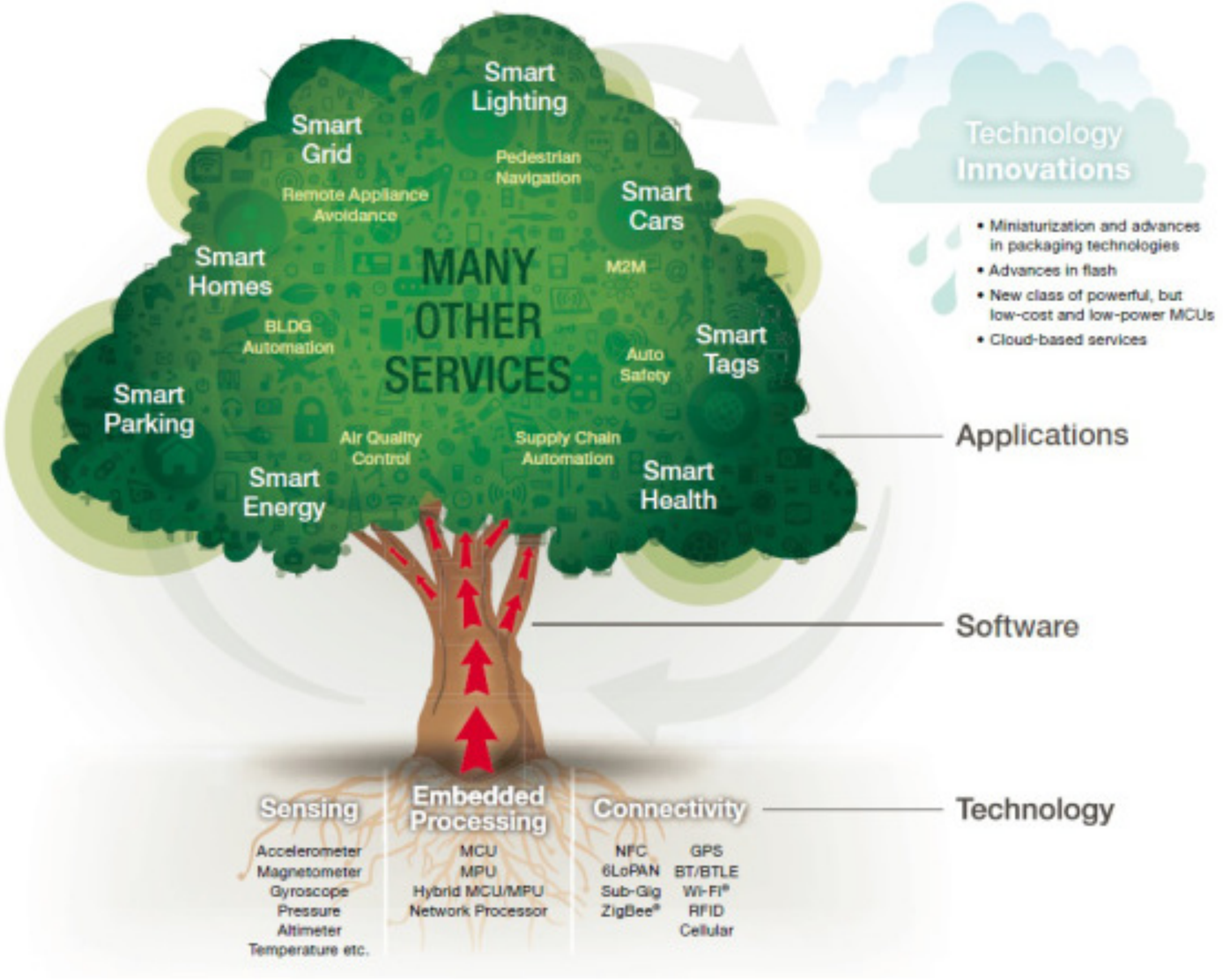
ENABLING TECHNOLOGIES FOR IOT

Sensing

Connectivity

Processing

- **Key technologies:**
  - Sensing
  - Processing
  - Connectivity
- **Supported by:**
  - Sensor / machine infrastructure
  - Communication backbone
  - M2M service layer
  - Application platform

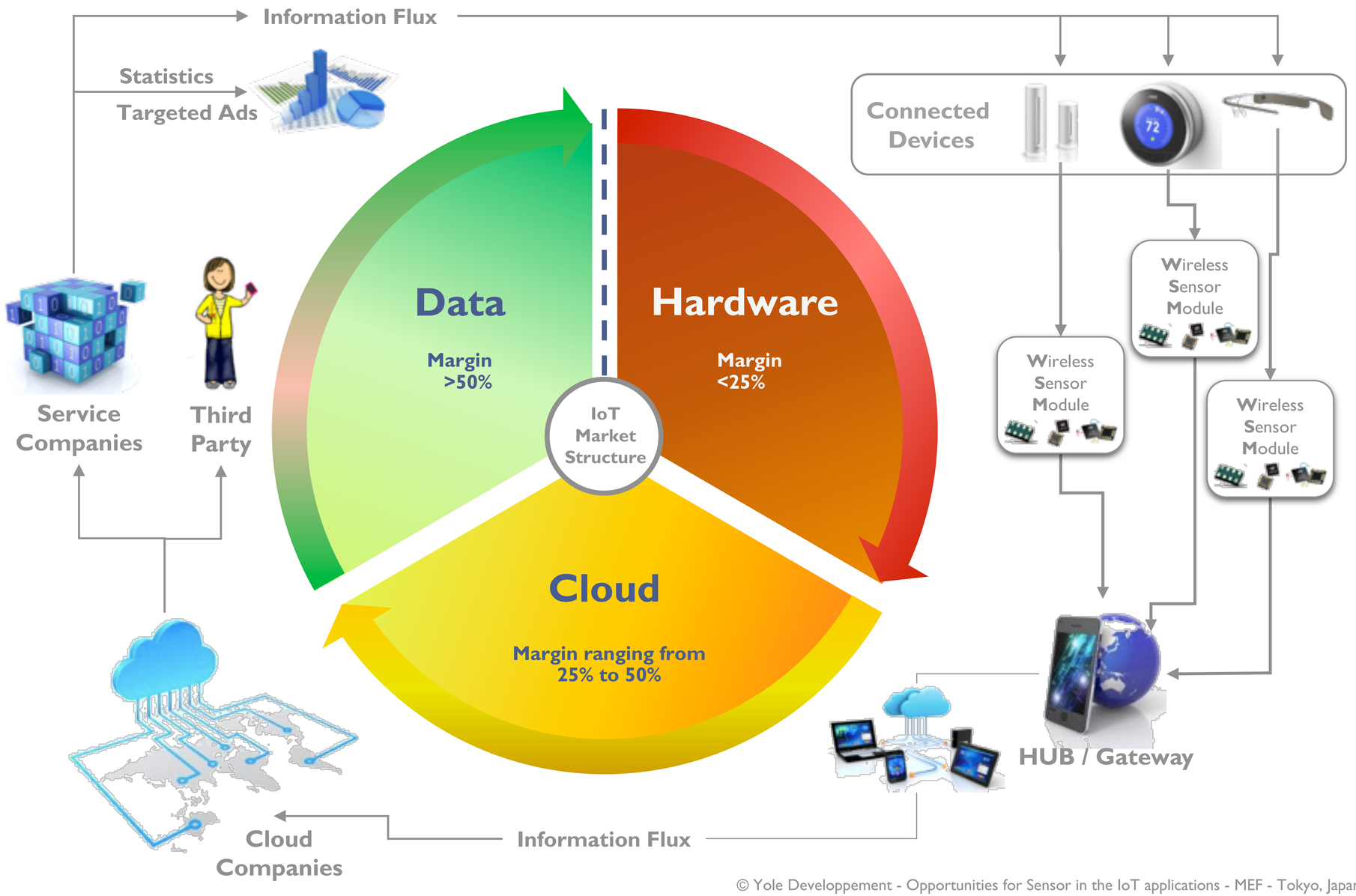


Source: Freescale

ENABLING TECHNOLOGIES FOR IOT

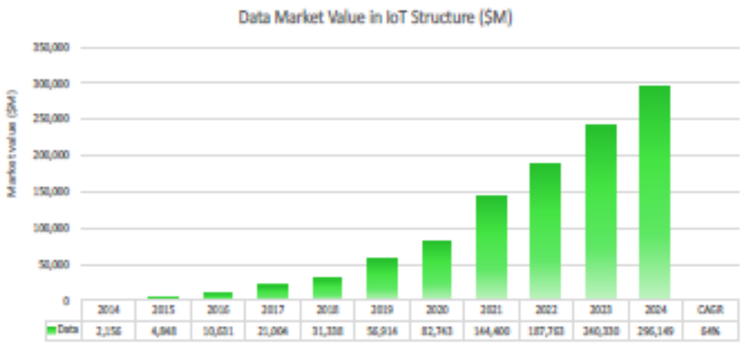
IoT Structure

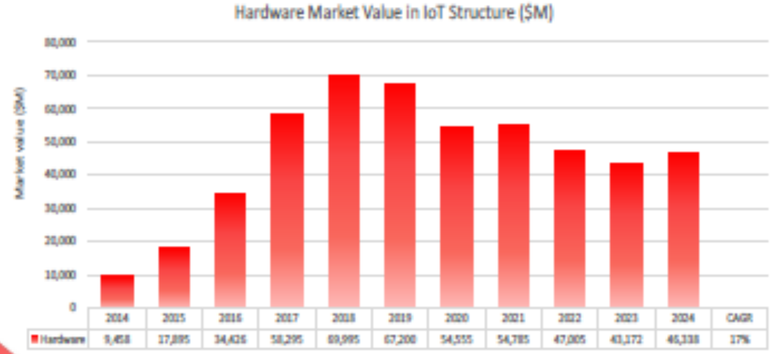
Hardware is not the long term winner in the IoT race



IOT GLOBAL STRUCTURE AND MARKET FORECAST

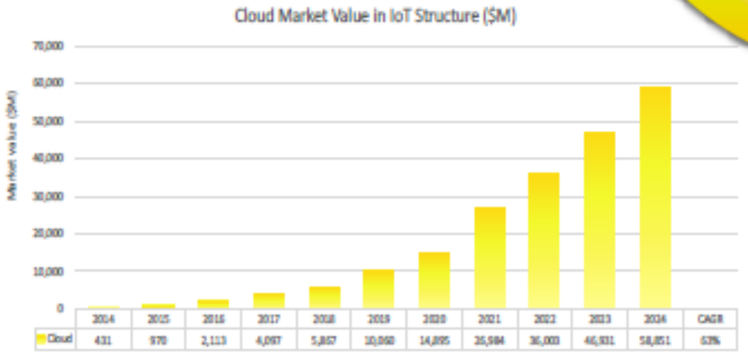
2020, starting year for IoT?



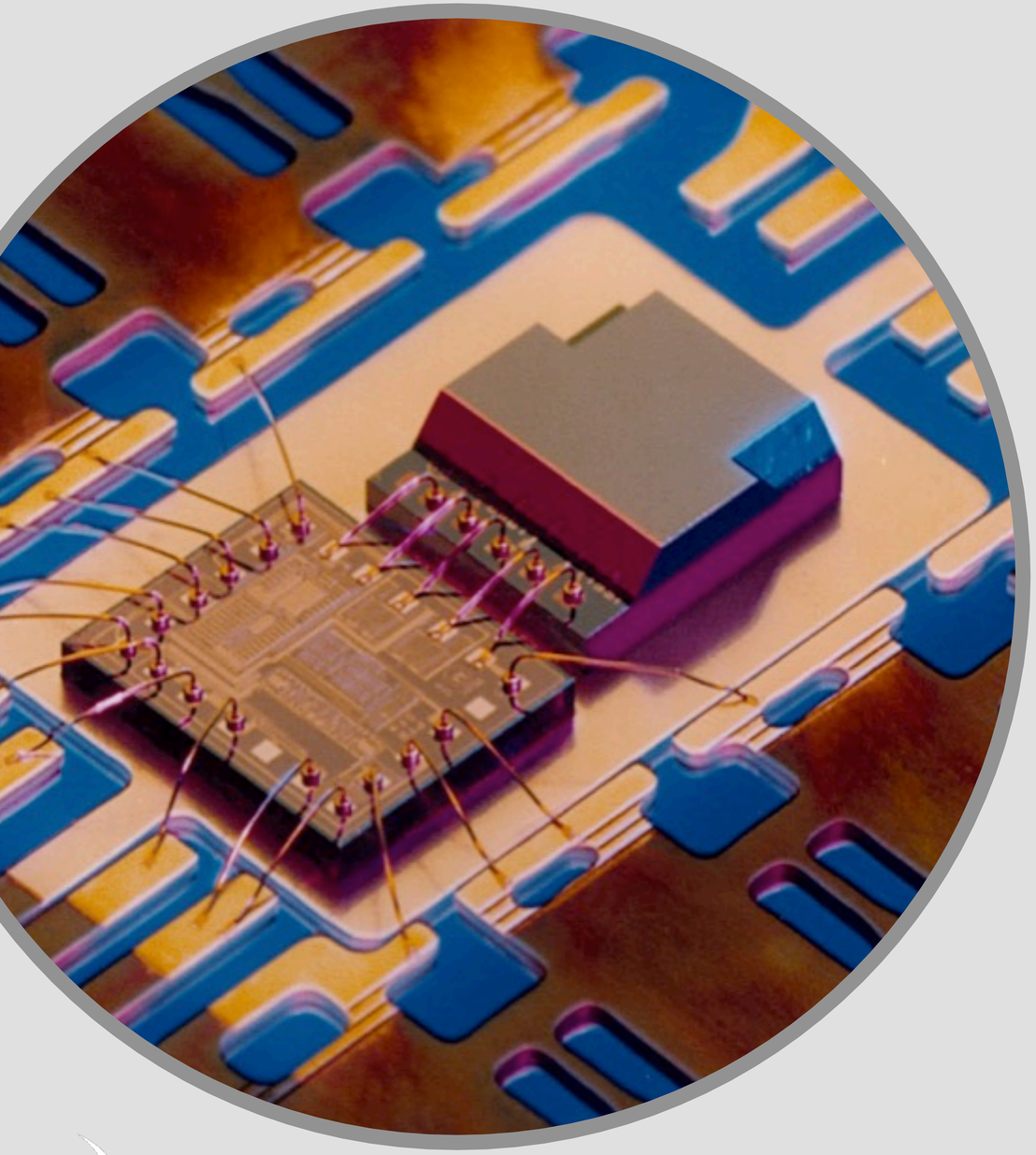


Data Processing

Hardware



Cloud



Roadmaps for IoT

TECHNOLOGIES OF IOT

Map of an IoT wireless sensor

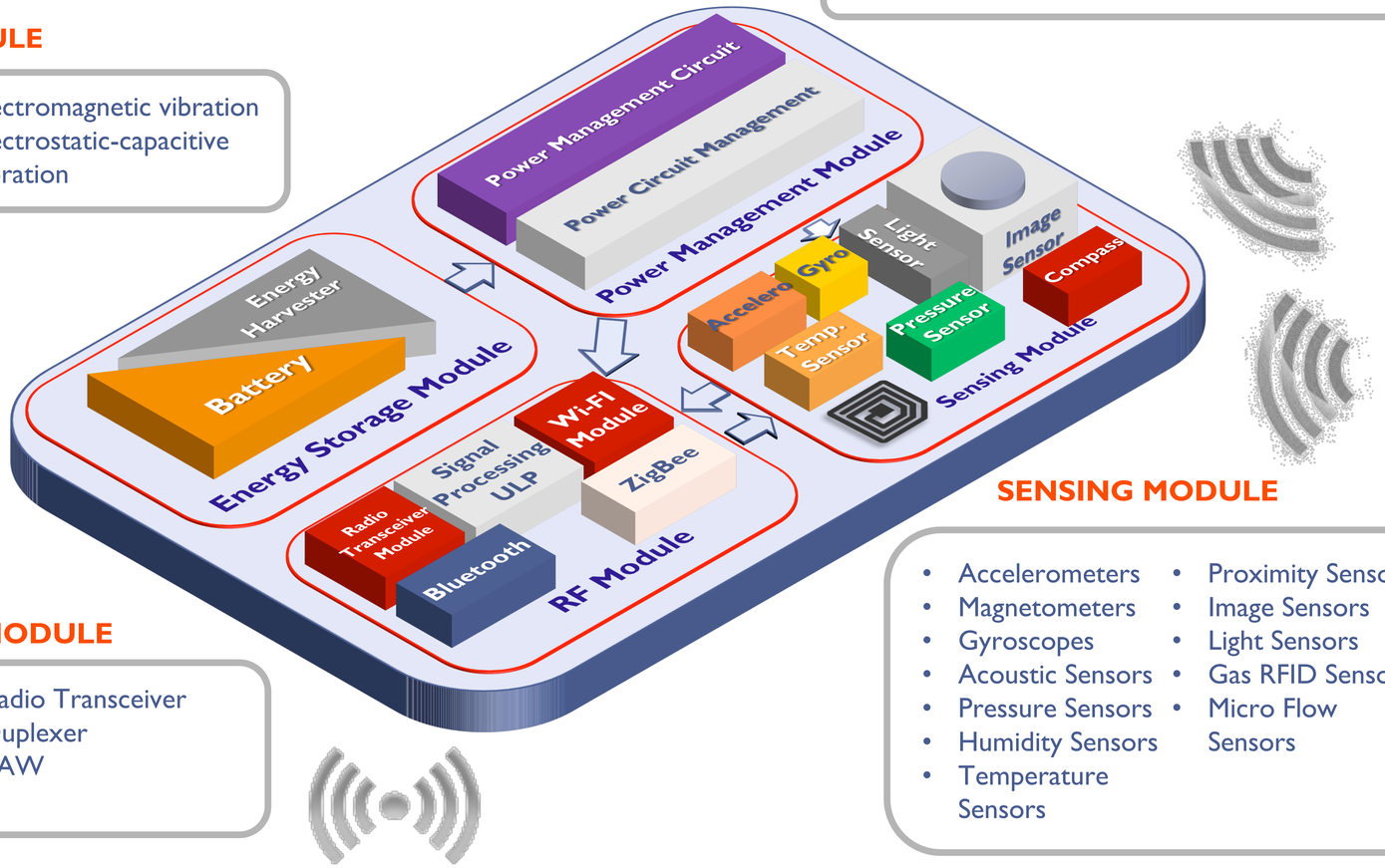
A standard IoT device includes 4 main modules

POWER MANAGEMENT MODULE

- Ultra-capacitors
- Microbatteries
- PMU

ENERGY STORAGE MODULE

- Li-Ion battery
- AA Battery
- Piezoelectric vibration
- Electromagnetic vibration
- Electrostatic-capacitive vibration



RF MODULE

- Signal Processing Unit
- Wifi
- ZigBee
- Bluetooth LE
- Radio Transceiver
- Duplexer
- BAW

SENSING MODULE

- Accelerometers
- Magnetometers
- Gyroscopes
- Acoustic Sensors
- Pressure Sensors
- Humidity Sensors
- Temperature Sensors
- Proximity Sensors
- Image Sensors
- Light Sensors
- Gas RFID Sensors
- Micro Flow Sensors

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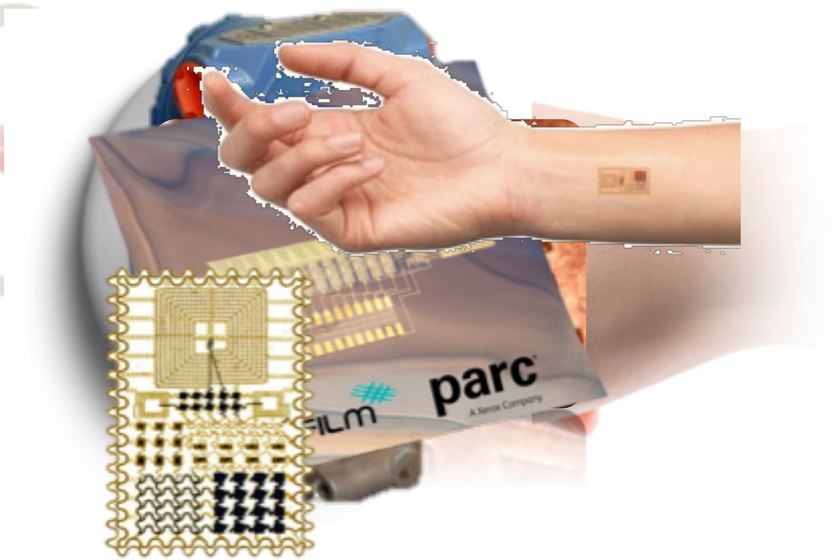
THE INTERNET OF THINGS ROADMAP (1/3)

7 generations of IoT products



GEN 7
Printed Electronics

GEN 5
Polytronics Systems

GEN 6
Sensors' Swarm

GEN 4
Integrated IoT Sensors

GEN 3
Advanced Generation of IoT Sensors

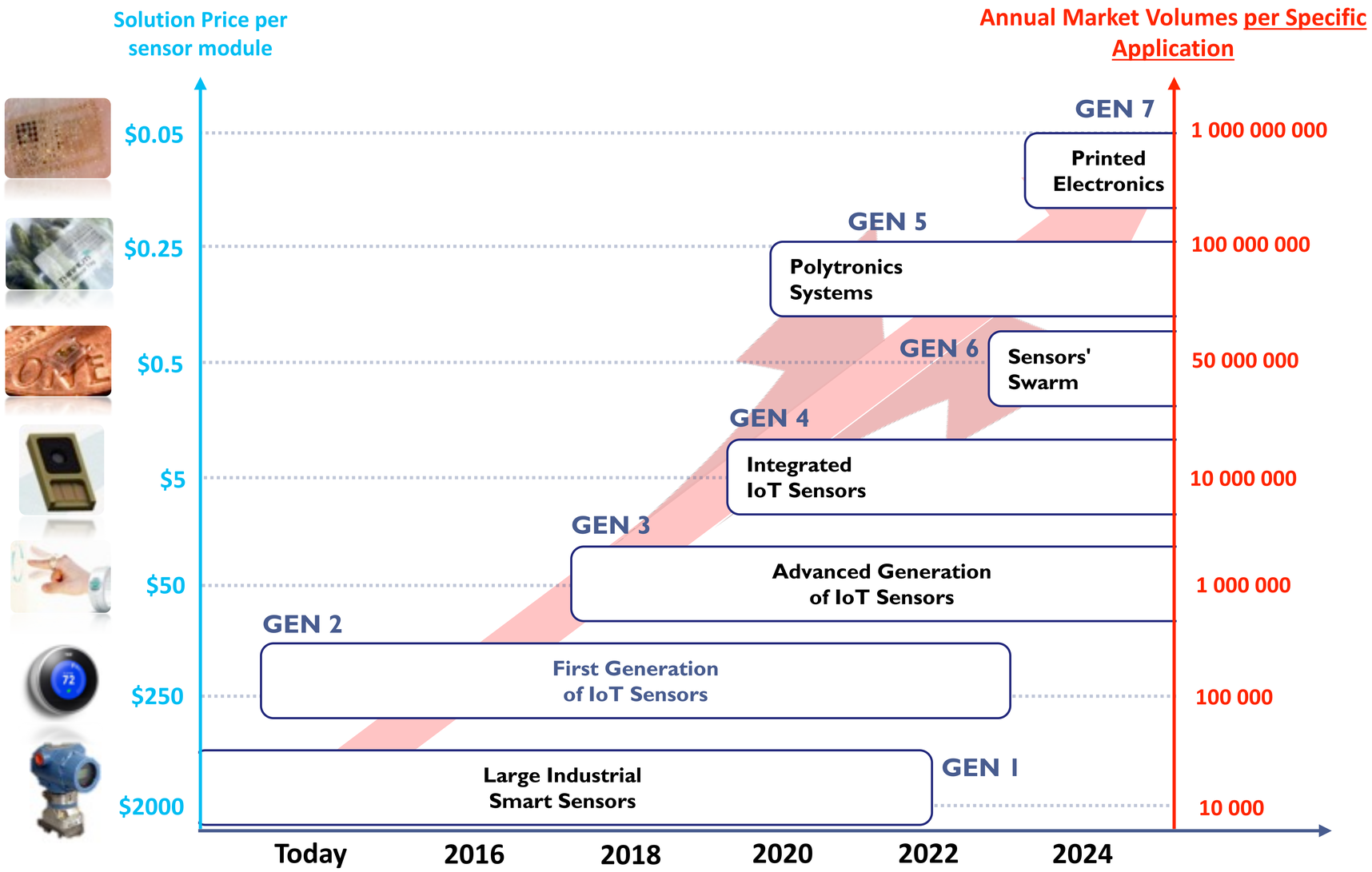
GEN 2
First Generation of IoT Sensors

GEN 1
Large Industrial Smart Sensors

Today 2016 2018 2020 2022 2024

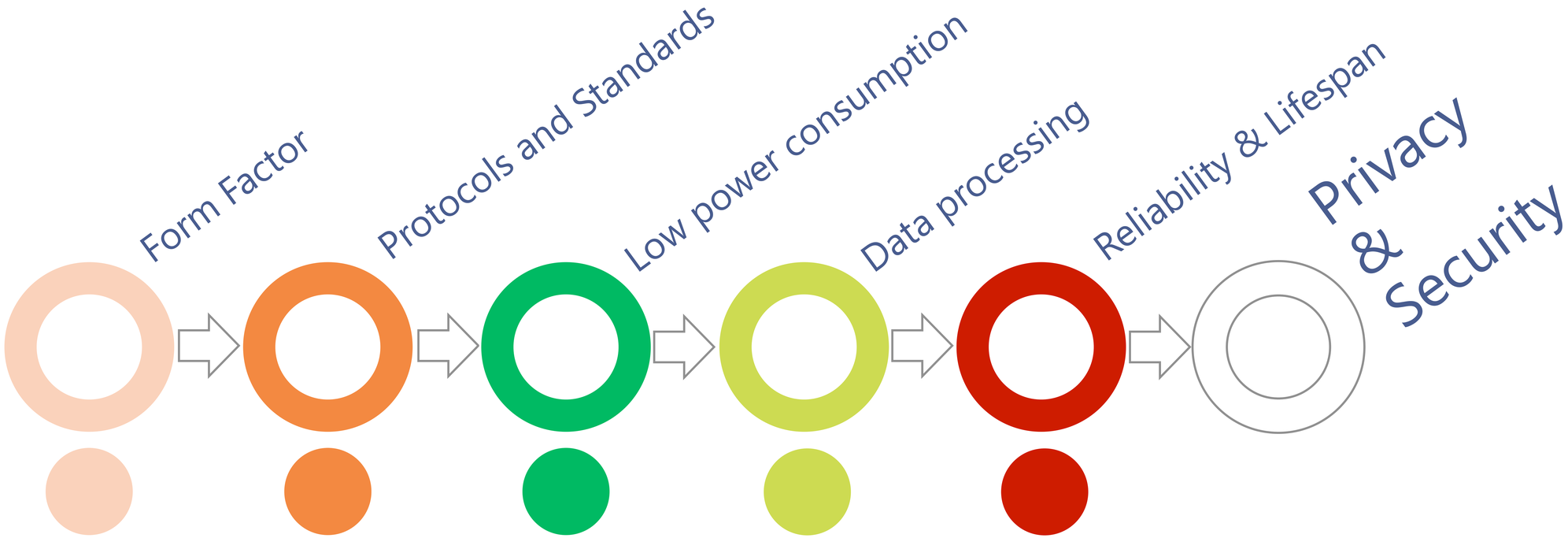
THE INTERNET OF THINGS ROADMAP (2/3)

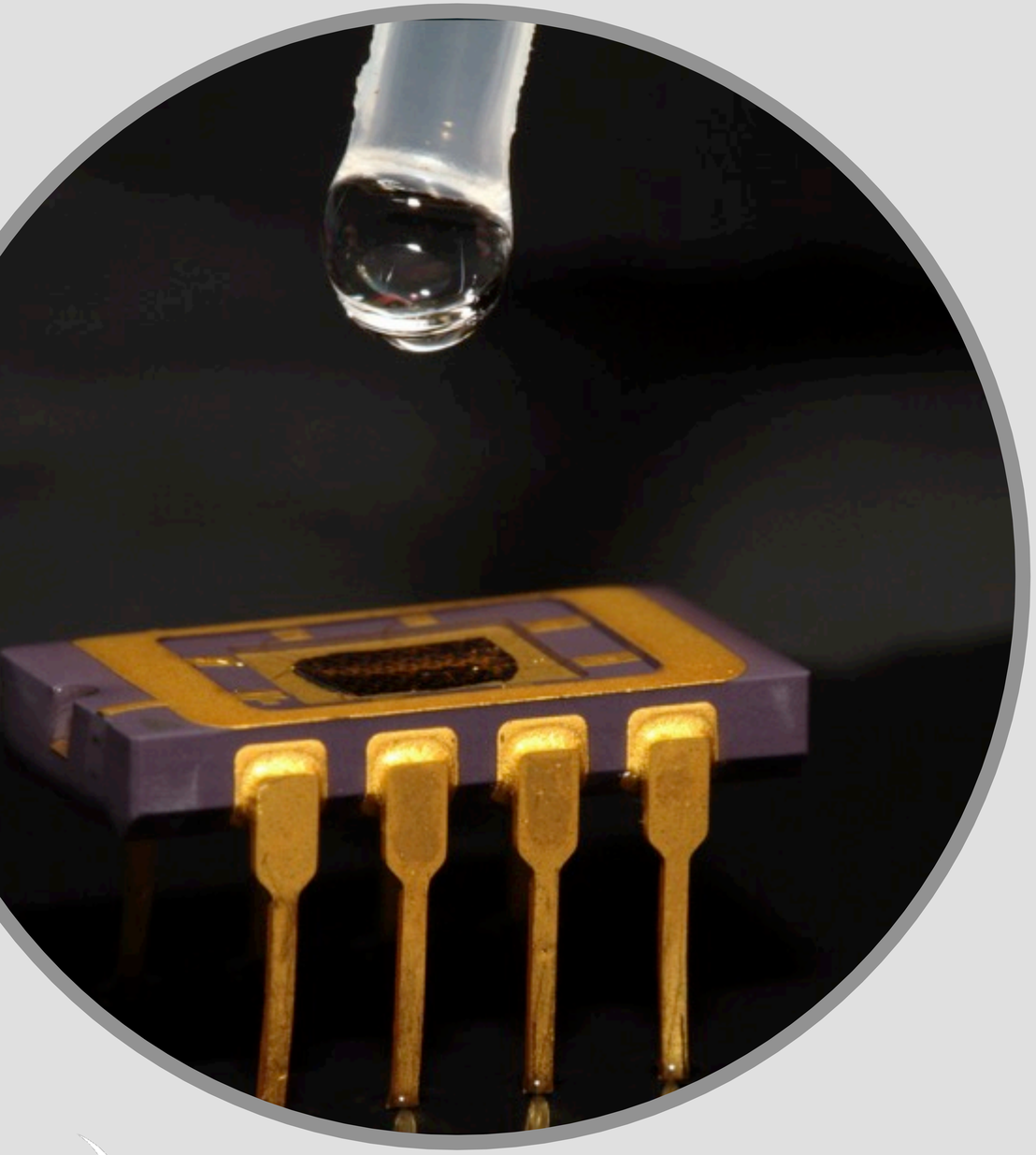
ASP from $2000 to $0.05



CHALLENGES FOR SENSORS

IoT #1 Obstacle:
Privacy and security





Sensors for IoT, growth drivers

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MARKETS AND SENSORS

- **Here are the main applications of IoT devices and sensors associated with.**

Legend:

Sensor

Level of demand

A large landscape of opportunities for IoT

SENSORS OF THE INTERNET OF THINGS

Building Automation

- Light (IR, visible)
- Hall Effect
- Temperature
- Chemical (CO_2)
- Accelero

Healthcare & Life science

- Pressure
- Bio Sensors
- Temperature
- Inertial
- Chemical
- Light (IR, X-Ray

Consumer & Home automation

- Gyroscope
- Temperature
- Accelero
- Chemical
- Magneto
- Pressure
- Microphone

Transportation

- Gyroscope
- Pressure
- Accelero
- Temperature
- Magneto
- Microphone

Industrial

- Pressure
- Hall Effect
- Light (IR,Optical)
- Accelero
- Chemical
- Temperature

Environment

- Chemical
- Humidity
- Temperature
- Light (IR, visible)
- Pressure

Security & Public Safety

- Gyro
- Light (IR,XRay,THz)
- Accelero
- Magneto
- Chemical

Retail & Logistics

- Light (IR/Optical)
- Magneto
- Pressure
- Temperature
- Chemical

SENSORS FOR IOT

4+1
type of
sensors
for IoT

4 types of sensors[1] are expected to grow a lot:

- Inertial sensors (Accelerometer/Gyroscope/Magnetometer/IMUs)
- Environmental sensors (Gas, Chemical, Pressure, Temperature, Humidity)
- Optical sensors (CMOS, IR)
- Microphone (MEMS Microphone, Piezo Microphone)

[1]RF MEMS sensors are also a huge opportunity in IoT market (Each device has to be connected,)

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INERTIAL SENSORS (ACCELEROMETER, GYROSCOPE, MAGNETOMETER, IMUS)

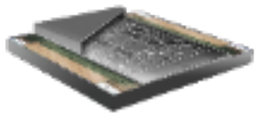
Growth for Inertial:

Consumer & Automotive

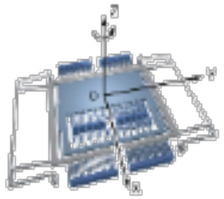
Market Description:
- Single accelerometers (1to3 axis) for consumer, medical, automotive, industrial, aeronautics & defense applications
- Gyros for consumer, medical, automotive, industrial, aeronautics & defense applications
- Magnetometers for consumer & automotive applications
- 6 to 10 DOF MEMS IMUs for consumer & automotive applications

Main MEMS devices Manufacturers:
Bosch, STM, InvenSense, Freescale, MEMSiC, Aichi, AKM, Alps

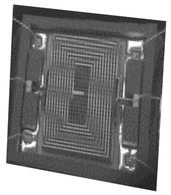
Main Trends:
- Single accelerometers for consumer: market will keep grow despite the large adoption of IMUs. Wearable and IoT are good opportunities to spread a large amount of discrete devices.
- Single Magnetometers for Consumer: more and more devices will require positioning system and magnetometer are required for such purpose for indoor navigation for instance.
- Consumer 9/10 DOF IMUS: Growth of 9/10 Axis IMUS will be driven by wearable.



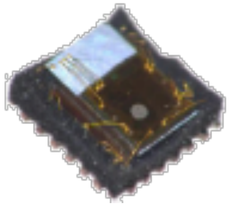
Accelerometer



Gyroscope



Magnetometer



Inertial Combos

Smartphone and Wearable

Automotive

ENVIRONMENTAL SENSORS (GAS, CHEMICAL, HUMIDITY, PRESSURE, TEMPERATURE)

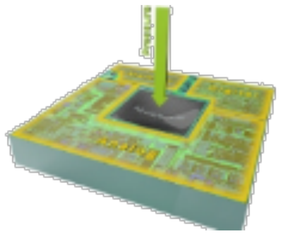
Growth for environmental:

Industry
Automotive
Building

Market Description:
- Gas sensor for industry and consumer, humidity and temperature sensor for consumer and medical
- Pressure sensors for automotive and consumer

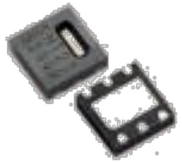
Main MEMS devices Manufacturers:
Sensirion, Bosch, Denso, Amphenol, Freescale, CCMOS, APIX, KWJ…

Main Trends:
- 6 segments for Gas sensors: consumer, HVAC, transport, medical, defense & industry, environment
- MEMS chemical sensors will become a major change with the adoption of chemical gas sensors in wearable & smart phones.
- Pressure sensors present a huge growth in consumer market (3D positioning)



Pressure sensors

Gas sensors



Humidity sensors

Thermopile sensors

Industry

Automotive

Building Automation

IMAGING SENSORS (CMOS, IR, MULTI-SPECTRAL)

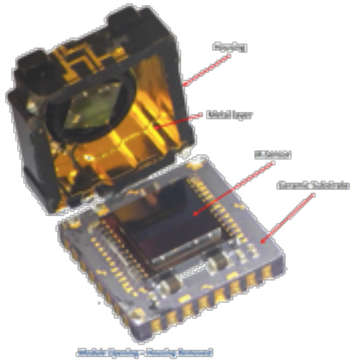
Growth for Imaging:

Drones
Automotive
Building

Market Description:
- MEMS microbolometers for auto, industrial, defense & consumer applications
- Non microbolometer imager technologies
- Pyro electric and thermopiles for temperature sensing and detection

Main MEMS devices Manufacturers:
FLIR, Raytheon, Robert Bosch, ULIS, …

Main Trends:
- Microbolometers were the dominant uncooled thermal imaging technology until 2012, thanks to their good cost/performance ratio. Microbolometers medium resolution (320 x 240 pixels) is currently the most widespread because of its favorable resolution/cost ratio, and will remain the dominant resolution due to its wide usage in the Automotive and Surveillance markets.
- Thermal sensor market is concentrated among 13 players, largest one are FLIR and Ulis.



Drones

Automotive

Building Automation

MICROPHONES (MEMS, PIEZO-MEMS)

Growth for Microphone:

Consumer
Automotive

Market Description:
- MEMS-based microphones for consumer, medical & automotive applications

Main MEMS devices Manufacturers:
Knowles, AAC, Goertek, STM, Infineon (dies foundry), Gettop, Bosch, InvenSense …

Main Trends:
- High adoption of MEMS microphones in all consumer applications, especially for smartphone and tablets with trends of integrating several microphones in one device to improve the performance
- Medical, automotive and other markets are still in their infancy
- Big effort of manufacturers to make microphones smaller and more robust

Microphone

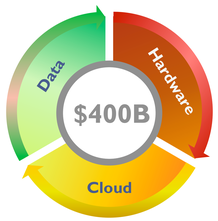
Smartphone and Wearable

Automotive

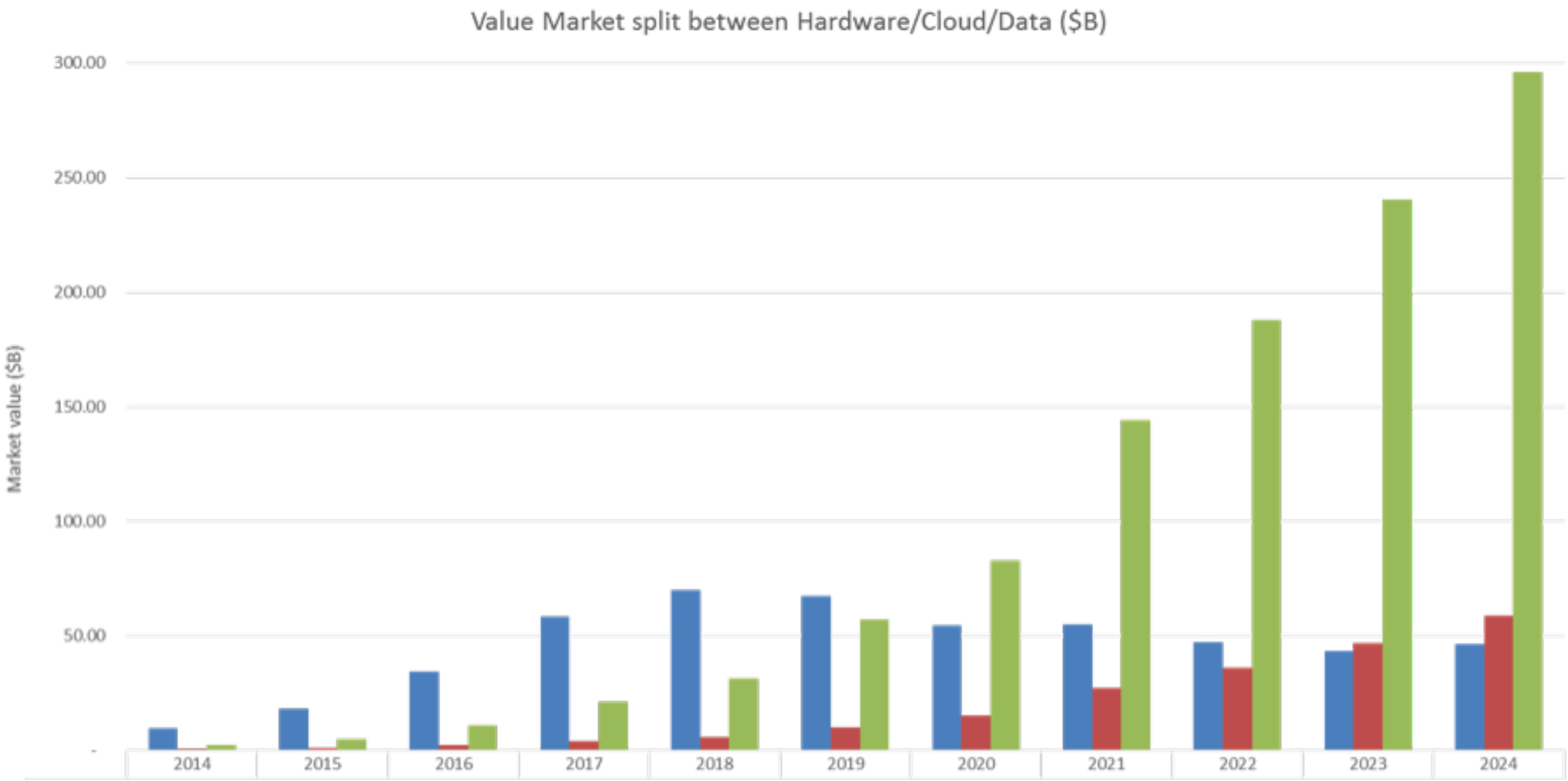
Forecast

FORECAST FOR TECHNOLOGIES OF IOT

Market Structure Value



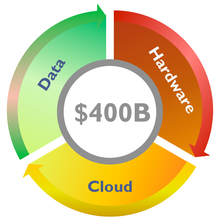
Market value from data processing could be almost x3 bigger than cloud and hardware values combined.



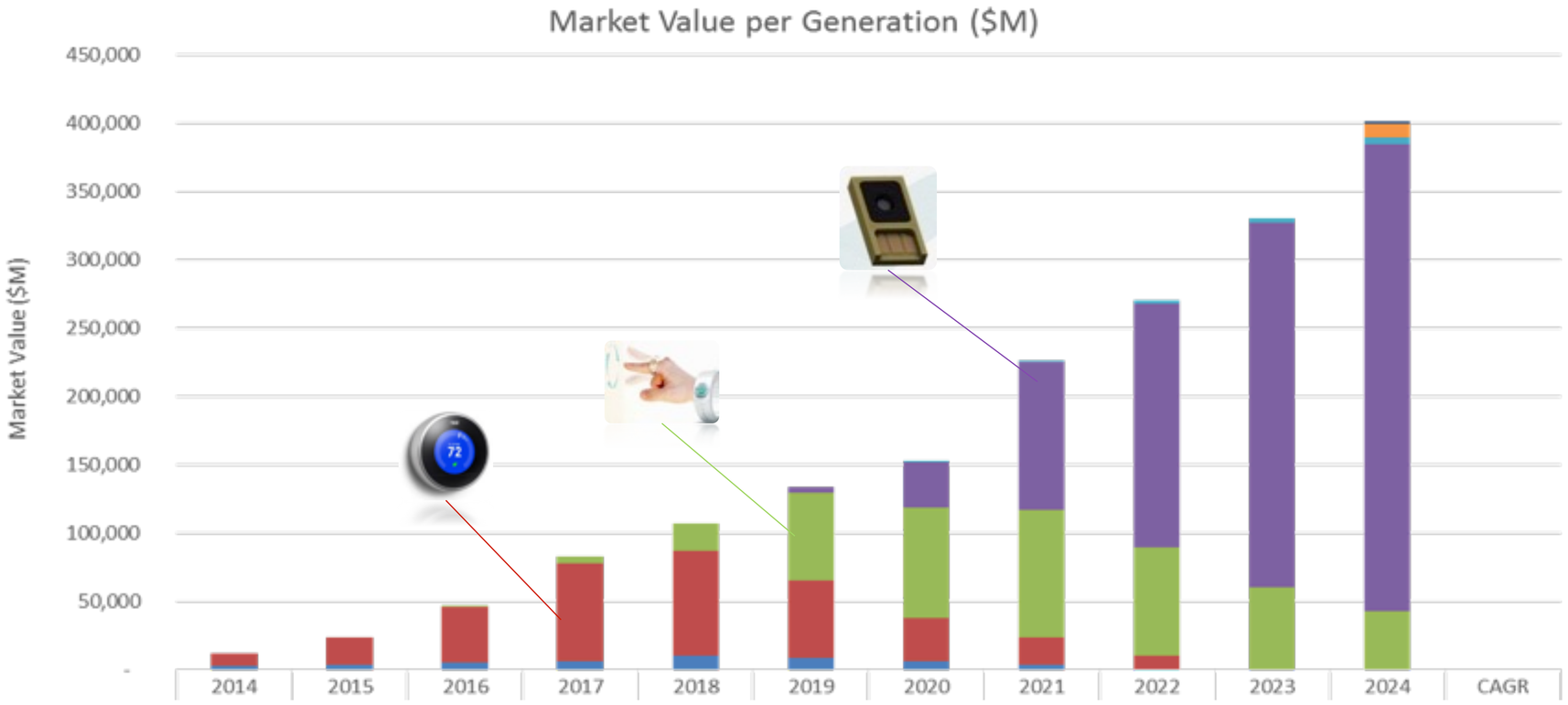
- In 2024, total market value from IoT should reach $400B with a global CAGR rate of 42%.

SUMMARY OF TECHNOLOGIES OF IOT

Forecast: Market Structure Value



Integrated IoT sensors will drive the market from 2020



Conclusion

SENSORS FOR IOT

4 type of sensors
3 markets

- 4 types of sensors are expected to grow in huge quantities

- Inertial
- Environmental
- Microphone
- Imaging

- 3 main markets will drive IoT in the next 5 to 10 years

Wearable

Automotive

Building Automation

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WHO WILL WIN THE IOT CHALLENGE?

Who is the best positioned?

Google and Apple, winners?

Clearly data will bring the main value in the IoT market, nevertheless, in order to extract data from our devices, we need software.

Software developments should be tailored for precise end-applications and the technology has to be adapted to the user

Therefore, developers are becoming the new kingmakers

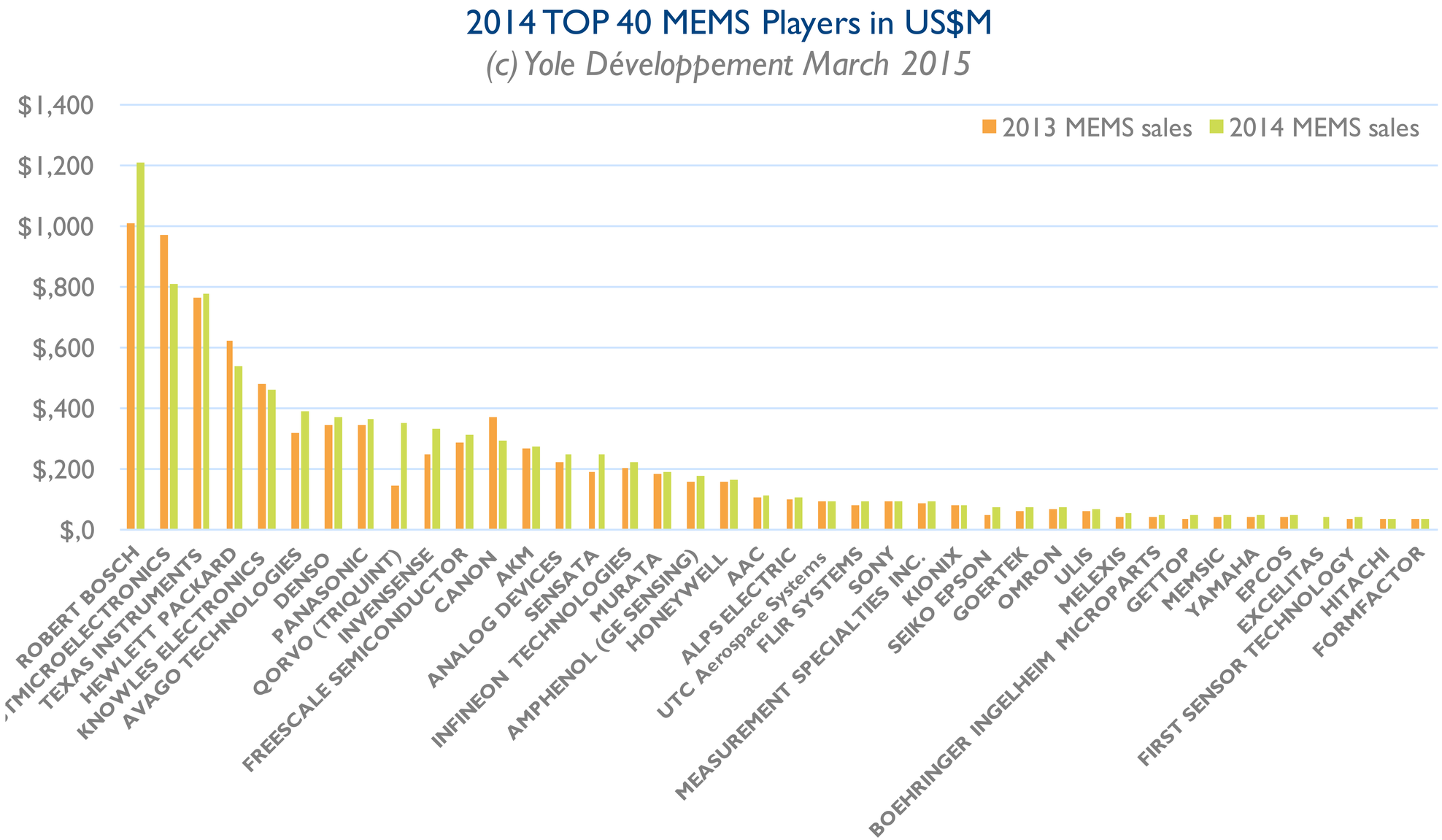
The company with the most developers wins. Google and Apple have amassed the most Internet of Things developers, that could position them to dominate the market for years.

But sensor manufacturing will still depend on few giants…

TOP40 RANKING

$400M difference between first & second.

This ranking shows a clear emerging of what could be a future "MEMS Titan": Robert Bosch.



INDUSTRIES EVOLVE THROUGH FOUR STAGES …

MEMS are today at the early Focus Stage (adapted from HBR 2002/Toshiba 2008)

An industry moves through 4 stages in ~25 years

Opening Stage

- Generally begins with single player
- Top 3 holds 10-30% market share

Scale Stage

- About building scale thru consolidation
- Top 3 holds 15-45% market share

Focus Stage

- Key players expand
- About 5-12 players
- Top 3 holds 35-70% share

The MEMS Industry today!

Who will be tomorrow's MEMS titans?

Balance & Alliance

- Titans emerge
- Top 3 typically hold 70-90% market share

Will IoT be the driver for the last two stages ?

YOLE'S REPORTS

Information in this presentation is extracted from the following reports

Fore more information, go to

www.i-micronews.com

- Sensors and Technologies for the Internet of Things

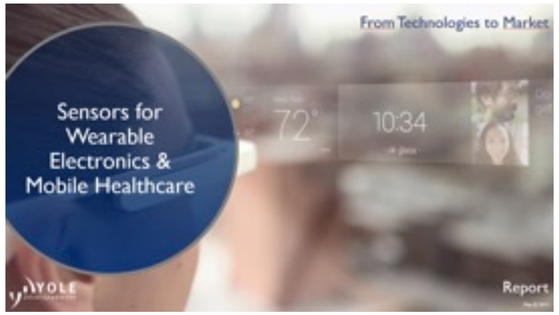
  Released in June 2014

- Status of the MEMS Industry 2015

  Available in May 2015

- Sensors for Wearable Electronics & Mobile Healthcare

  Available in June 2015



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Thank you

If you want the full presentation, please don't hesitate to give me your business card at the end of the session
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From Technologies to Market

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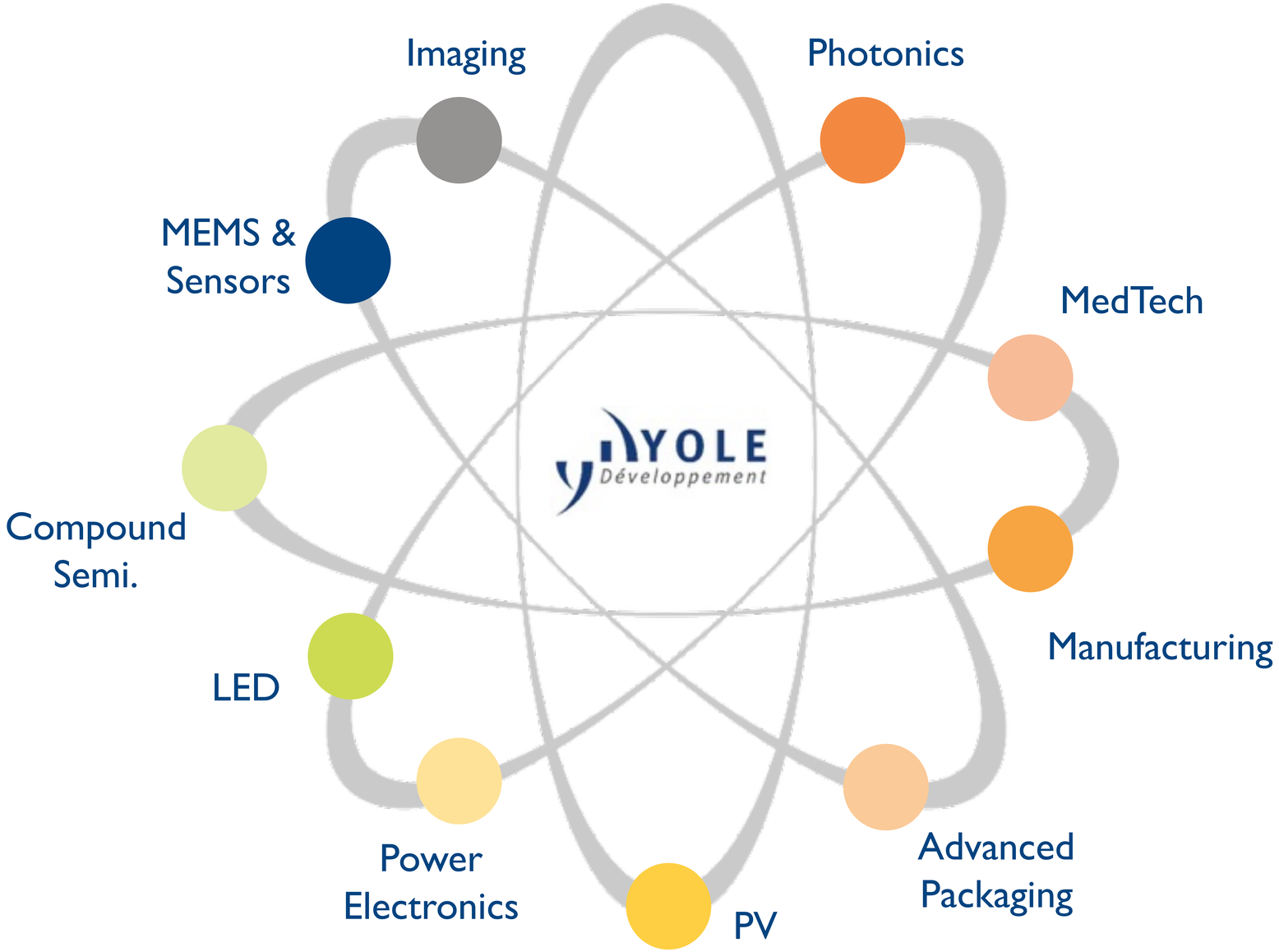
FIELDS OF EXPERTISE

Yole Développement's 30 analysts operate in the following areas



4 BUSINESS MODELS

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- Market data & research, marketing analysis
- Technology analysis
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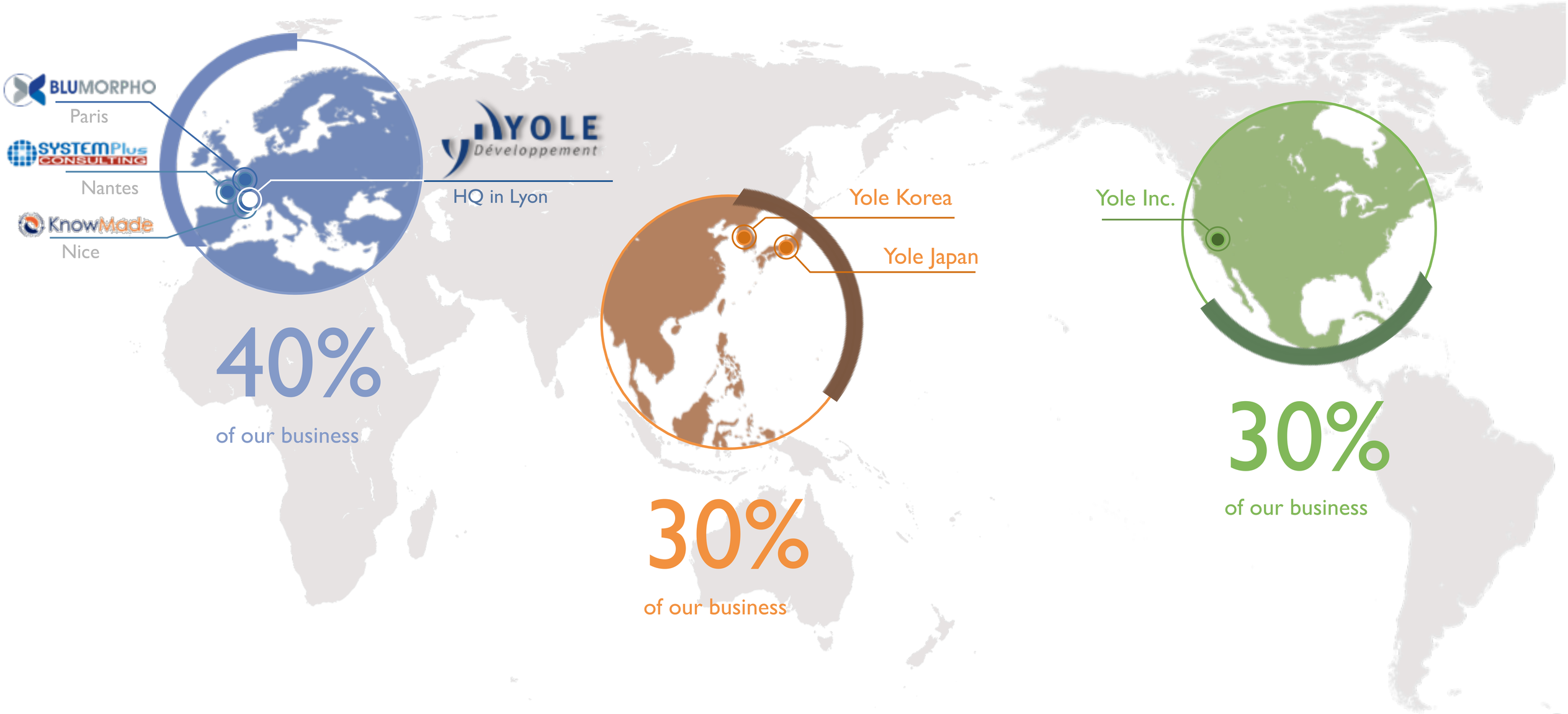
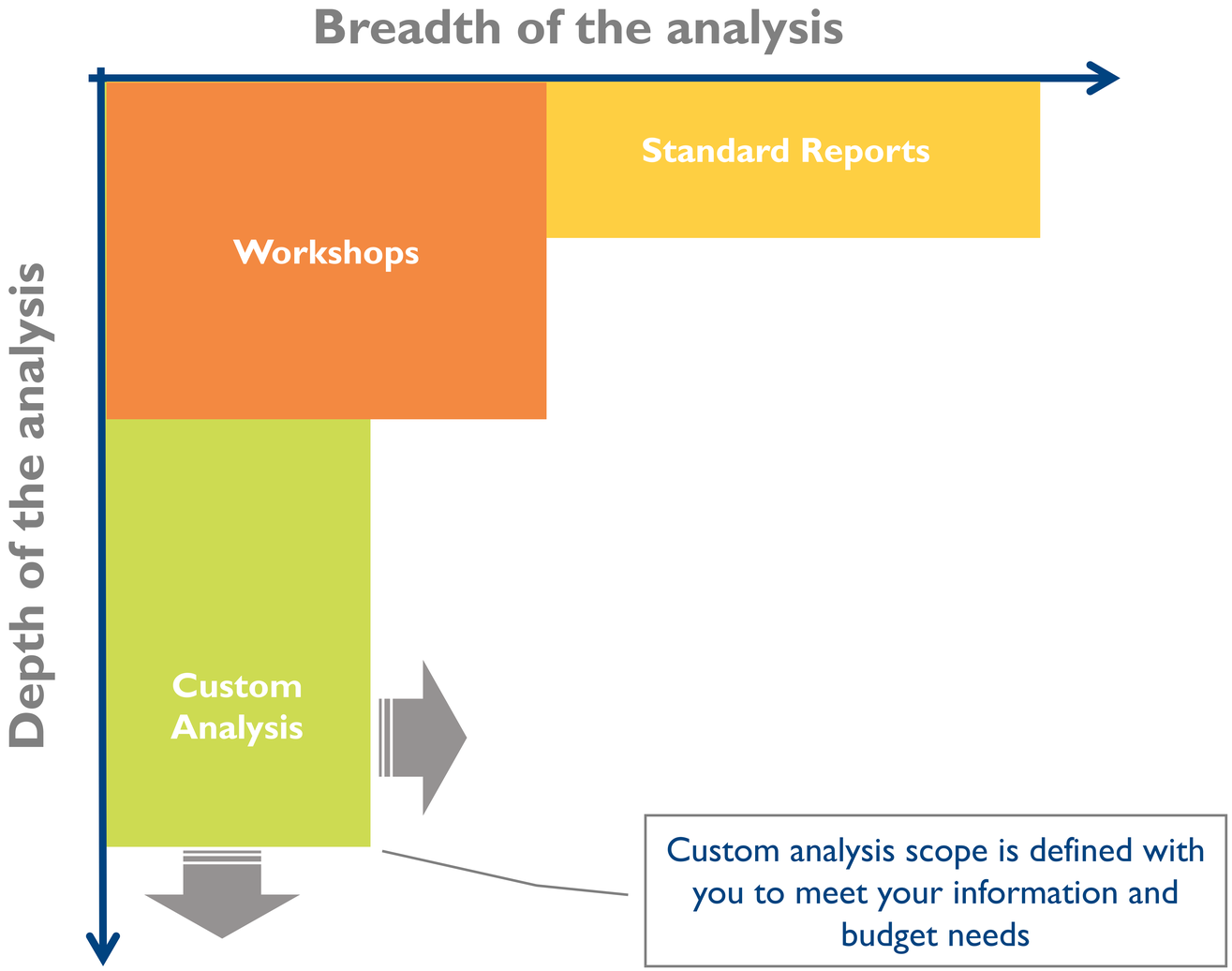
OUR GLOBAL ACTIVITY



RESEARCH PRODUCTS - CONTENT COMPARISON



SERVING THE ENTIRE SUPPLY CHAIN

Our analysts provide market analysis, technology evaluation, and business plan along the entire supply chain

Integrators and end-users

Panasonic, CSR, SONY, Canon, TOYOTA, MITSUBISHI, hp, HUAWEI, VW, GE, IBM

Device makers

BOSCH, infineon, ROHM SEMICONDUCTOR, SAMSUNG, LG, TEXAS INSTRUMENTS, intel, OSRAM

Suppliers: material, equipment, OSAT, foundries…

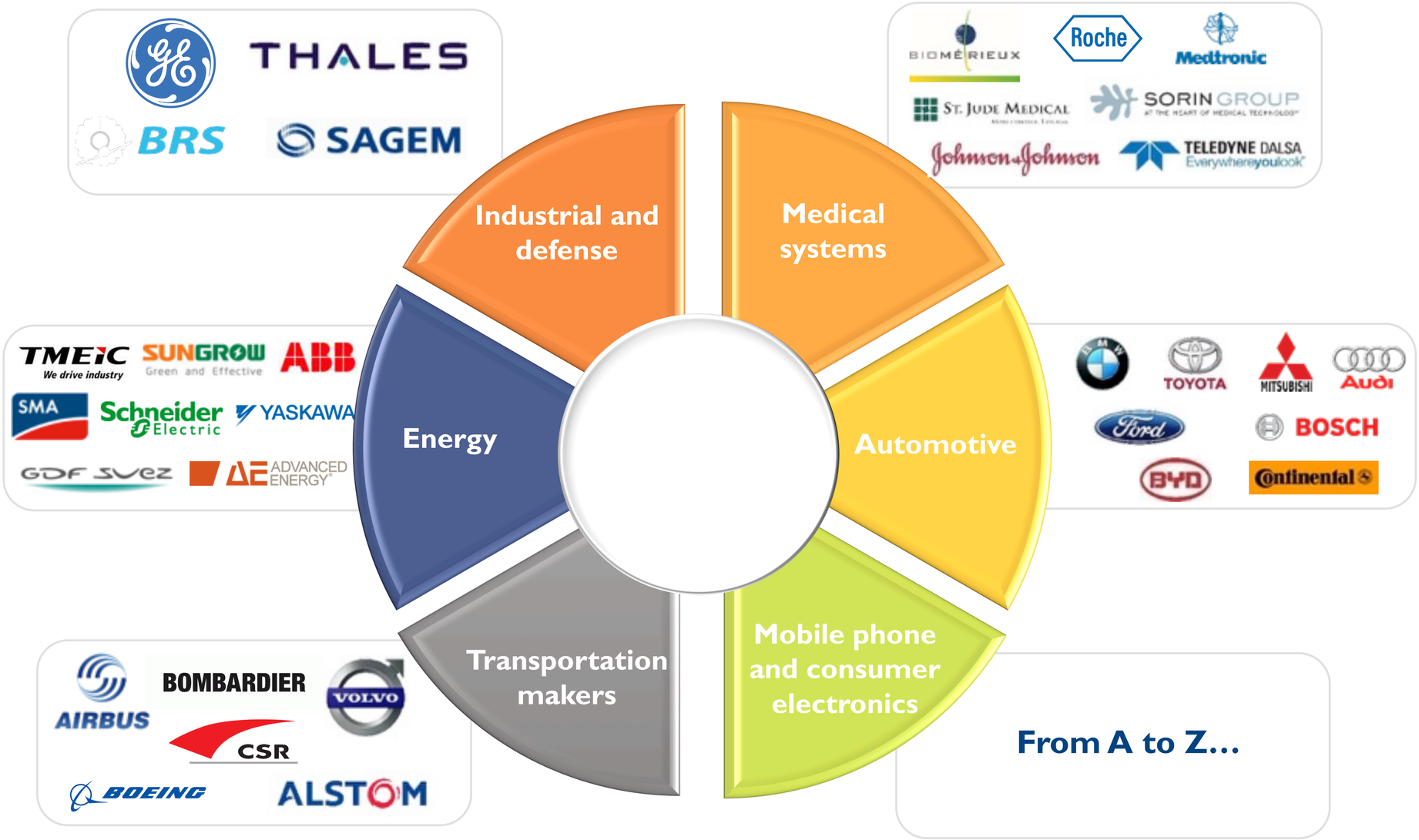
SMIC, SÜSS MicroTec, DOW CORNING, UMC, tsmc, Amkor Technology, EVG, ASE GROUP

Financial investors, R&D centers

ITRI, Fraunhofer, Berkeley, STANFORD UNIVERSITY, TPG

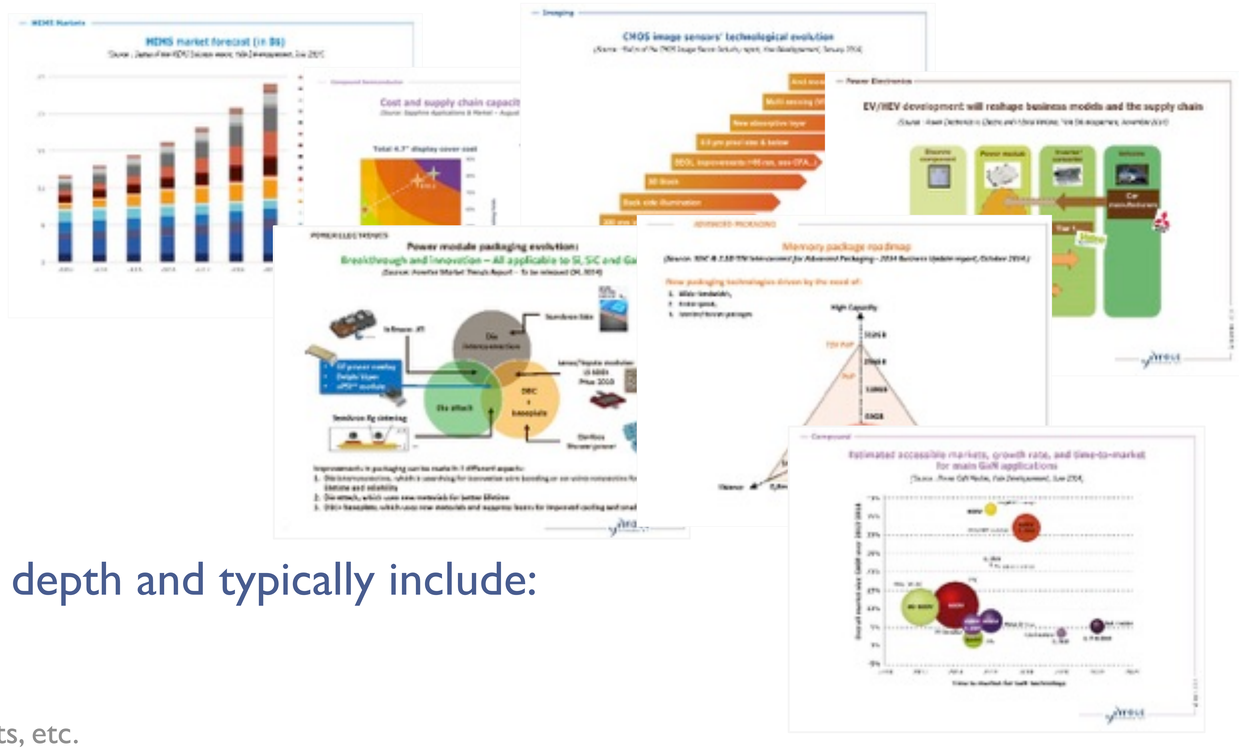
SERVING MULTIPLE INDUSTRIAL FIELDS

We are working across multiples industries to understand the impact of More-than-Moore technologies from device to system



REPORTS COLLECTION

- Yole Développement publishes a comprehensive collection of market & technology reports and patent analysis in:
  - MEMS & Sensors
  - Imaging
  - Medical technologies (MedTech)
  - Advanced packaging
  - Power electronics
  - Compound semiconductors
  - OLED, LED & Laser diode
  - Semiconductor Manufacturing
  - Photovoltaics
  - Batteries



- Our reports are unmatched in quality and technology depth and typically include:
  - Technology trends and evolution: costs, barriers, roadmaps, etc.
  - Supply & value chain analysis: business models, relationships, value flows, etc.
  - In-depth analysis of applications and market drivers: challenges, inflection points, etc.
  - Market data ($, units, wafer starts, etc.)

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OUR 2015 MARKET & TECHNOLOGY REPORTS PLANNING

- **MEMS & SENSORS**
  - Sensors and Data Management for Autonomous Vehicles
  - AlN Thin Film Markets And Applications
  - Sensors for Wearable Electronics And Mobile Healthcare
  - Status of the MEMS Industry
  - Uncooled IR Imagers
  - IR Detectors
  - High End Gyro, Accelerometers and IMU
  - Non-Volatile Memory
  - MEMS for RF filters and Antena Switches - BAW / SAW

- **IMAGING & OPTOELECTRONICS**
  - Camera Module Packaging (Vol 1 : Market & Technology Trends / Vol 2 Teardowns & Reverse Engineering)
  - Uncooled IR Imagers
  - Wafer Level Optics
  - Status of the CMOS Image Sensors
  - Machine Vision

- **MEDTECH**
  - Microfluidic for Sample Preparation
  - Microfluidic Applications
  - Sensors for Wearable Electronics And Mobile Healthcare

- **COMPOUND SEMICONDUCTORS**
  - High Purity Alumina (HPA)
  - Sapphire
  - Wide Bandgap Materials For Power Electronics: SiC, GaN (and also Ga2O3, AlN, Diamond, Graphene… as a trend)

- *Reports to be decided within 2015*

- **LED**
  - LED Module
  - OLED for Lighting
  - UV LED
  - LED Phosphors Market

- **POWER ELECTRONICS**
  - Power Packaging
  - Thermal Management for LED and Power
  - Power Electronics for Renewable Energy
  - Energy Management For Smart Grid And Smart Cities
  - Status of Chinese Power Electronics Industry
  - New Technologies For Data Center
  - Inverter Market Trends For 2013 – 2020 And Major Technology Changes*
  - IGBT Markets And Application Trends
  - Power Electronics for HEV/EV*
  - Status of Power Electronics Industry

- **ADVANCED PACKAGING**
  - Advanced Packaging in Emerging Markets in China
  - Status of the Advanced Packaging Industry
  - Supply Chain Readiness for Panel Manufacturing in Packaging
  - WLCSP*
  - Flip Chip Business Update
  - 2.5D & 3DIC Business Update
  - Fan-Out and Embedded Business Update

- **MANUFACTURING**
  - Lithography for MEMS, Advanced Packaging and LED
  - Thinning & Dicing Equipment for Advanced Packaging, MEMS, Photovoltaics, LED, CMOS Image Sensors
  - Non-Volatile Memory

OUR 2015 REPORTS PLANNING

PATENT ANALYSIS by KnowMade

- **Patent Infringement (crossed analysis based on KnowMade and System Plus Consulting analysis expertise)**
  - MEMS Microphone Applications
  - Infrared Imaging

- **Patent Investigation (crossed analysis based on KnowMade & Yole Développement expertise)**
  - Power GaN
  - MEMS Gyroscope
  - 6-axis & 9-axis Inertial MEMS IMUs
  - Microbatteries
  - Embedded Active & Passive Packages
  - Interposer
  - Phosphors for LED

TEARDOWN & REVERSE COSTING by System Plus Consulting

More than 30 teardowns and reverse costing analysis and cost simulation tools to be published in 2015.

OUR 2014 PUBLISHED REPORTS LIST

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  - Technologies & Sensors for the Internet of Things: Businesses & Market Trends 2014-2024
  - MEMS Microphone: Market, Applications and Business Trends 2014
  - Status of the MEMS industry
  - MEMS & Sensors for Mobile Phones and Tablets
  - High End Gyroscopes and Accelerometer Applications
  - Inertial MEMS Manufacturing Technical Trends
  - New Detection Principles & Technical Evolution for MEMS & NEMS
  - 6/9 DOF Applications in Consumer Electronics
- **IMAGING & OPTOELECTRONICS**
  - Status of the CMOS Image Sensor Industry
  - Uncooled Infrared Imaging Technology & Market Trends
  - Silicon Photonics
- **MEDTECH**
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  - Solid State Medical Imaging: X-ray and Endoscopy
- **COMPOUND SEMICONDUCTORS**
  - RF GaN Technology & Market Analysis: Applications, Players, Devices & Substrates 2010-2020
  - SiC Modules, Devices and Substrates for Power Electronics Market
  - GaN-on-Si Substrate Technology and Market for LED and Power Electronics
  - Power GaN Market
  - Graphene Materials for Opto & Electronic Applications
  - Sapphire Applications and Market: from LED to Consumer Electronics
- **LED**
  - LED Packaging
  - LED Front-End Manufacturing Trends
  - LED Front-End Equipment Market
- **POWER ELECTRONICS**
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  - 3DIC & 2.5D TSV Interconnect for Advanced Packaging - 2014 Business Update
- **MANUFACTURING**
  - Market & Technology Trends in Materials & Equipment for Printed & Flexible Electronics
  - Permanent Wafer Bonding for Semiconductor: Application Trends & Technology

PATENT ANALYSIS by Knowmade

- LED Based on Nano-wires Patent Investigation
- GaN on Si Patent Investigation (LED, Power devices and RF Devices)
- New MEMS Devices Patent Investigation
- Non Volatile Memory Patent Investigation

TEARDOWN & REVERSE COSTING by System Plus Consulting

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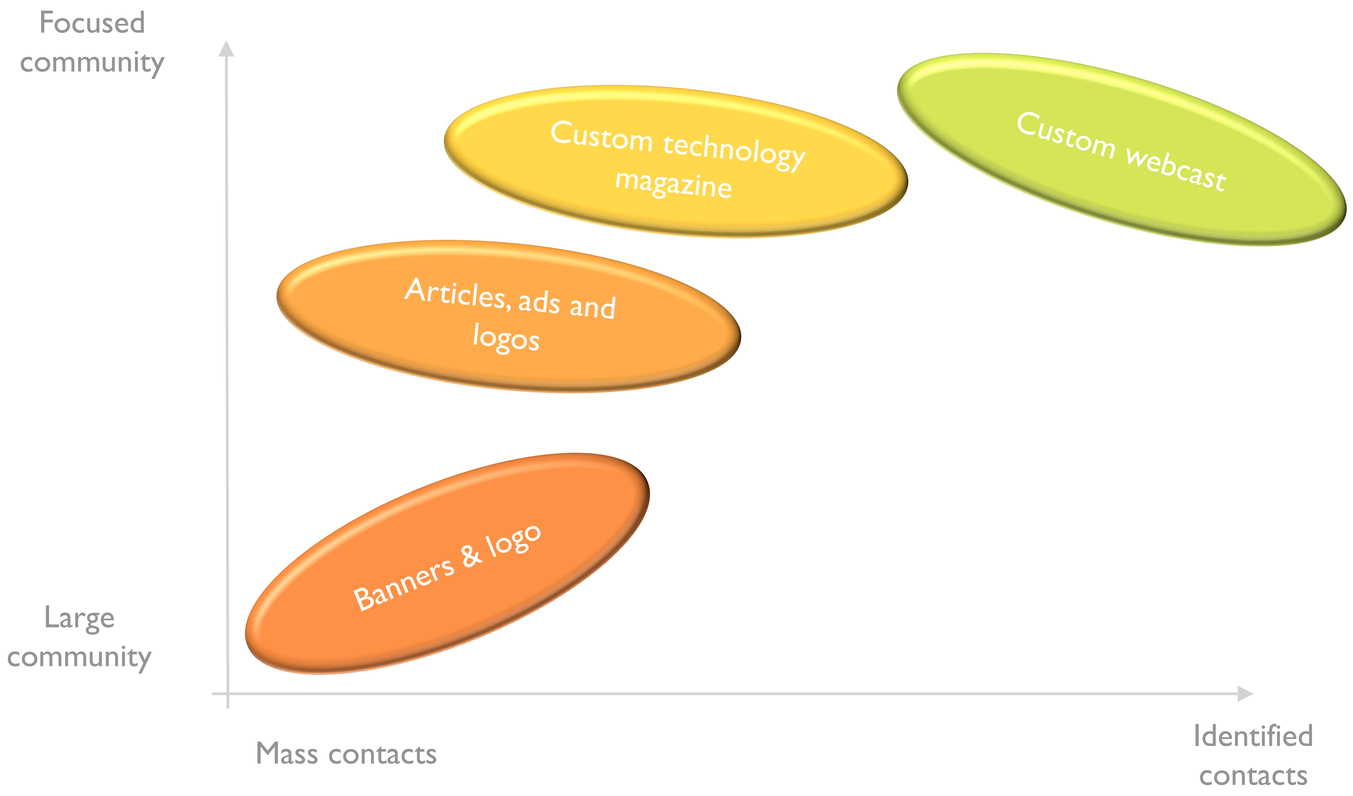

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