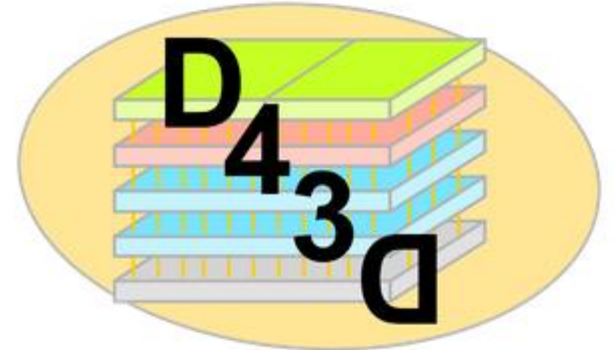
From Technologies to Market

# Evolution and adoption of 3D TSV and 2.5D technology : From high performance to consumers applications




27/06/17

Emilie Jolivet

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Picture source: http://www.nexdatacenter.com

# OUTLINE

## *From consumers to high-performance applications*

Introduction

❖ Consumers applications

- Imaging

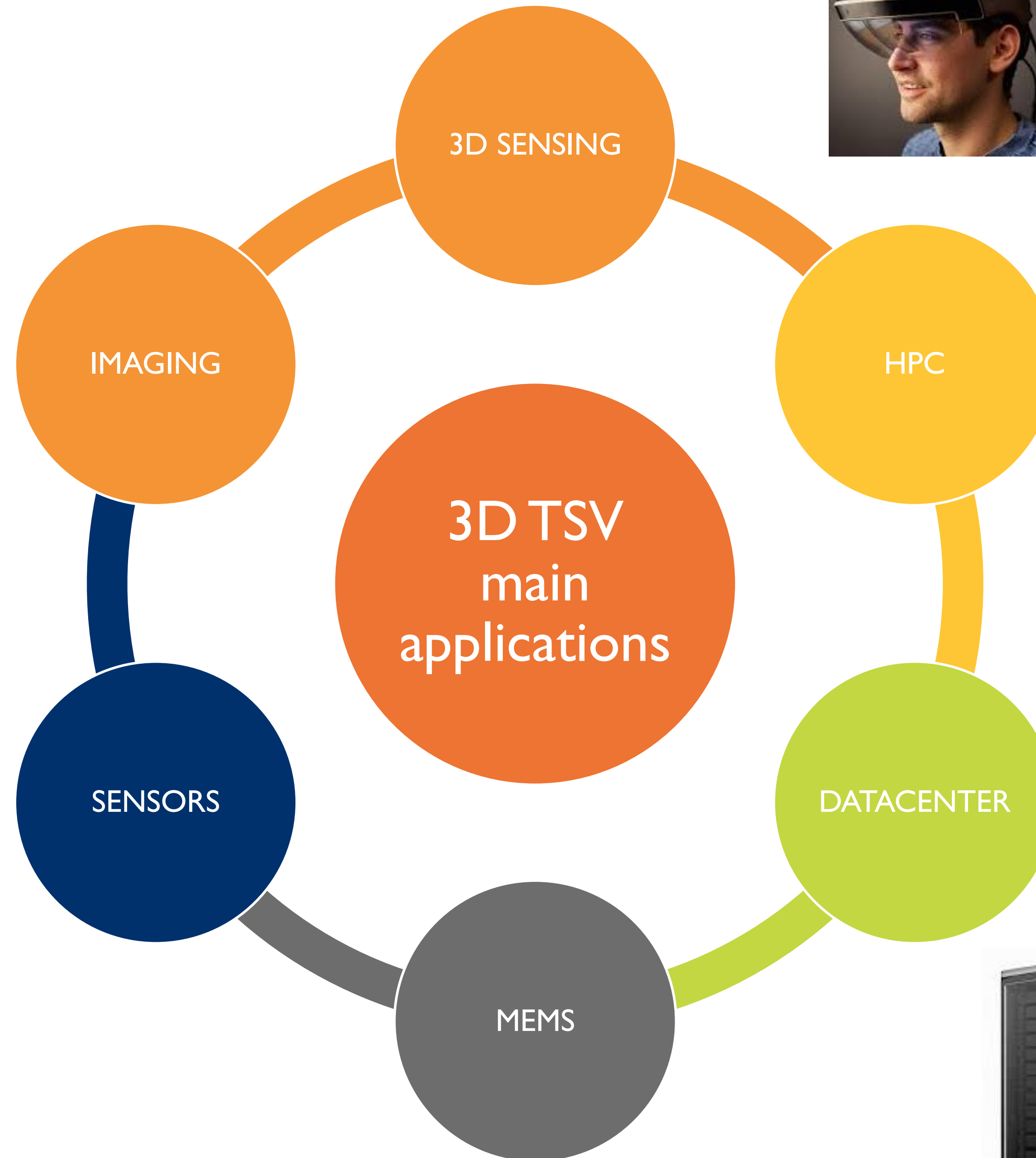
❖ High performance applications

- *Commercial products*
- *Artificial intelligence: Focus on deep learning*

Conclusions and what is coming next ?

# WHERE 3D INTERCONNECTIONS GROWTH IS COMING FROM ?

3D interconnecti-ons enables present and future performance applications



# TSV IMPLEMENTATION ROADMAP

TSV has been adopted in the MEMS/Sensor application since 2007!

**2007–2010**

*Early adoption Via last*

- *CIS*
- *MEMS*
- *RF filter*

*Demonstration of via-middle: DRAM*

**2011–2014**

*Volume production (Via last)*

*- CIS, MEMS/sensor, RF filters*

*Development / sampling via middle*

- *- DRAM stacks*
- *-Logic + Memory*

*LVM of 2.5D (Si interposer)*

**2015–2020**

*Production of via middle*

*-DRAM stacks*

*- Logic + memory integration*

*HVM of 2.5D (Si interposer)*

*LVM of HBLEDs*

# TSV IC device

TSV enables heterogeneous integration at both high & low ends

## Low end

- Driven by form factor
- Sensor – ASIC integration
- Low I/Os
- Small size SiP
- Cost sensitive

**Applications**

- MEMS and Sensors
- HBLEDs

## Middle end

- Driven by form factor
- Driven by performance

**Applications**

- CMOS Image sensor
- Logic

## High end

- Driven by performance
- Logic + Memory integration Die partitioning
- Higher I/Os
- Large size SiP
- Relatively less cost sensitive

**Applications**

- 3D Memories
- Si interposer (2.5D)
- Si Photonics

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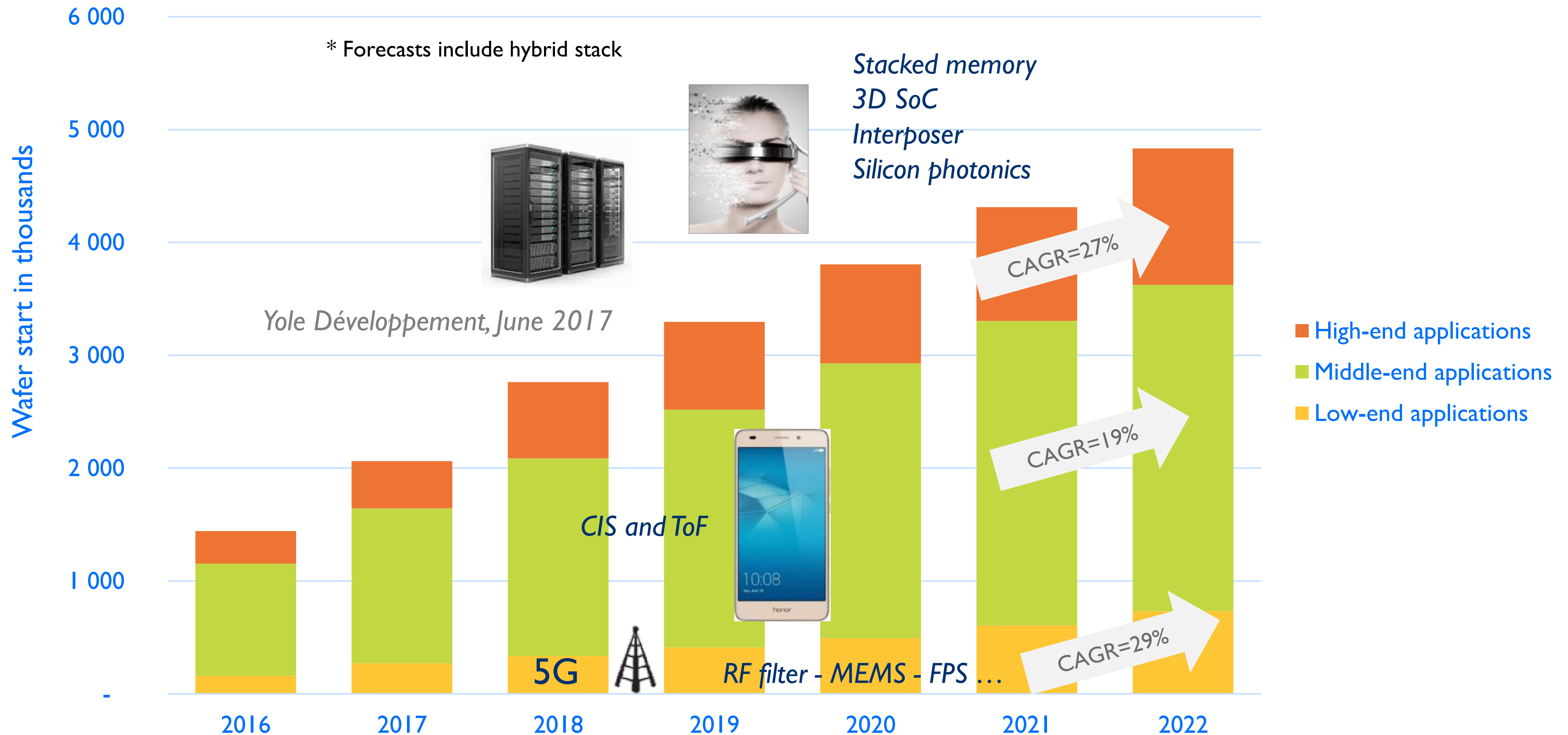
# TSV TOTAL MARKET FORECASTS 2016-2022

## Breakdown by wafer start

Wafer start per year (12 " eq) will amost reach 5 million in 2022



# Consumers Applications

# MARKET AND APPLICATIONS FOR HETEROGENEOUS INTEGRATION

Imaging

Lighting

Connecting

Sensing

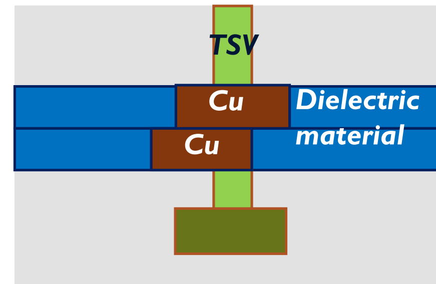
# CU-CU DIRECT BONDING

## Novel permanent bonding technology

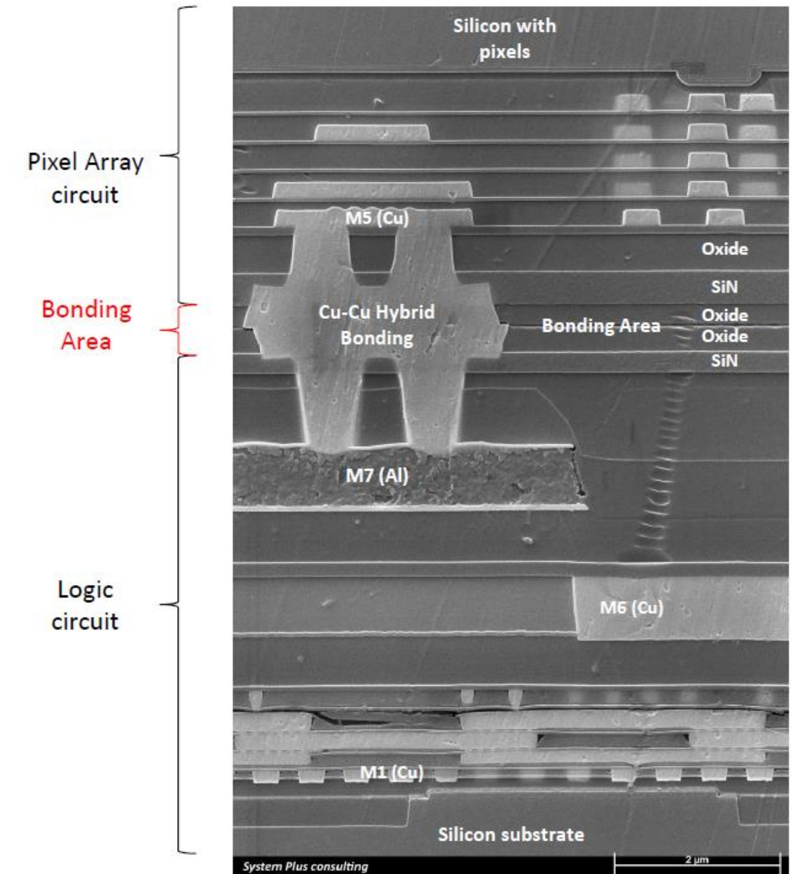
Hybrid bonding

Cu-Cu

- Permanent bonding using copper to copper connection through bonding is now in production and offers higher density interconnect
- It consists in bonding two wafers and making TSV with copper pads on each of them and stack them through a low temperature process
- This technology was used to build the CIS of the camera module of the samsung galaxy S7 smartphone
- It is not only to be used for imaging devices but also in die partitioning of logic




*Hybrid bonding*




*Cu-Cu Hybrid Bonding Cross-Section – SEM View*

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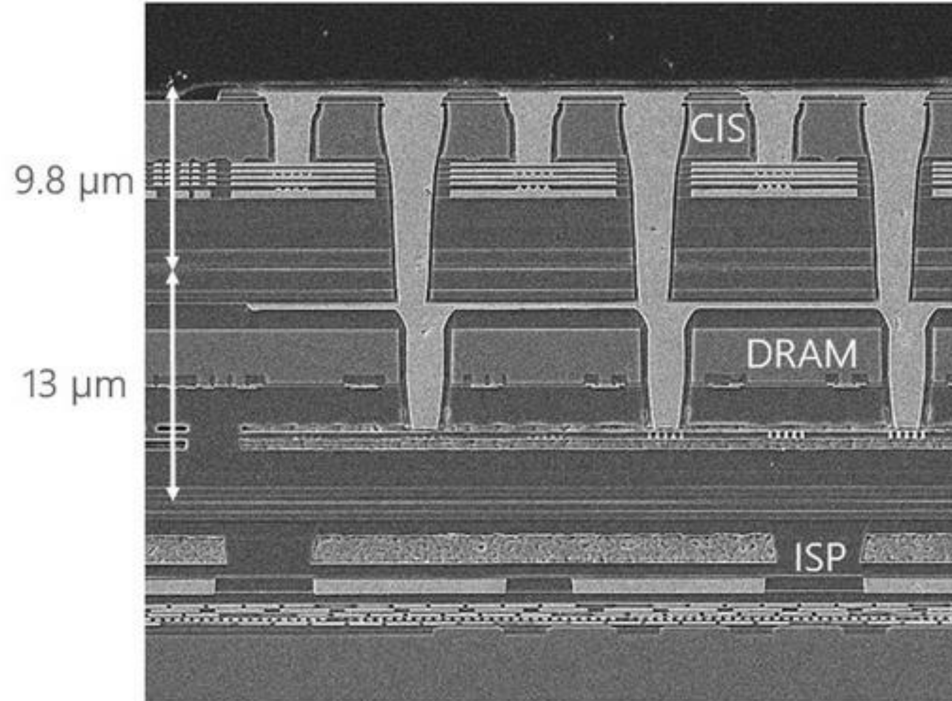
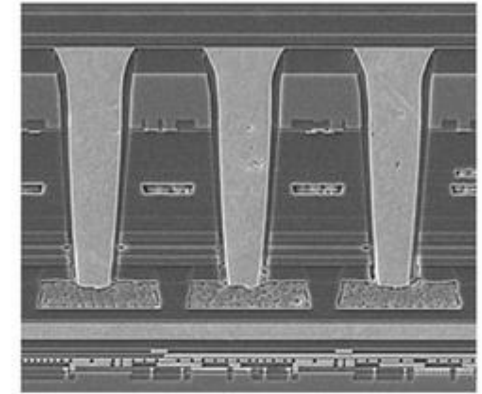
# TRIPLE STACK TECHNOLOGY

Triple stack with DRAM layer

- Sony has gone another step further in inserting a DRAM memory layer between the imaging (CIS) and digital layers.
- DRAM layer was thinned down to enable low aspect ration TSV through it
- This technology was found in the camera of the smartphone Xperia XZ Sony
- It allows to take pictures in slow motion until 1 000 frames per second



Source: TechInsights

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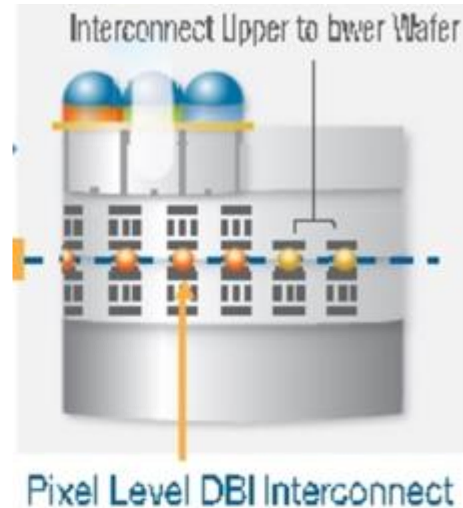
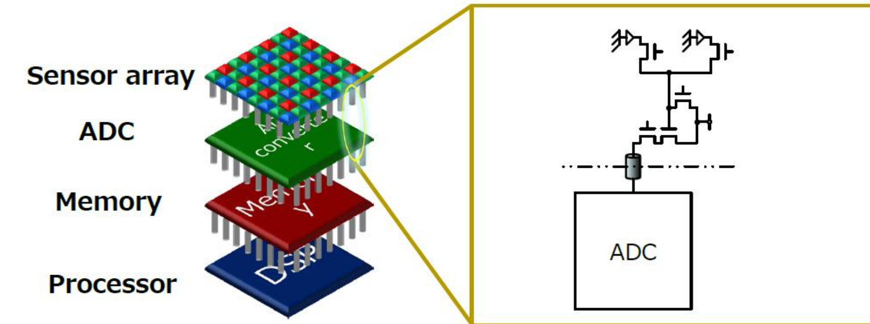
# PIXEL LEVEL INTERCONNECT

## Next evolution for real time image processing

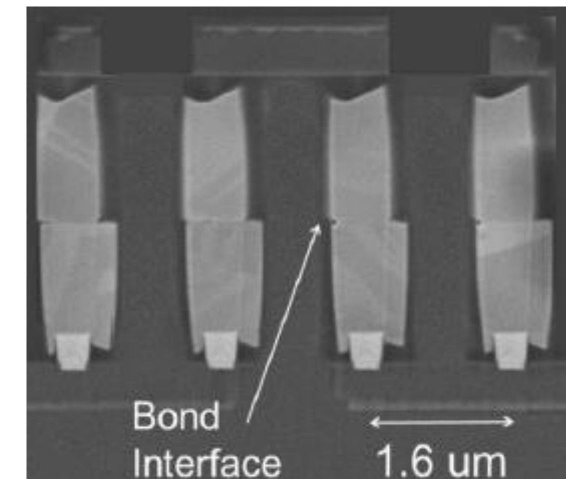
Pixel level interconnection will be the next technology evolution

- Sony is working on next gen technology to implement the interconnection at the pixel level for real time image processing.




- Xperi (Tessera and Ziptronix) is developing a process to achieve small area bond pads. 1,6µm pitch between pads was demonstrated (picture).
- Yole expects this new process for CIS interconnection to be used for commercial products in 2019




XPERI

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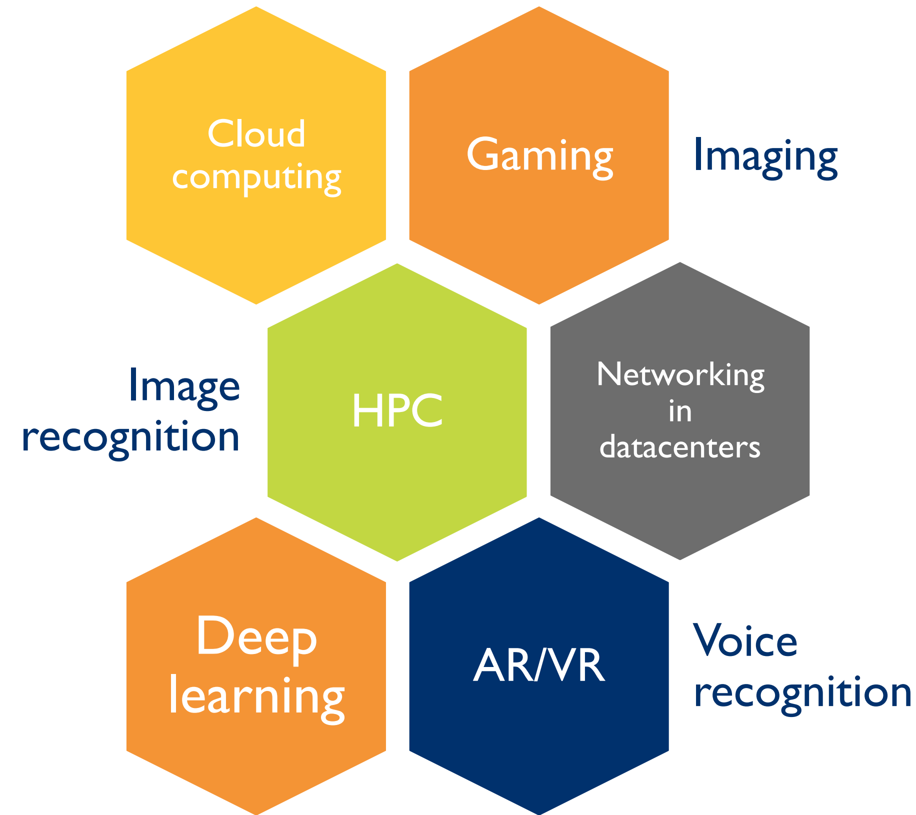
# High Performance Applications

# INTRODUCTION ON HIGH PERFORMANCE BUSINESS

- To transfer large amount of data at high-speed
- To get access to the data with minimum latency
- To store huge amount of data

=> applications which are less cost-sensitive than other market segments

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# HIGH PERFORMANCE MARKET AND APPLICATIONS

## Where 3D stacked components make the point

3D stacked IC find their place in performance demanding applications

| | ICT & networking | High performance computing for data analytics | Consumer computing (gaming + AR/VR) | Aerospace and defense | Automotive computing | Medical computing |
|---|---|---|---|---|---|---|
| **Memory cube** | x | x | x | x | | |
| **Silicon interposer** | x | x | x | x | x | x |
| **3D System On Chip *** | x | | x | | | |
| **Silicon photonics** | x | x | | x | | x |

* 3D System On Chip consists in logic-on-logic and memory-on-logic stacked 3D IC

# HIGH PERFORMANCE 3D TSV COMMERCIAL PRODUCTS LAUNCH

2011 — FPGA (Xilinx)

2014 — DDR4 3D 128GB (SK hynix); DDR4 3D 64GB (Samsung)

2015 — GPU Fiji (AMD); DDR4 3D 128GB (Samsung)

2016 — FPGA Virtex Ultrascale + 16nm (Xilinx); GPU Pascal 100 (NVIDIA); POST FX10 (Fujitsu); Networking solutions (Avago Technologies, Broadcom); Xeon Phy processor based on Knight Landing processor (Intel)

2017 — GPU Vega 10 (AMD); Lake Crest based product (Intel Nervana Systems); GPU Volta (NVIDIA); Stratix 10 FPGA (Intel); Xeon Phy based on Knight Mill processor (Intel); Kaby Lake-**G** processor (Intel)

2018 — GPU Vega 20 (AMD)

2019 — GPU Navi (AMD)

2020 — Xeon Phy based on Knight Hill processor (Intel)

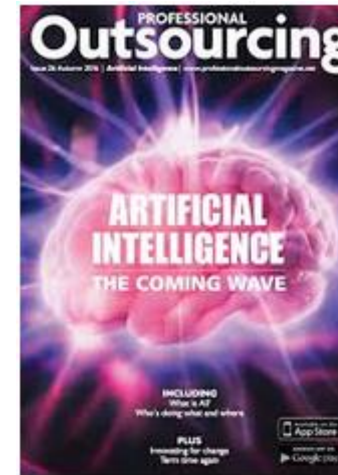
*Yole Développement, May 2017*

# ARTICLES ON ARTIFICIAL INTELLIGENCE AND DEEP LEARNING HARDWARE

**Intel Creates New Unit to House AI Efforts**

**Intel Launches New Xeon CPU, Announces Deep Learning Inference Accelerator**

**Tencent Cloud Taps Nvidia Tesla GPU Accelerators For AI**



**Cray Sets Deep Learning Milestone**

**Facebook unveils Big Basin, new server geared for deep learning**

# ARTIFICIAL INTELLIGENCE SEGMENTATION



Artificial Intelligence: any technique that enables computers to mimic human intelligence

Machine Learning: the subset of AI that includes abstruse statistical techniques that enable machines to improve at tasks with experience

Deep Learning: the subset of machine learning composed of algorithms that permit software to train itself to perform tasks, like speech and image recognition, by exposing multilayered neural networks to vast amounts of data

Adapted from Fortune

# DEEP LEARNING TREND

## *Driven by big data availability*

- *350 millions images uploaded per day*
- *2.5 Petabytes of customer data hourly*
- *300 hours of video uploaded every minute*

facebook

> ***Requires powerful GPU for high throughput & High end memory for larger bandwidth***

**Deep learning ubiquitous**

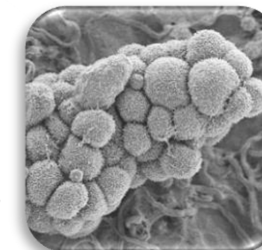
**Internet & Cloud**

- ✓ *Image Classification*
- ✓ *Speech Recognition*
- ✓ *Language Translation*
- ✓ *Language Processing*
- ✓ *Sentiment Analysis*
- ✓ *Recommendation*

**Autonomous vehicles**

- ✓ *Pedestrian Detection*
- ✓ *Lane Tracking*
- ✓ *Recognize Traffic Sign*

**Medicine & Biology**



- ✓ *Cancer Cell Detection*
- ✓ *Diabetic Grading*
- ✓ *Drug Discovery*

**Security & defense**

- ✓ *Face Detection*
- ✓ *Video Surveillance*
- ✓ *Satellite Imagery*

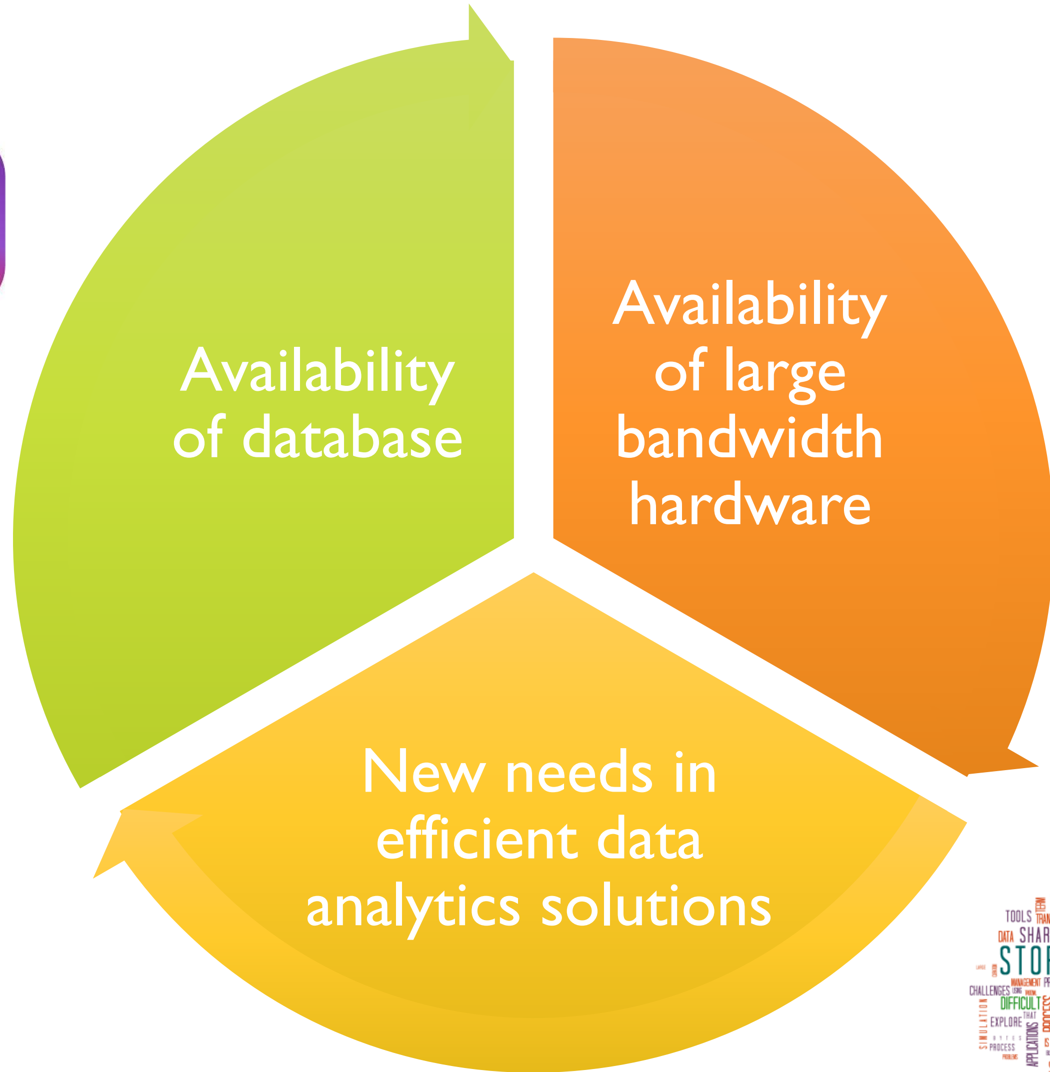
**Media / Entertainment**

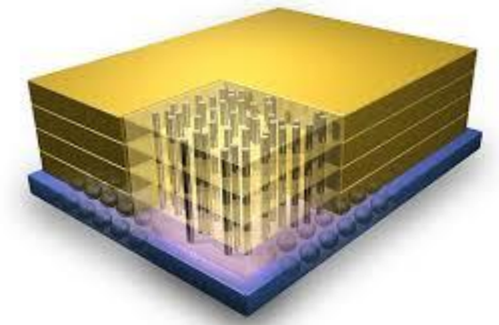
- ✓ *Video Captioning*
- ✓ *Video Search*
- ✓ *Real Time Translation*

*Source: Adapted from Nvidia*

# WHY DEEP LEARNING TAKES PLACE NOW?

Deep Learning has gained more interests for the last 5 years



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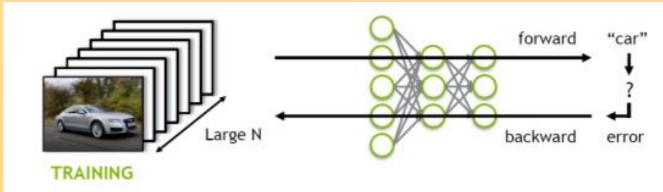
# PATTERN RECOGNITION PROCESS

## Enhanced by deep learning algorithm

DATACENTER




PARAMETERS IDENTIFICATION

consists in defining parameters that characterize the patterns (shape, edges, colors….)

TRAINING AND TESTING

consists in training several layers of neurons until they identify patterns

**Machine Learning or Deep Learning algorithms**

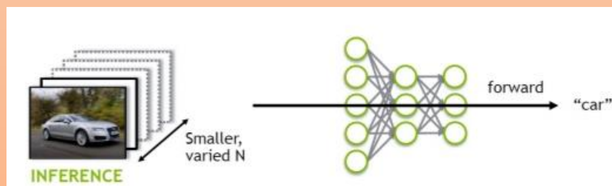
CLOUD-BASED

INFERENCE

consists in considering elements and making a decision out of them.

EMBEDDED

EMBEDDED (on-site)



# DEEP LEARNING HARDWARE

Hardware for TRAINING require large bandwidth, 3D-based products offer solutions.

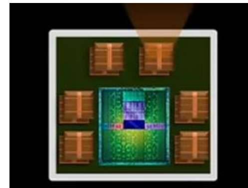
INFERENCE require less bandwidth but low latency. Interposer could come as a solution because of its modularity and its capacity to integrate more than 4 chips.

Main players offer clear different product lines as solutions for both steps.

3D and 2.5D packages have enabled performance hardware for deep learning applications

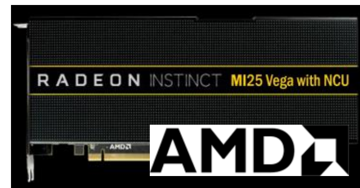
## TRAINING

### 3D-based solutions



Volta

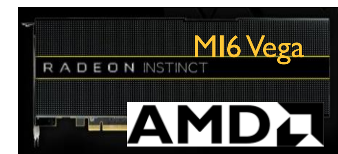
Tesla P100



Titan X

## INFERENCE

DLIA FPGA based accelerator



Tensorflow Accelerator

Jetson TK1/TX1

Tesla P40 and P4 accelerator

Drive PX2

# HPC & DEEP LEARNING: VALUE CHAIN IN MOTION

End-products & services

Systems & software

Card/ Processor

Manufacturing

Design

Internal design

Need of customed chips: own brand design

Tencent 腾讯

ZF

BOSCH

IBM

Alibaba.com Global trade starts here.™

Audi

Mercedes-Benz

CRAY

IBM

CISCO

DELL

Atos

FUJITSU

hp

intel

NVIDIA

AMD

Baidu 百度

Microsoft

Google

amazon

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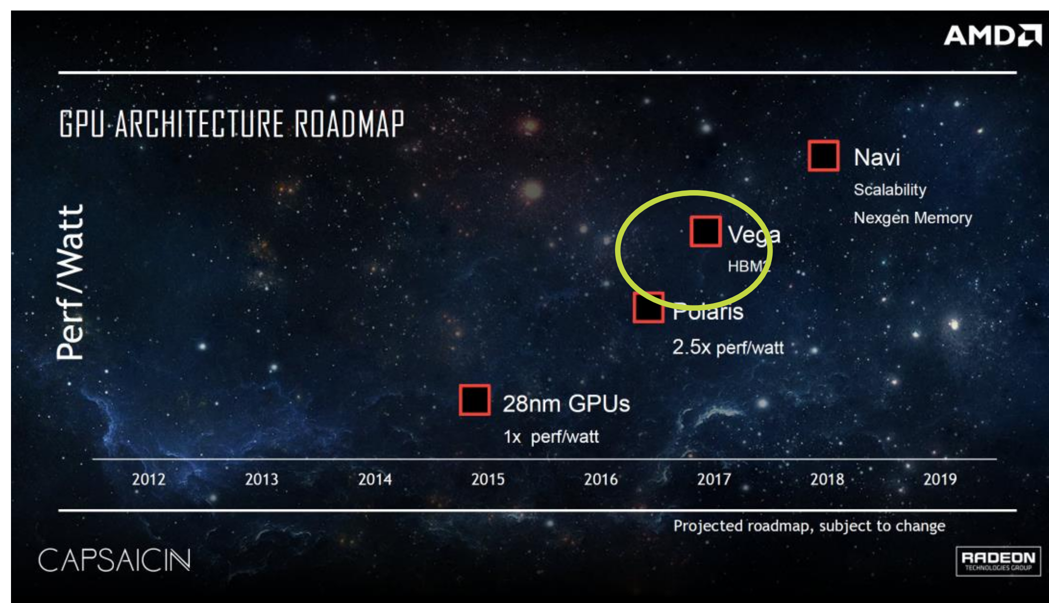
# PRODUCTS LAUNCHED IN 2017: GPU VEGA (AMD)

## HBM2 inside on VEGA architecture

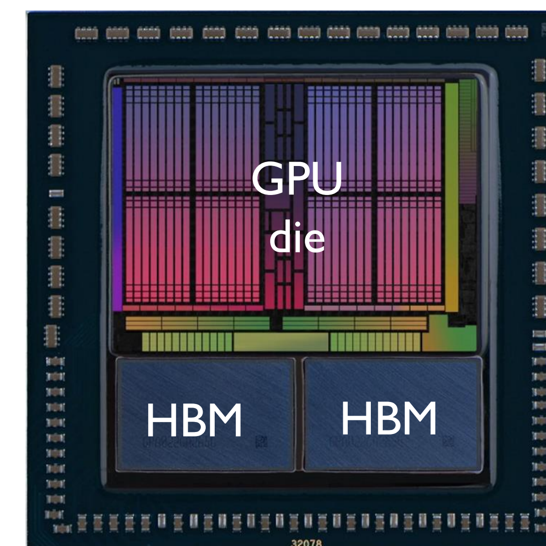
AMD

- In Q1 2017, AMD has released its lattest GPU named Vega that comes as next generation of GPU Fiji that was equipped with HBM1, it is to be used in GPU Radeon family
- In this new version, AMD has selected the 2nd generation of High Bandwidth Memory (8GB and 16GB) to be combined to their GPU chip
- Manufacturing is done by Globalfoundries on a 14nm node.

Radeon graphic card to use 14nm node combined with HBM2 memory




* Illustration of what the chip could look like




**GPU Vega 10 Pro**, HBM2 on interposer Radeon family, will be found in Apple iMac Pro

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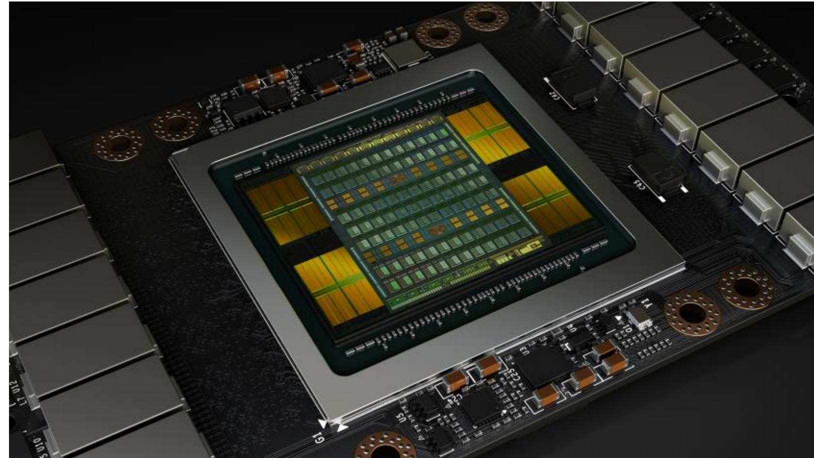
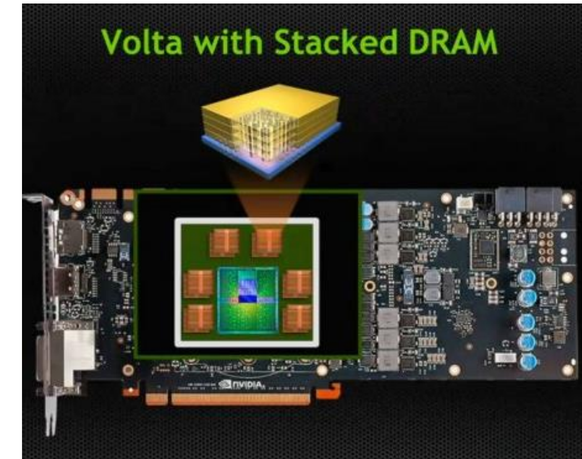
# PRODUCTS LAUNCHED IN 2017: GPU TESLA V100 (NVIDIA)

## HBM2 inside and VOLTA architecture

- In Q2 2017, Nvidia has launched it lattest generation of GPU for Tesla family
- The product will fall under two categories, one is for consumers using GDDR6 for consumer market and 16GB HBM2 up to 900GB/s for HPC
- Manufacturing is done by TSMC on a 12 nm FinFET using TSMC proprietary CoWoS package





# AUGMENTED & VIRTUAL REALITY

## Head-set process unit: a « mobile APU » to be upgraded

AR/VR head set require computing performance higher than smatphone in keeping good form factor

CPU/APU performance

3D TSV integration needed

Computing complexity requirements

# Conclusions and what is coming next

# CONCLUSIONS

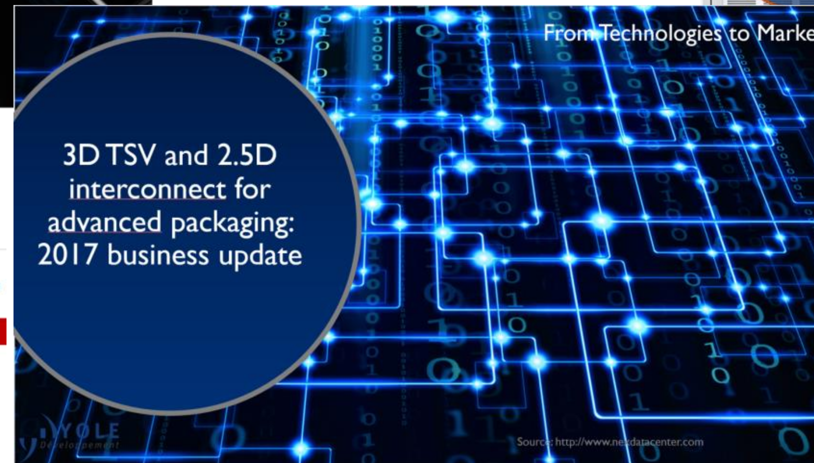
- IMAGING
- 3D integration essential for Imaging
- Several technologies available
- Bonding at pixel-level: Next Gen

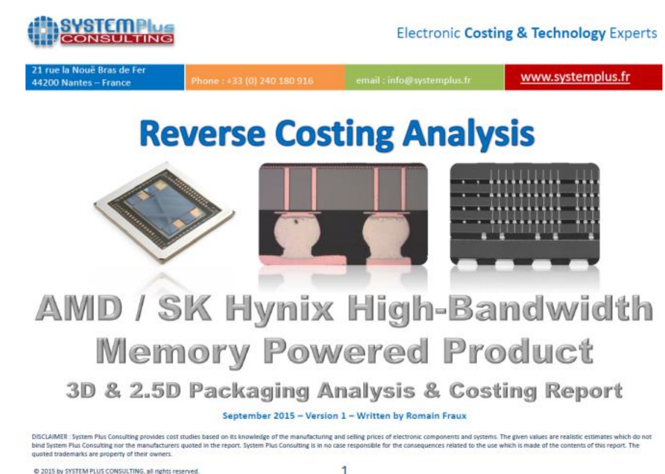
- HIGH PERFORMANCE COMPUTING
- 3D TSV and 2.5 packaging platforms are gaining interests for high-performance applications
- Main market segments: HPC and networking
- Artificial intelligence using deep learning algorythms require consequent number of memory cubes

- High Bandwith Memory (HBM) is becoming a standard
  - Increase of production capacity in 2018
  - HBM 3rd generation expected 2019 - 2020

# DATA SOURCES

## Information in this presentation is extracted from the following reports





# CONTACT & SOURCES

## Biography & contact

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Emilie Jolivet is a Technology & Market Analyst, in the Advanced Packaging and Semiconductor Manufacturing team, at Yole Développement the "More than Moore" market research and strategy consulting company. She holds a master's degree Applied Physics specialized in Microelectronics from INSA Toulouse. After an internship in failure analysis in Freescale, she took the position of R&D engineer for 7 years in photovoltaic business and co-authored several scientific articles. Strong for this experience, she graduated from a master in Business Administration at IAE Lyon and then joined EV Group as a business development manager in 3D & Advanced Packaging before joining Yole Développement in 2016.

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*From Technologies to Market*

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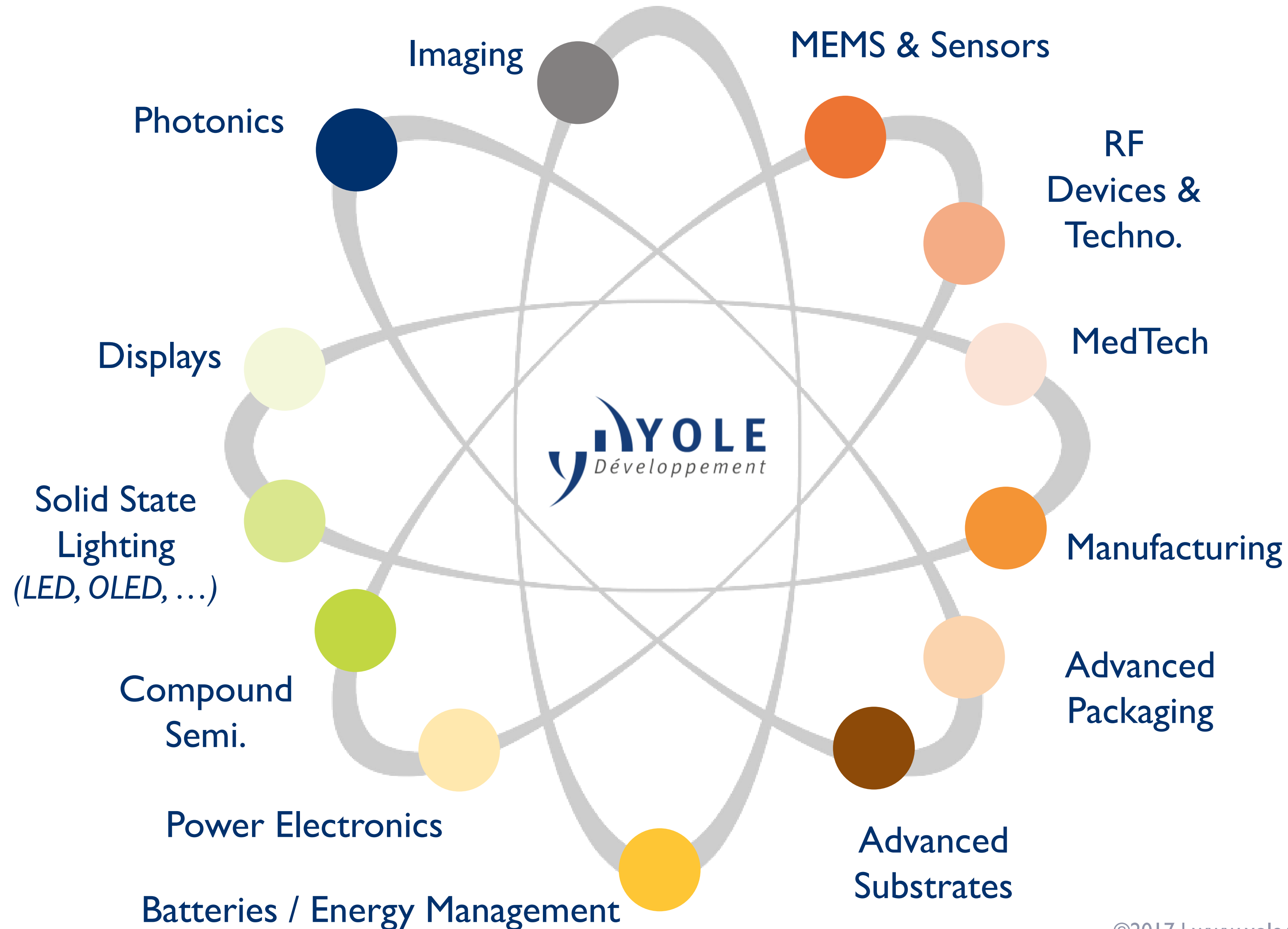
## Yole Développement's 30 analysts operate in the following areas



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- Technology analysis
- Strategy consulting
- Reverse engineering & costing
- Patent analysis

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- M&A (buying and selling)
- Due diligence
- Fundraising
- Maturation of companies
- IP portfolio management & optimization

www.yolefinance.com

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## Reports

- Market & technology reports
- Patent Investigation and patent infringement risk analysis
- Teardowns & reverse costing analysis
- Cost simulation tool

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Nice

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40%

of our business

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30%

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Breadth of the analysis

Depth of the analysis

Standard Reports

Workshops

Custom Analysis

Custom analysis scope is defined with you to meet your information and budget needs

# SERVING 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…

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

Financial investors, R&D centers

ITRI Industrial Technology Research Institute, Fraunhofer, Berkeley, STANFORD UNIVERSITY, TPG

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

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# SERVING MULTIPLE INDUSTRIAL FIELDS

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

Industrial and defense: GE, THALES, BRS, SAGEM

Medical systems: BIOMÉRIEUX, Roche, Medtronic, St. Jude Medical, SORIN GROUP, Johnson & Johnson, TELEDYNE DALSA

Energy: TMEIC, SUNGROW, ABB, SMA, Schneider Electric, YASKAWA, GDF SUEZ, AE ADVANCED ENERGY

Automotive: BMW, TOYOTA, MITSUBISHI, Audi, Ford, BOSCH, BYD, Continental

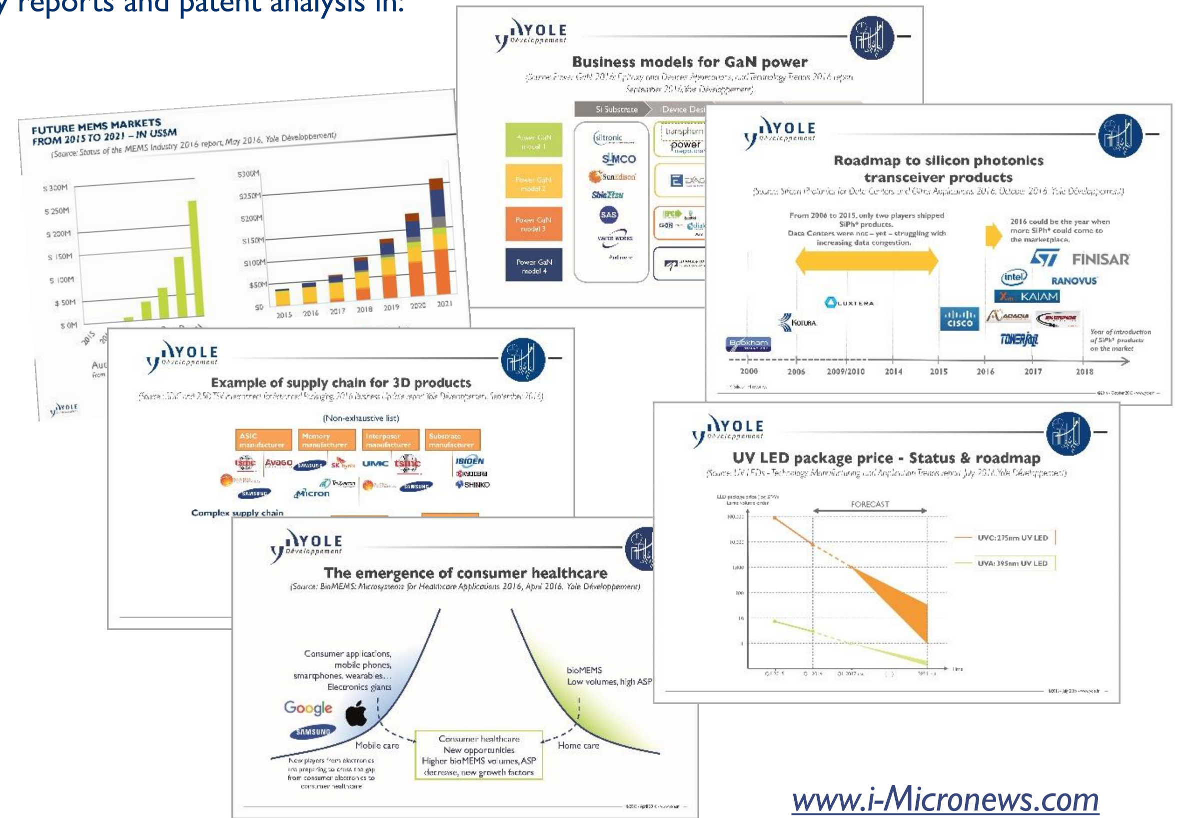
Transportation makers: AIRBUS, BOMBARDIER, VOLVO, CSR, BOEING, ALSTOM

Mobile phone and consumer electronics

From A to Z…

# REPORTS COLLECTION

- Yole Développement publishes a comprehensive collection of market & technology reports and patent analysis in:
  - MEMS & Sensors
  - RF devices & technologies
  - Imaging
  - Medical technologies (MedTech)
  - Photonics
  - Advanced packaging
  - Manufacturing
  - Power electronics
  - Batteries and Energy management
  - Compound semiconductors
  - LED
  - Displays

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- You are looking for:
  - An analysis of your product market
  - A review of your competitors evolution
  - An understanding of your manufacturing and production costs
  - An understanding of your industry technology roadmap and related IPs
  - A clear view on the evolution of the supply chain

  The combined team of 50+ experts (PhDs, MBAs, industry veterans…) from Yole Développement, System Plus Consulting and KnowMade, collect information, identify the trends, the challenges, the emerging markets, the competitive environments and turn it into results to give you a complete picture of your industry landscape.

  In the past 18 years, we worked on more than 1 500 projects, interacting with technology professional and high level opinion makers from the main players of the industry.

- Every year, Yole Développement, System Plus Consulting and Knowmade publish +120 reports. Gain full benefit from our **Bundle and Annual Subscription** offers.

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**MARKET AND TECHNOLOGY REPORTS** by Yole Développement

- **MEMS & SENSORS**
  - Fingerprint Sensor Applications and Technologies - Consumer Market Focus 2017
  - MEMS Microphones, Speakers and Audio Solutions 2017
  - Status of the MEMS Industry 2017
  - MEMS & Sensors for Automotive 2017
  - High End Inertial Sensors for Defense and Industrial Applications 2017
  - Sensor Modules for Smart Building 2017
  - Sensing and Display for AR/VR/MR 2017 (Vol 1)
  - MEMS Packaging 2017
  - Magnetic Sensors Market and Technologies 2017**
  - Microspectrometers Markets and Applications 2017**
- **RF DEVICES AND TECHNOLOGIES**
  - RF Components and Modules for Cellphones 2017
  - Advanced RF SiP for Cellphones 2017
  - 5G and Beyond (Vol 1): Impact on RF Industry, from Infrastructure to Terminals 2017
  - 5G and Beyond (Vol 2): RF Materials Platform, from Infrastructure to Terminals 2017
  - RF Technologies for Automotive Applications 2017
  - GaN and Si LDMOS Market and Technology Trends for RF Power 2017
- **IMAGING & OPTOELECTRONICS**
  - 3D Imaging & Sensing 2017
  - Status of the CMOS Image Sensor Industry 2017
  - Camera Module for Consumer and Automotive Applications 2017
  - Uncooled Infrared Imaging Technology & Market Trends 2017
  - Active Imaging and Lidars 2017 (vol 1)
- **MEDTECH**
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  - Power GaN 2017: Materials, Devices, and Applications
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  - Power Management ICs Market Quarterly Update 2017
  - Power Electronics for Electrical Aircraft, Rail and Buses 2017
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- **LED**
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  - Agricultural Lighting 2017 - Technology, Industry and Market Trends
  - Automotive Lighting 2017 - Technology, Industry and Market Trends
  - Active Imaging and Lidar 2017 (Vol 2) - IR Lighting**
  - LED Lighting Module 2017 - Technology, Industry and Market Trends
  - IR LEDs 2017 - Technology, Manufacturing and Application Trends
  - Phosphors & Quantum Dots 2017 - LED Downconverters for Lighting & Displays
  - CSP LED Module 2017
  - LED Packaging 2017

**PATENT ANALYSIS** by Knowmade
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- MEMS Microphone: Knowles' Patent Portfolio Analysis**
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- Miniaturized Gas Sensors Patent Landscape Analysis
- 3D Cell Culture Technologies Patent Landscape
- Phosphors and QDs for LED Applications Patent Landscape 2016 report
- TSV Stacked Memory Patent Landscape
- Fan-Out Wafer Level Packaging Patent Landscape Analysis

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