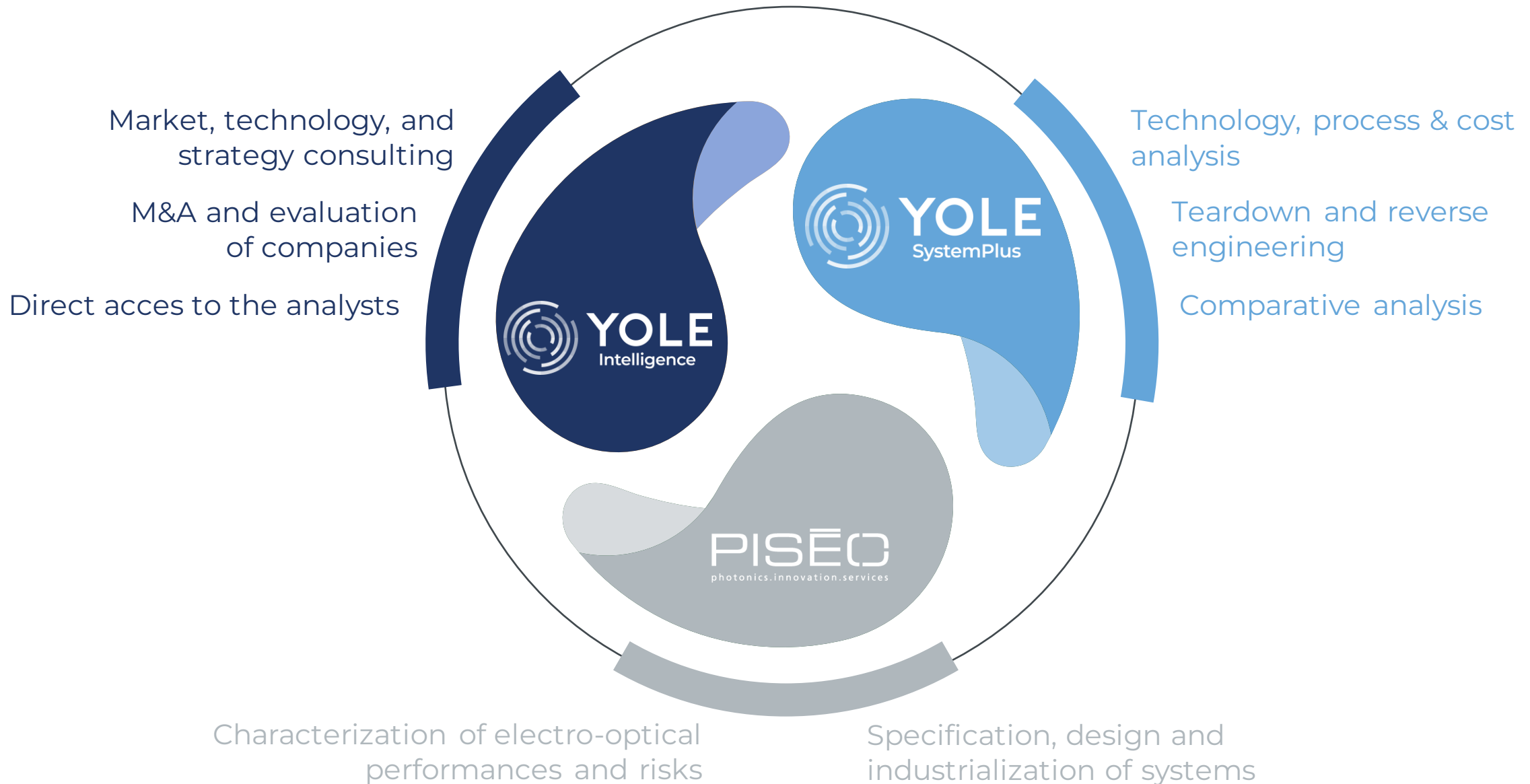


# What's Next in the Digital X-Ray Medical Imaging Industry?

Jérôme Mouly  
November 16<sup>th</sup> 2022

# YOLE GROUP'S MAJOR ACTIVITIES PER ENTITY



# FIELDS OF EXPERTISE COVERING THE SEMICONDUCTOR INDUSTRY



- Photonics & Lighting
- Imaging
- Sensing & Actuating
- Display



- Semiconductor Packaging
- Semiconductor Manufacturing
- Memory
- Computing and Software



- Radio Frequency
- Compound Semiconductors
- Power Electronics
- Batteries



- Electronic Systems
- Emerging Technologies

# Introduction

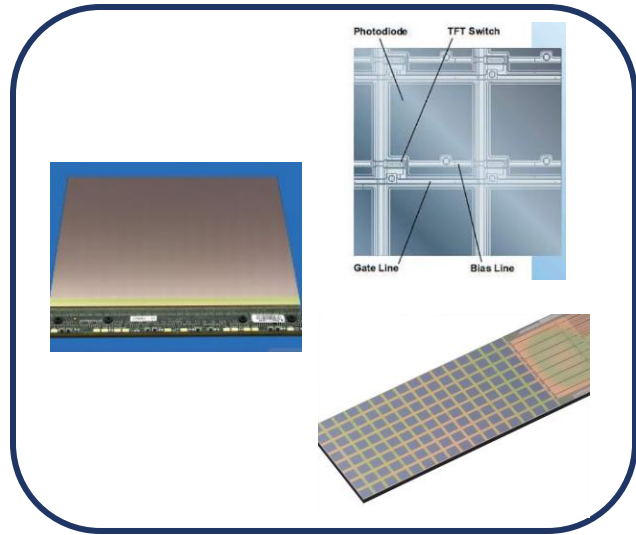
# DETECTORS, PACKAGED DETECTORS, AND END-SYSTEMS



## Different levels of integration

### Main scope of Yole's analysis

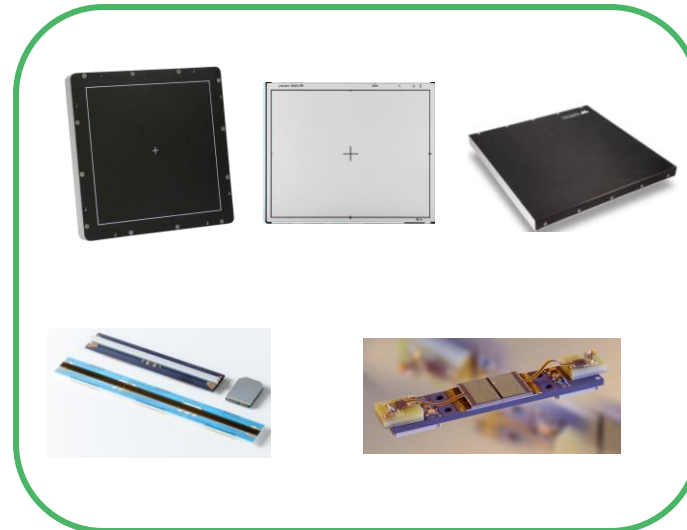
#### Raw detectors



courtesy of Dpix, ISDI, ams-OSRAM

Semiconductor photodiodes

#### Packaged detectors



courtesy of: Varex, Trixell, Hamamatsu, Teledyne Dalsa, CEA-LETI

Scintillator + photodiodes + electronics

#### End-systems



courtesy of: Philips, Siemens, Sirona

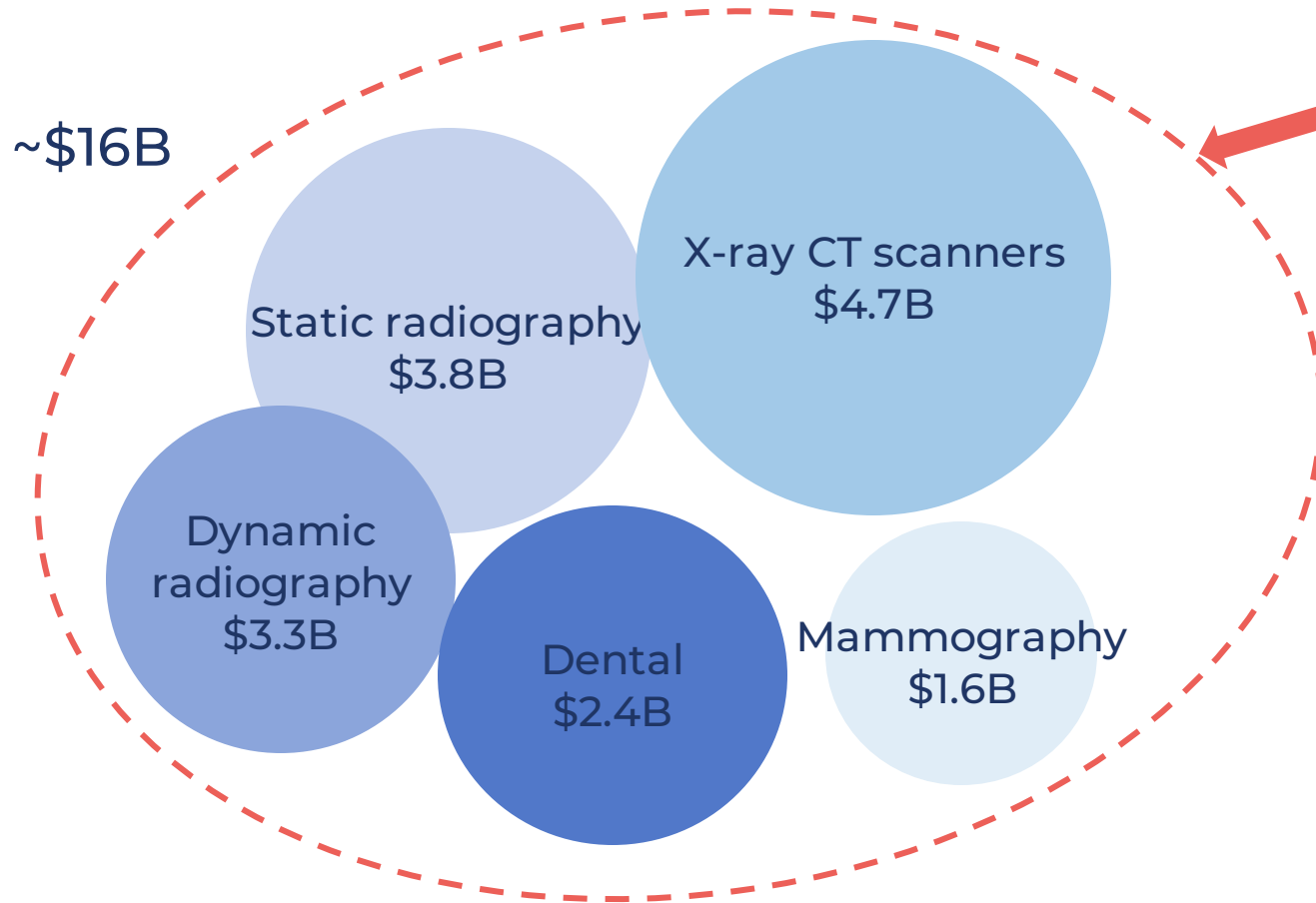
Medical imaging systems integrating detectors

# MAJOR MEDICAL SYSTEM MAKERS

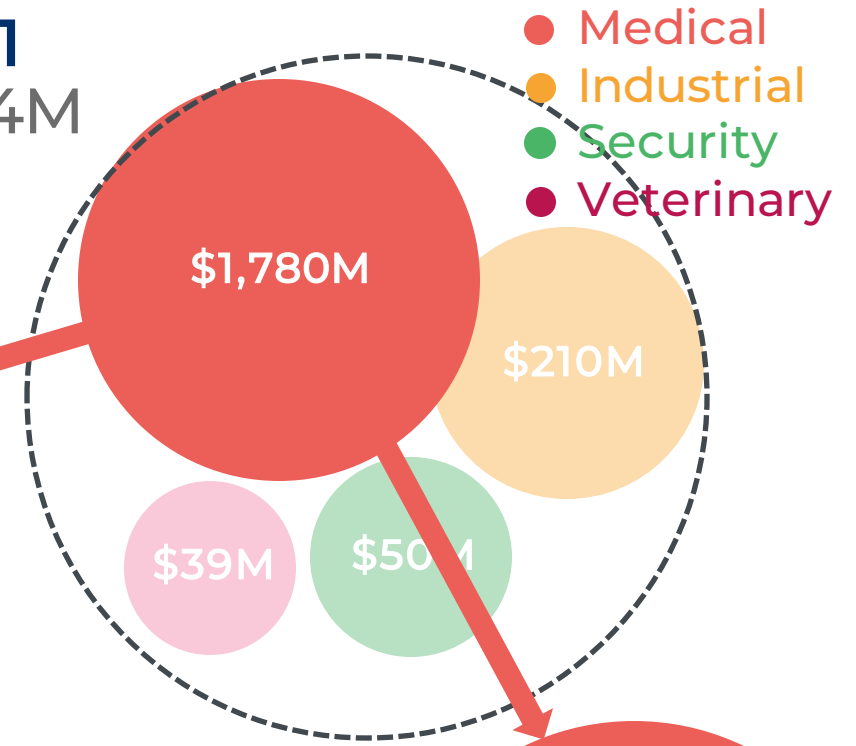
## Generated market value



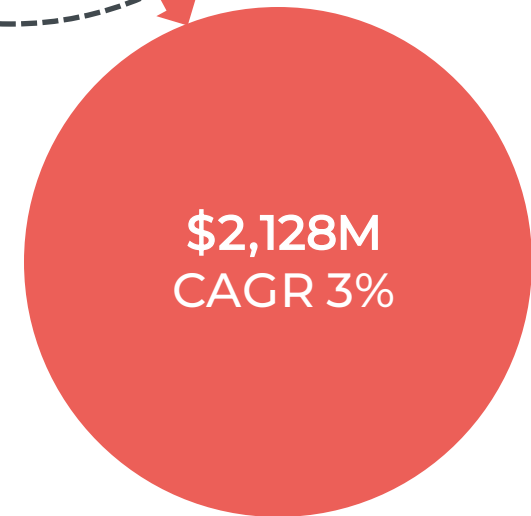
Medical X-ray equipment in 2021:



2021  
\$2,034M



2027 forecast:

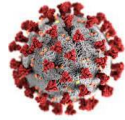


# General trends

# YEARS OF CRISIS



Covid-19 pandemic



Effect on demand in 2020

Static	Interventional & surgery	Mammography	Dental	CT scan
↗	↘	↘	↘	↗

Chip shortage



8-inch wafer big price inflation

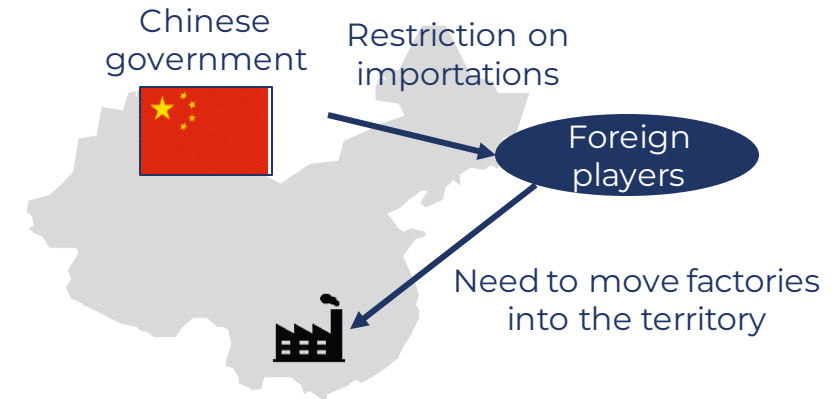


Delays in CMOS technologies

China-U.S. trade war



"local for local" policy



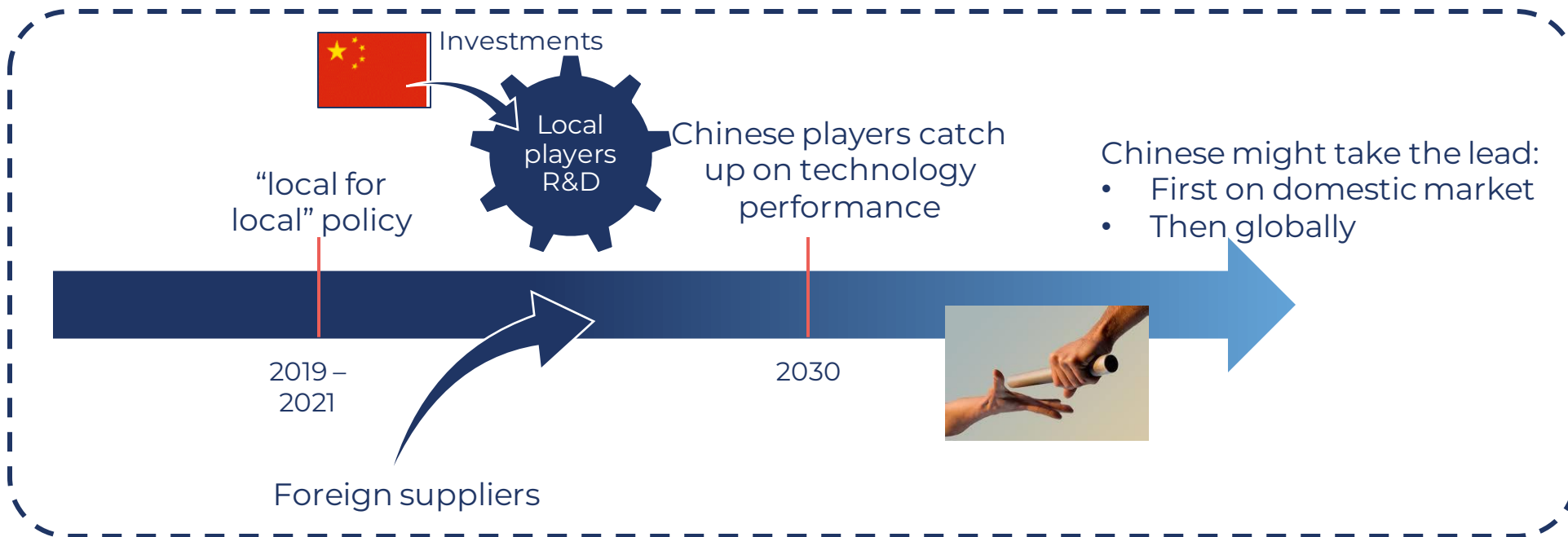
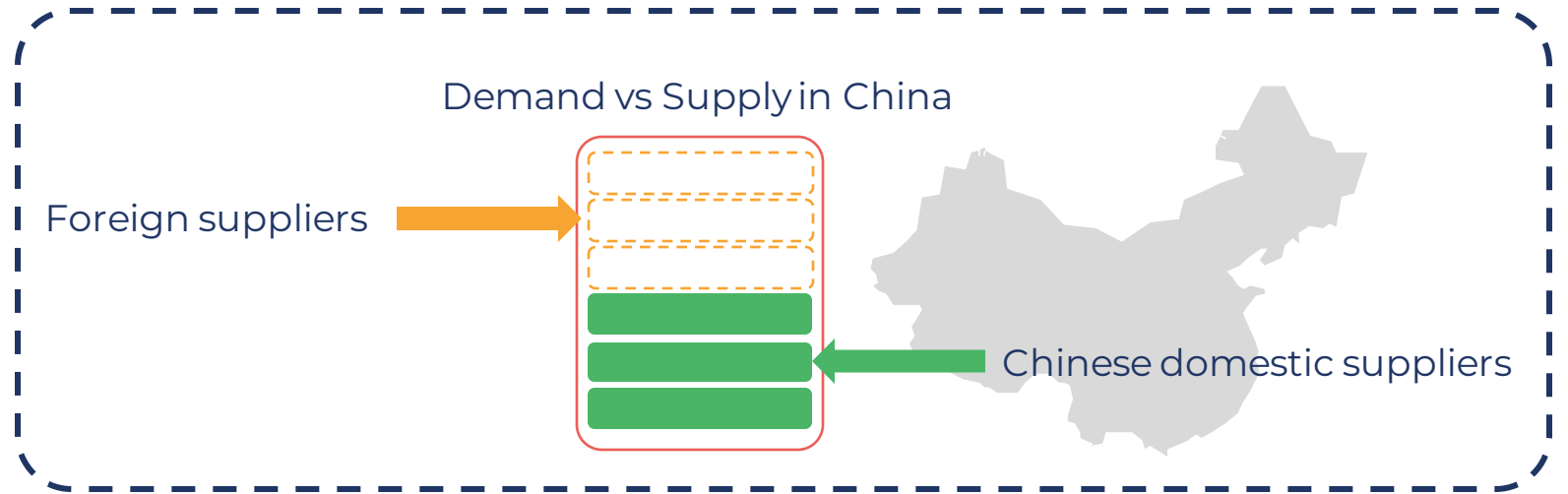
Ukraine-Russia war



Contributes to global inflation

From 2020, several crisis had consequences on both demand and supply chain of X-ray imaging industry

# CHINA, OPPORTUNITY OR COMPETITION ?





# MEDICAL TRENDS

## More CT scan in the clinical practice

CT scanners are versatile and allow accurate 3D representation of body diseases. More and more practitioners use CT directly instead of classical flat panel-based systems.

### CT won't be used in:

#### Mammography:

- Mammography is operated at low energy (30/40keV). This energy range is not allowed for CT in a number of countries, due to elevated dose.

#### Dental:

- Uses specific compact systems that can be installed in a dentist's office. Use more and more 3D CBCT, no classical CT scan...

CT scan

### CT might be used in:

#### Static:

- CT scan is more and more used for classical emergency cases where it was more usual to use static radiography. CT offers a wider range of diagnosis than classical radiography systems.

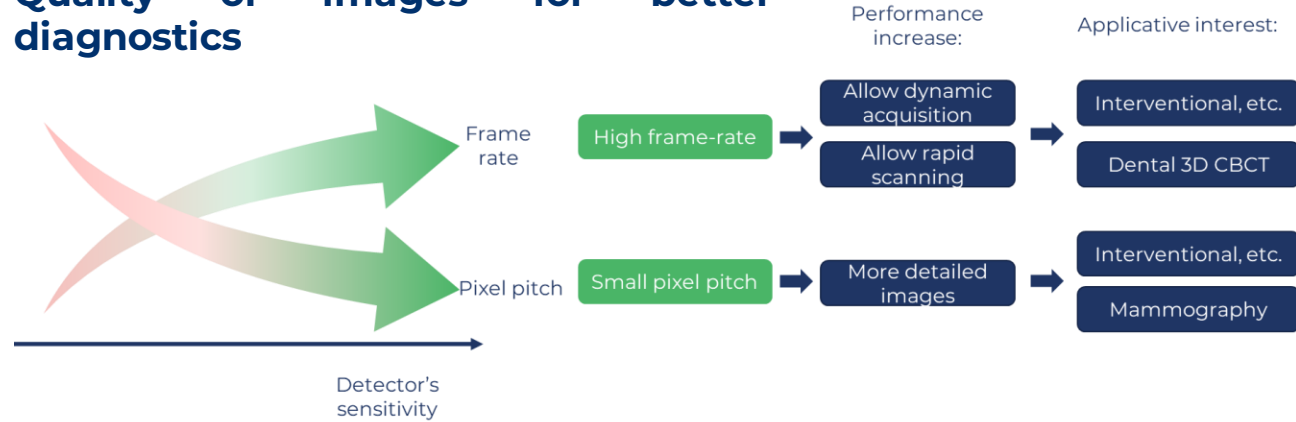
#### Interventional / surgery:

- There are now interventional CT allowing to track artificial material in real-time and display it to a surgeon. In some cases, this could replace classical interventional systems.

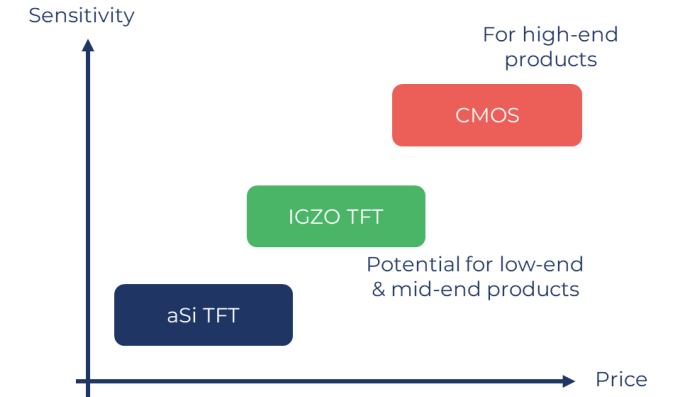
# WHAT IS DRIVING X-RAY INNOVATION?



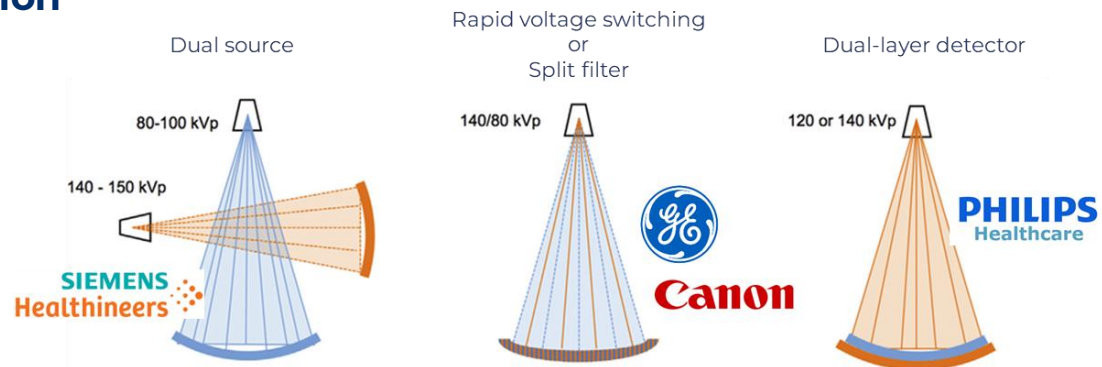
## Quality of images for better diagnostics



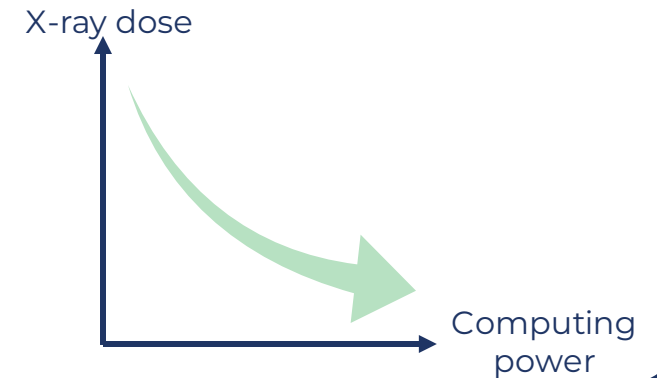
## Price vs. sensitivity – affordable diagnostics



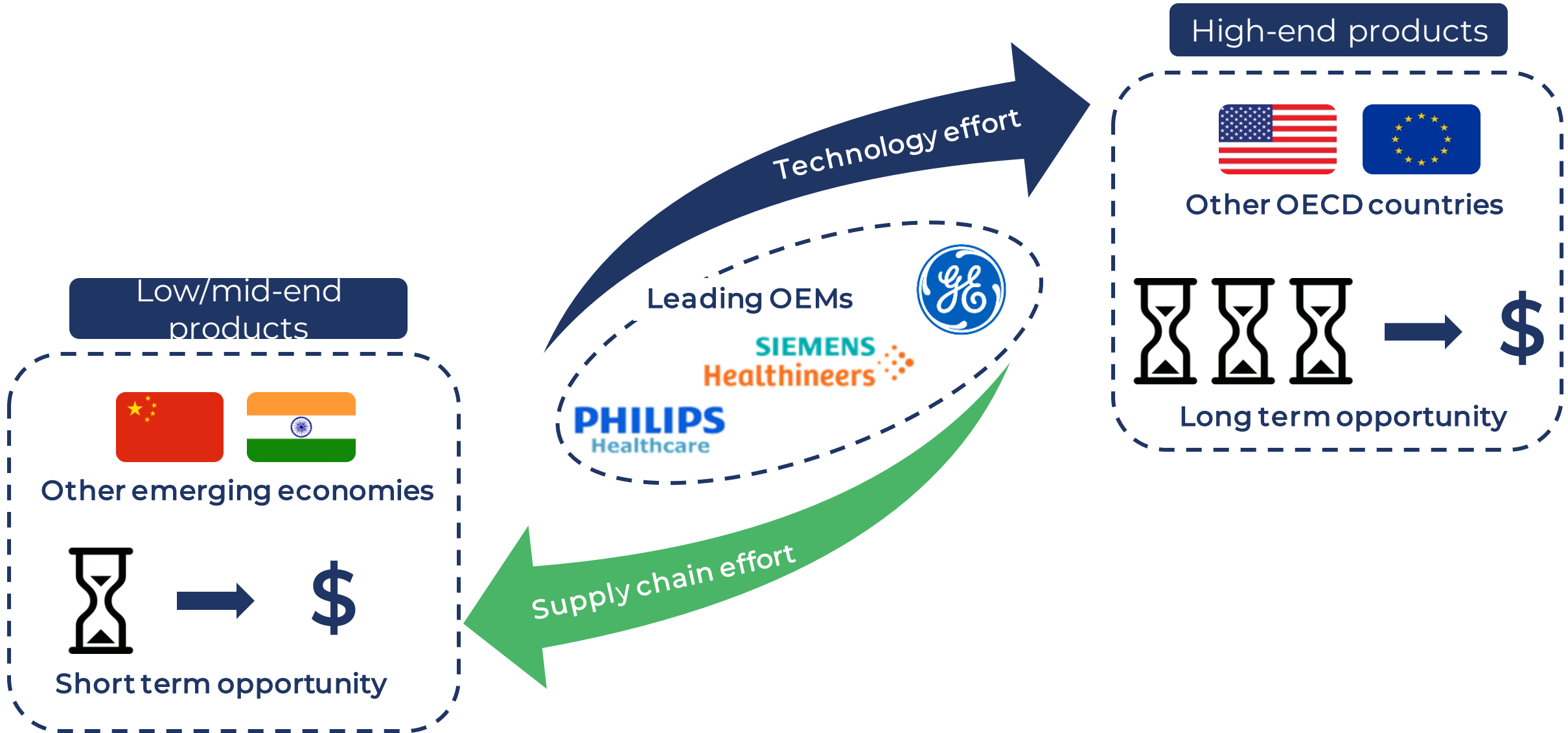
## Multispectral X-Ray imaging – High level of information



## Low dose – Patient safety



# MAJOR FOCUS OF LEADING OEM

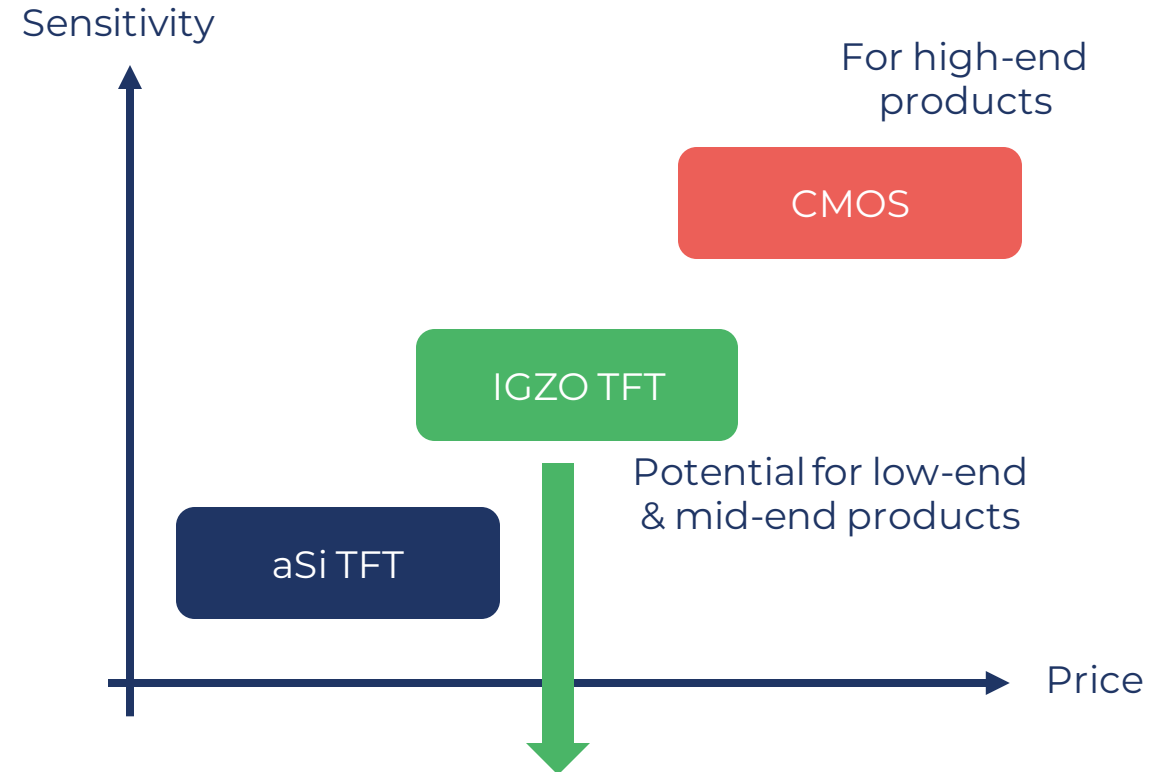


# Technology consequences



IGZO would be a compromise between CMOS and aSi in terms of performance and price.

- Igzo has better absorptive material than aSi TFT
- IGZO is an affordable solution compared to CMOS FPD
- IGZO could be the solution for countries developing their own X-Ray industry



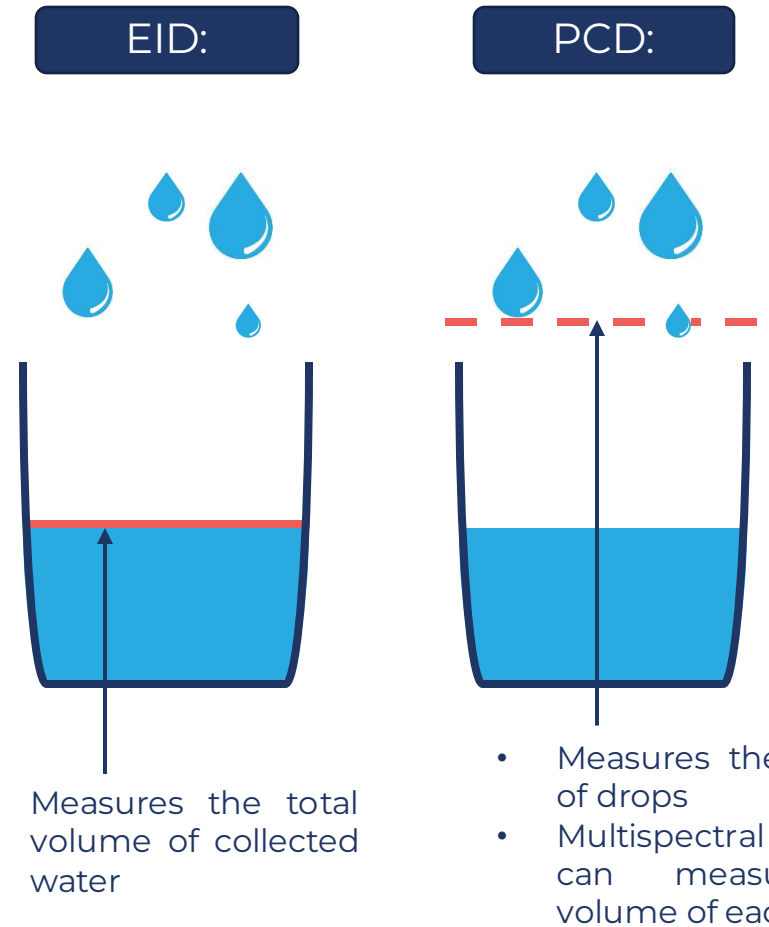
Target applications:

- Interventional, surgery...
- Dental 3D CBCT
- Mammography

# PHOTON-COUNTING DETECTORS

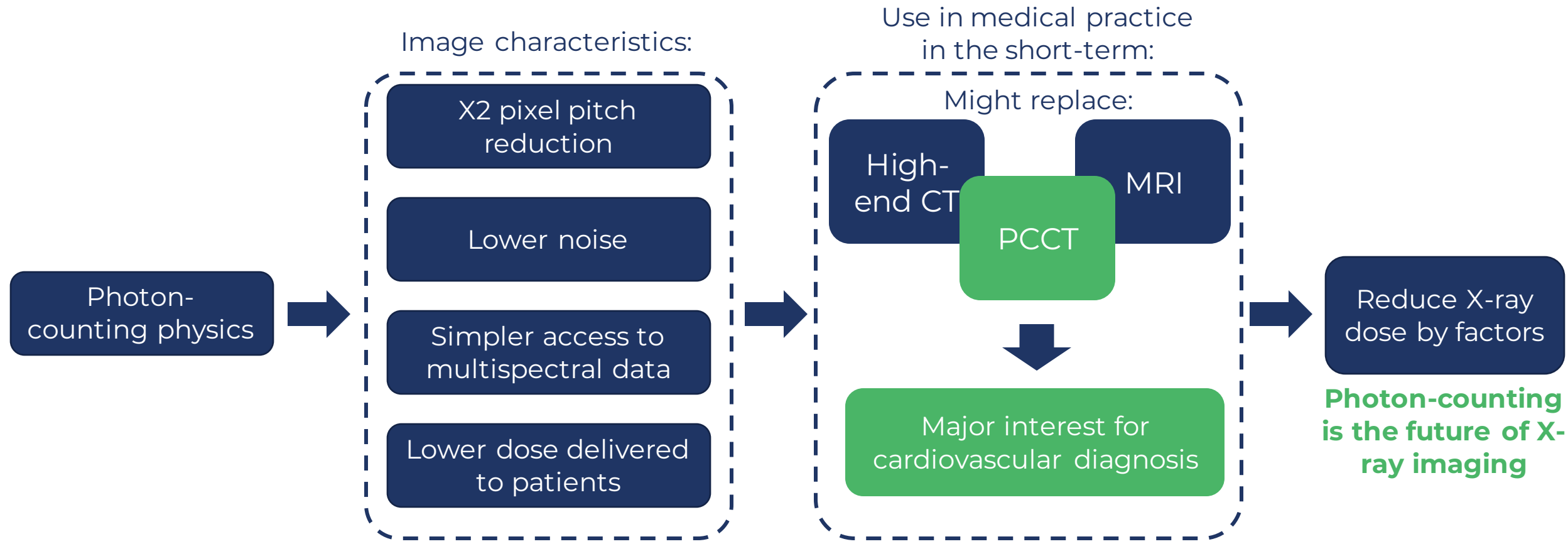
## A paradigm shift in X-ray photon detection

- PCD use energy of photon collected and not the charges
- PCD is based on direct detection
- PCD is counting low-energy photons
- PCD enable drastic decrease of pixel pitch for high resolution
- Higher sensitivity of the PCD crystal and lower noise



In this scheme:

- 1 drop = 1 X-ray photon
- Size of the drop = energy of the photon
- Collected water = electronic charges



# PHOTON-COUNTING DETECTORS

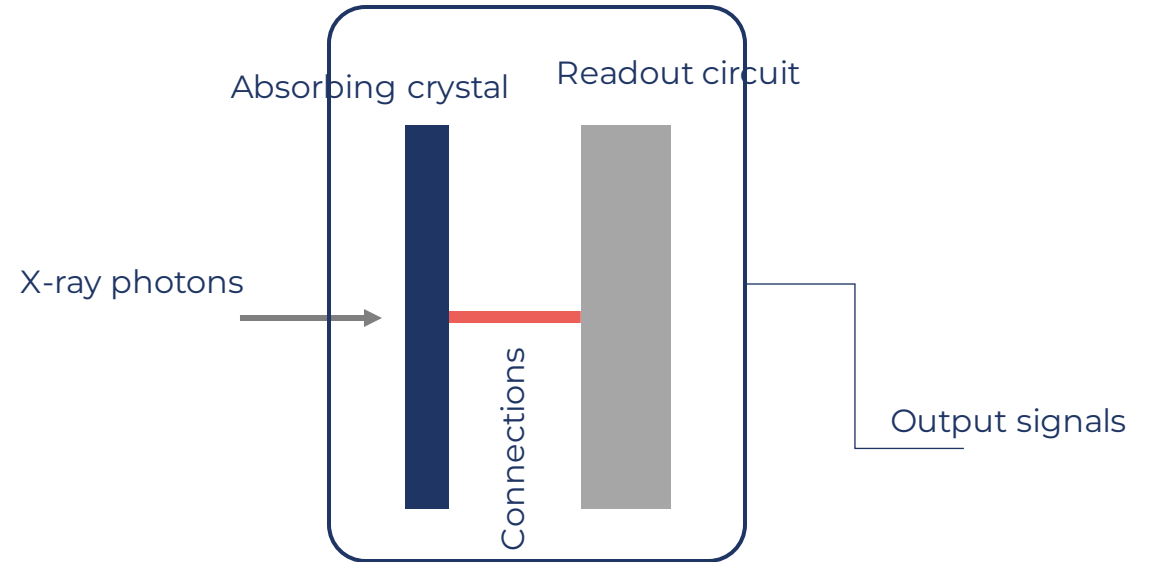
## Technical challenges of PCD design and manufacturing

In PCD, all sub-components are very important for the functioning of the device. Challenges occur at each level of the detector.



source: Siemens

PCD key components:



Components:	Absorbing crystal	Connections	Readout circuit
Technical challenges	<ul style="list-style-type: none"> <li>• Need to be stable to avoid artifacts</li> <li>• Need to be robust</li> </ul>	<ul style="list-style-type: none"> <li>• Fast connections are required to avoid photon piling</li> <li>• Minimize parasite capacitance</li> </ul>	<ul style="list-style-type: none"> <li>• Photon count-rate needs to be fast</li> <li>• Low power consumption</li> <li>• Proper design for energy binning (if multispectral)</li> </ul>

# FOCUS ON PHOTON-COUNTING TECHNOLOGY

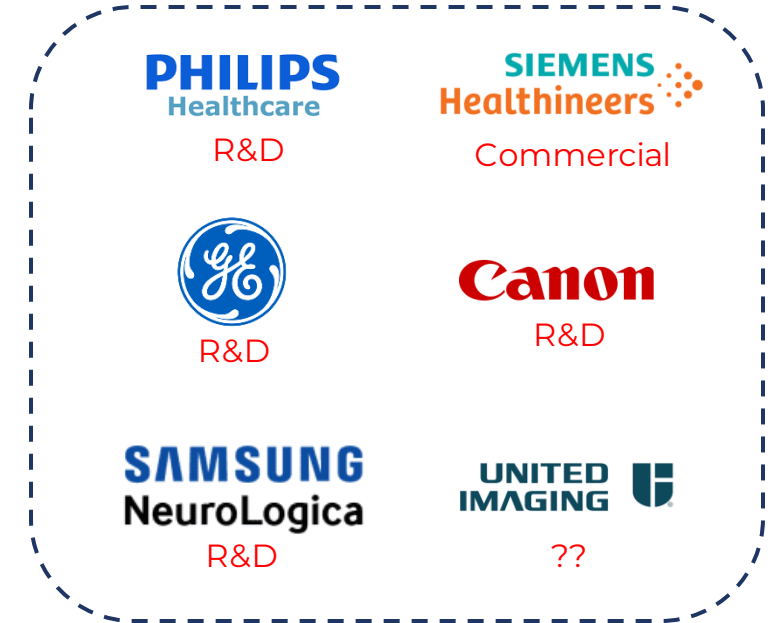
## Ecosystem (non-exhaustive)

- Major OEMs providing medical CT are engaged in photon-counting technology.
- Siemens is the first big company to release commercial medical-grade PCCT.
- In 2018, United Imaging also announced the release of photon-counting technology in the “near future”.
- MARS Bioimaging provides multispectral microCT for medical and biology applications.
- In 2021, Kromek, a CZT supplier, was awarded a \$58M contract with an OEM customer for medical imaging.

### CdTe/ CZT material supplier



### Photon-counting CT scan OEM



### microCT



### Other detector makers



# PHOTON-COUNTING CT SCANNERS

## Tentative roadmap



Siemens released Naeotom Alpha, the first commercial CT scanner based on PCD technology

All major OEMs have commercial photon-counting CT scanners

SIEMENS  
Healthineers

2021

Canon  
PHILIPS

SAMSUNG  
GE Healthcare

2025

2027

2030

Around the 2010s, first clinical prototypes are released by some major OEMs and used in clinical research.

Siemens is the only OEM to release a commercial product in 2021, supplying early adopters and university hospitals. We expect competitors to catch up with commercial products before 2025.

Due to competition, price of PCCT systems drop. PCCT becomes affordable for more practitioners.

PCCT technology starts to penetrate high-end segments, especially for cardiac diagnosis.

PCCT technology matures, prices continue to erode. PCCT starts penetrating lower-end segments of radiology.

Few units for clinical research

Few tens of units per year

Starts reaching few hundred units per year

Reaching nearly one thousand units per year (penetration regime in the high-end)

# Key Takeaway



- X-Ray medical imaging detector industry has reached \$1.78B in 2021, expected to reach more than \$2.1B in 2027 with a CAGR<sub>21-27</sub> of 3%
- Single digit growth expected but new technologies are penetrating existing markets for improvement or replacement.
- IGZO and Photon counting are two of them targeting the challenges of medical imaging.
- Major leaders of medical imaging continue to invest in high-end technologies to serve mainly US and Europe, while China invest to structure its own Digital X-Ray industry.
- And what about Perovskite based technologies ? Computing ? Not discussed here but other challenges for a growing transformation of Digital X-Ray imaging.

# THANK YOU FOR YOUR ATTENTION



[Digital X-Ray Imaging 2022](#)



[Status of the CMOS industry 2022](#)

Thank you for listening, and if you have any question on the presentation or on related topics, don't hesitate to contact me at:

**[Contact: Jerome.mouly@yolegroup.com](mailto:Jerome.mouly@yolegroup.com)**