

X-RAY DETECTORS FOR MEDICAL, INDUSTRIAL AND SECURITY APPLICATIONS 2019

Market & Technology Report - May 2019

New technologies are finally arriving in the X-ray market and reshuffling the pack of players.

WHAT'S NEW

- The previous report about X-ray imaging also included other medical imaging technologies like PET, endoscopy, OCT, and ultrasound. We have now decided to analyze each modality more deeply
- We also enlarge the scope of the report adding the veterinary, industrial and security markets
- This report focuses on X-ray imaging at the system and detector level

REPORT KEY FEATURES

- Historical perspective and synergies with other markets
- Market data and forecasts at the system and detector level by applications including medical, veterinary, industrial and security and technologies like aSi, aSe, CCD, CMOS, photodiodes and IGZO, in dollar value and in unit volumes. The medical market is subdivided into static, mammography, surgery and interventional, CT and dental
- Technology penetration and market trends by segment, including medical, covering static, mammography, surgery and interventional, CT and dental, as well as veterinary, industrial and security
- Supply chain analysis with market shares at the system level by segment and at the detector level by technology
- Technology landscape, evolution and roadmaps

THE X-RAY DETECTOR MARKET REACHED \$2B IN 2018 DRIVEN BY THE MEDICAL SEGMENT, ACCOUNTING FOR 75% OF THE MARKET, BUT THE INDUSTRIAL AND SECURITY MARKET ARE GAINING SHARES

X-ray imaging's first application was in the medical area, with the first radiography being done in 1895 by Wilhelm Röntgen. The discovery of X-rays led to a revolution in medical imaging. Today the technology is gaining traction in the fields of veterinary care, industrial non-destructive testing (NDT) and security.

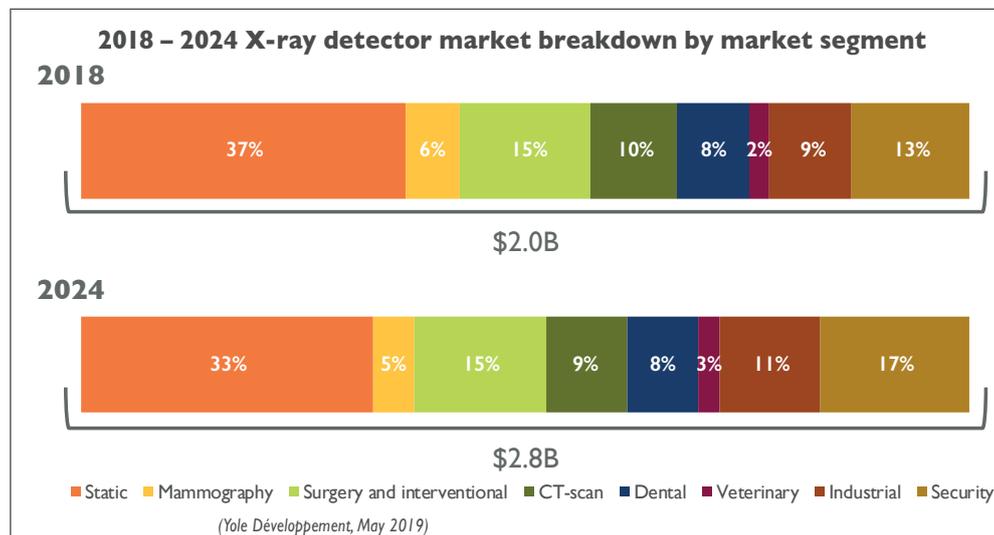
The X-ray market was worth \$19B in 2018 at the system level. The medical market is by far the biggest, with \$16B revenues in 2018.

At the detector level, the X-ray market was worth \$2.0B in 2018 and is expected to grow with a Compound Annual Growth Rate from 2018-2024 (CAGR₂₀₁₈₋₂₀₂₄) of 5.9% to reach \$2.8B in 2024. Today, X-ray imaging is almost exclusively based on solid-state sensors. Flat panel detectors using amorphous silicon (aSi) and CMOS represent the biggest share of the market, being worth \$1.3B in 2018. They were followed by silicon photodiode

array detectors, which were worth \$500M. Yole Développement is expecting Indium Gallium Zinc Oxide (IGZO) flat panels to make a big entry into the market as soon as 2021 and to reach \$236M in 2024.

IGZO is directly competing with aSi and CMOS, but CMOS is still the reference technology for applications needing high resolution. However, the price erosion is slow with CMOS because the number of systems sold is still low in the X-ray field and the size of the flat panels is large. The only reason for price erosion is the competition with aSi. That explains why the price difference between CMOS and aSi is decreasing, especially for smaller panels.

This report summarizes market data and forecasts for the period 2018-2024, breaking the system market into segments and dividing the detector market by application and technology. It also covers market drivers and cost analyses.



IGZO AND PHOTON COUNTING TECHNOLOGIES ARE READY TO FINALLY REACH COMMERCIALIZATION, HELPED BY ECONOMIC AND TECHNICAL DRIVERS

Commercialization of IGZO flat panels for X-ray imaging begun last year with Rayence, iRay and Varex presenting IGZO based products. Yole Développement is expecting a rapid ramp-up of IGZO integration in new products as the technology is ready and the supply chain is almost ready too. Imaging system manufacturers are eager to use

this new technology because it offers better image quality at an affordable cost. However, ramp-up will depend on how rapidly the technology is integrated into new products.

Another very interesting development is single photon counting for spectral imaging. With the acquisition of MultiX by Detection Technology

and with Varex buying Direct Conversion AB, photon counting is no longer just a promising technology. It will soon be available in products from the biggest detector manufacturers. System manufacturers’

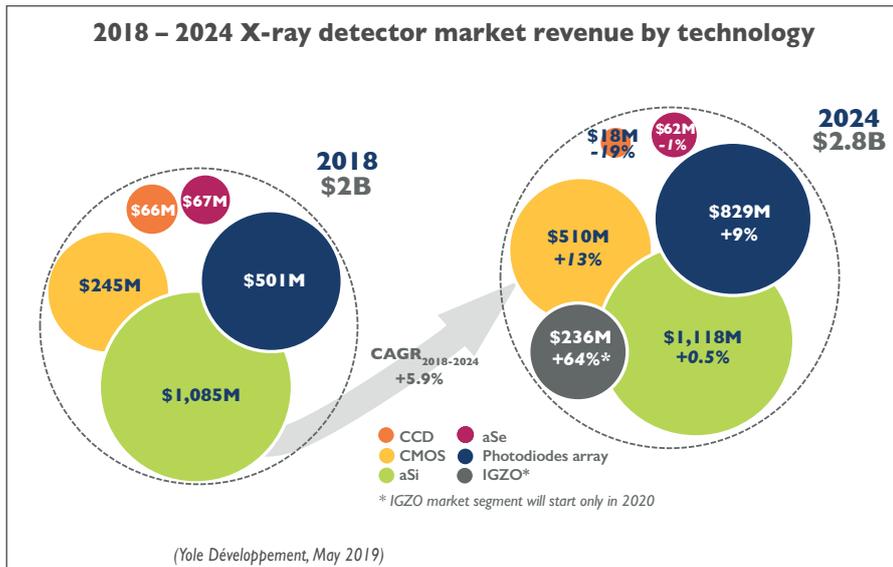
interest in single photon counting and spectral imaging is focused on discrimination of materials in security and industrial applications and use of targeted contrast agents in medical applications.

We are also seeing a growing trend towards 3D imaging that translates into more computed tomography (CT) being sold into various medical, security and industrial applications.

X-ray line scan cameras are mainly used in industrial and security applications. The next trend in this field is the use of time delay integration (TDI) cameras to enhance image quality. We are already seeing TDI cameras in food sorting and non-destructive testing of microelectronics.

Artificial intelligence (AI) will be the next megatrend to follow in the field of imaging. This is especially true in X-ray, as 3D and multi-spectral imaging requires processing of massive amounts of data.

This report describes the technology landscape and evolution and lays out the roadmaps Yole Développement expects that progress might follow.



NEW TECHNOLOGIES REACHING COMMERCIALIZATION ARE RESHUFFLING THE CARDS OF MANY PLAYERS IN THE SUPPLY CHAIN

The X-ray detector market is now like the electronics market. It’s becoming difficult to develop all the components internally. A company needs a supply chain with partners that are expert in their domains: detector companies, software companies that have AI specialists, etc.

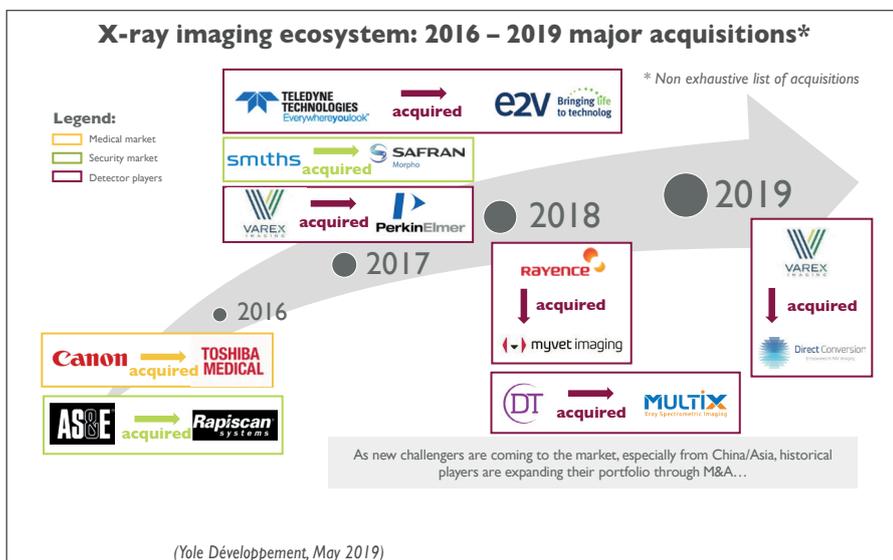
After a consolidation of the supply chain in the medical business (Canon acquired Toshiba Medical), the security business (Smiths Detection acquired Safran Morpho, OSI Systems acquired Rapiscan) and the detector manufacturers (Teledyne Dalsa acquired e2v, Varex acquired Perkin Elmer) in 2016-2017, we now see the detector makers expanding their product portfolio to add photon counting (Varex, Detection Technology).

At the system level, the medical and dental segments are dominated by few major players, like Siemens, Philips, GE and Canon. Smaller players with niche products are also gaining market share in areas like mammography, dental or surgery. Chinese players such as United Imaging are also gaining market share, even in the high-end markets. The X-ray security market is very consolidated, with a few key players accounting for around 60% of the overall market share in 2018. The key players include OSI Systems, Smiths Detection, L3 and Analogic Corporation, but also Chinese players such as Safeway System and Nuctech. The industrial segment is divided up into a lot of applications with very different needs and specifications. This explains the large number of small companies in this segment compared to the medical segment where the main products are in the hands of 4-5 main players.

In the flat panel market, big companies such as Teledyne Dalsa, Varex and Trixell are still the main players. However, Asian manufacturers such as Vieworks, Rayence, iRay and CareRay are gaining market shares and are at the forefront of new technologies.

The main applications of photodiode array detectors in X-ray imaging are line scan imaging, mainly for industrial applications but also and CT-scan, in medical, industrial and security applications. The main players are Hamamatsu, ams and Detection Technology.

This report includes a complete supply chain analysis and describes market shares by segment at the system level, and by technology at the detector level.



REPORT OBJECTIVES

- Provide an overview of X-ray imaging markets and technological landscapes at the system and detector levels, as well as an understanding of established and upcoming players, their technologies and their advantages/drawbacks, and how these will evolve in coming years.
- Provide market data and forecasts, along with market share at the system and detector levels by applications, including medical, veterinary, industrial and security, and technologies, including aSi, aSe, CCD, CMOS, photodiodes and IGZO, in dollar value and in unit volumes.
- Identify where the opportunities lie for the different players along the supply chain, from materials suppliers and foundries, to detectors manufacturers and system developers.
- Discuss the different technologies used today, such as aSi, aSe, CCD, CMOS, photodiodes, but also the alternatives coming to the market in the next few years, including IGZO and single photon counting and possible new technologies being tested in R&D, such as perovskites, organic materials and curved sensors.

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Jérôme Mouly serves as a Senior Technology & Market Analyst & Business Developer specialized in microtechnologies for inkjet & bioMEMS sensors at Yole Développement (Yole). Jérôme is supporting the development of strategic projects, following leading customers of the company, within the Life Sciences & Healthcare division. Since 2000, he is also engaged in more than 100 marketing and technological analyses for industrial groups, start-ups and institutes related to semiconductor & medical technologies industry, in the field of inkjet functional printing, wearable sensors and connected medical devices. Jérôme is also regularly involved in international conferences, giving presentations and delivering keynotes. Jérôme Mouly holds a Master of Physics from the University of Lyon (France).

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9. GOVERNING LAW AND JURISDICTION

- 9.1 Any dispute arising out or linked to these Terms and Conditions or to any contract/orders entered into in application of these Terms and Conditions shall be settled by the French Commercial Courts of Lyon, which shall have exclusive jurisdiction upon such issues.
- 9.2 French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.