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Strengths and Challenges of X-ray Diffraction Imaging

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XD*i* stands for **X**-ray **D**iffraction **I**maging

- „X-ray Diffraction" is a well-established scientific method to identify molecular structures in material science and biology

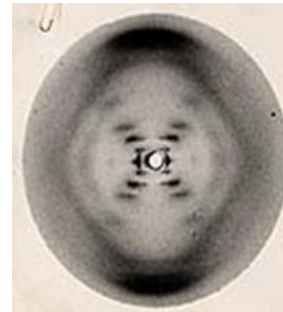- XD*i* enables for the first time using this technology for fast baggage screening
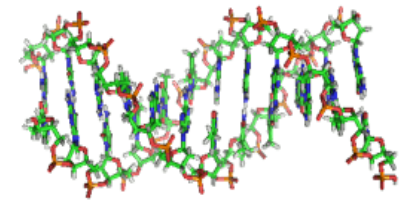
Conventional X-ray imaging

X-ray diffraction revealing crystal structure
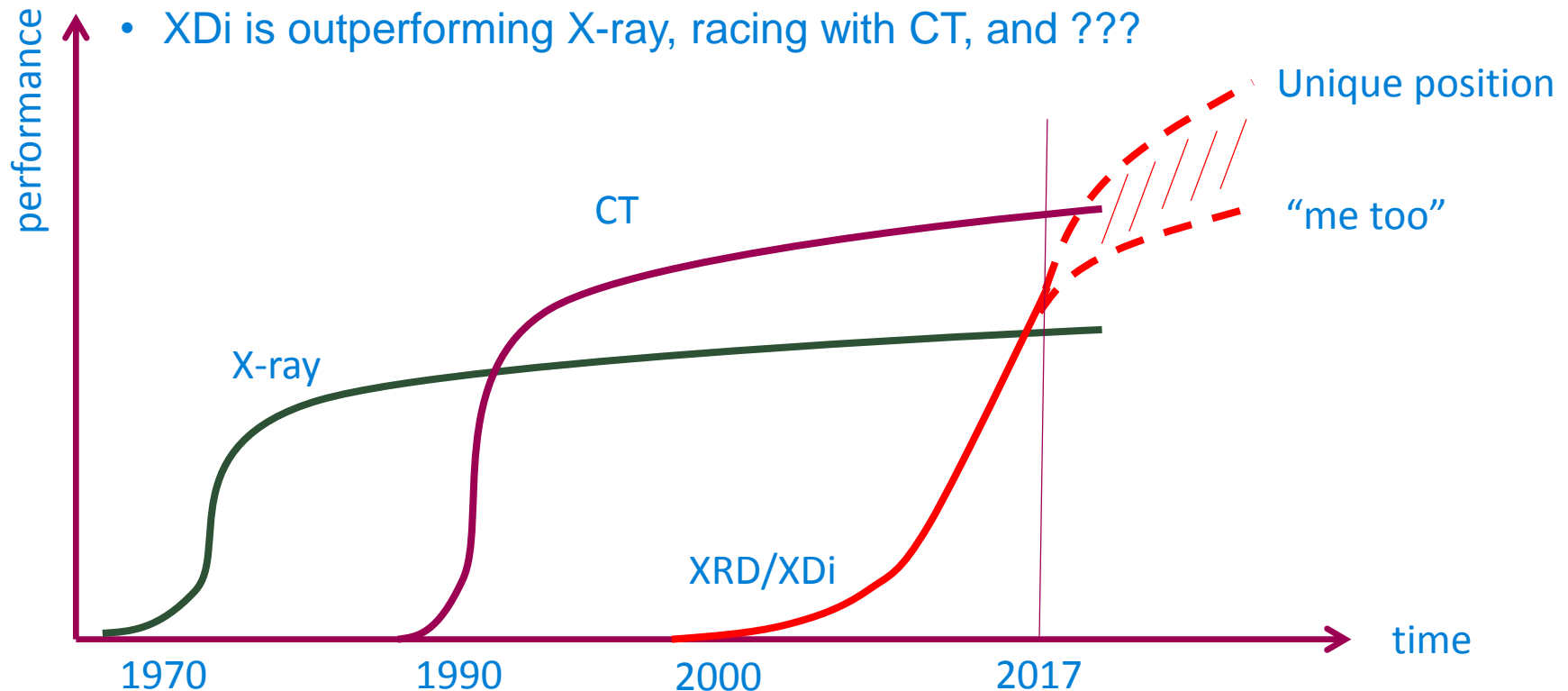
Röntgen 1896
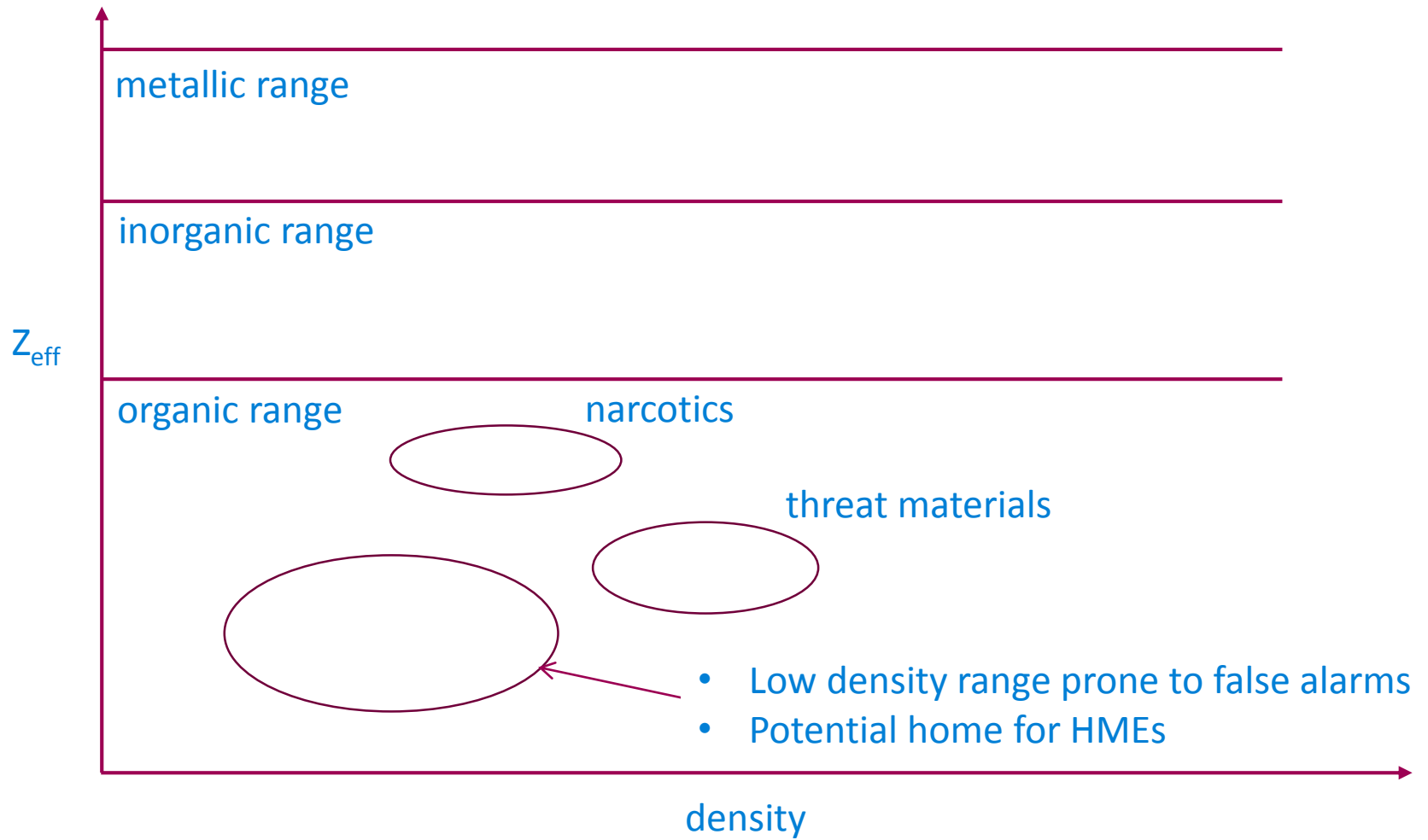
Franklin 1950's   Crick, Watson, Wilkins

Noble prize for DNA structure revealed by X-ray diffraction

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XD*i* - Maturity

- "Performance" is connected to the market & regulatory requirements

- Diffraction is emerging technology

- Performance has not yet reached saturation and the achievable limits are to some extent unknown

- XDi is outperforming X-ray, racing with CT, and ???

performance

Unique position

CT

"me too"

X-ray

XRD/XDi

1970   1990   2000   2017   time

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CT density-Z_{eff} Feature Space

Z_{eff}

metallic range

inorganic range

organic range narcotics

threat materials

- Low density range prone to false alarms
- Potential home for HMEs

density

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X-ray Diffraction: "What difference does it make?"
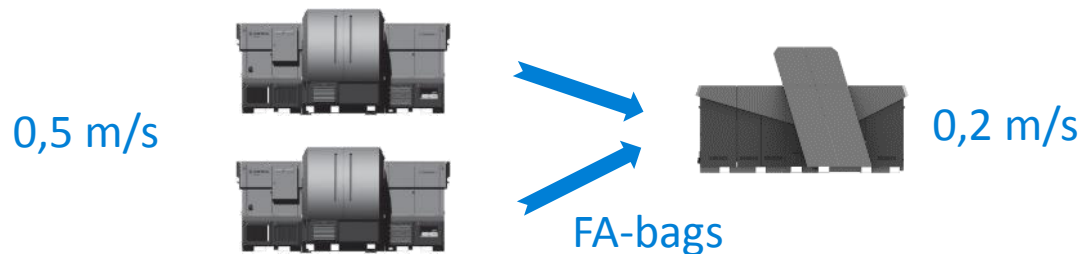
	Feature	Comment
Orthogonal technology to CT / X-ray	XDi is the only method with high penetration, which probes different features than CT	• XDi can be (and is) applied to resolve CT false alarms without just repeating the measurement • As ultimate solution a combination of CT and XDi features can be used for extreme low-false alarm method
Density-independent discrimination	Detection of lighter materials Detection of materials with varying density and Zeff	• Home-made explosives using varying recipes → Recent test @ ICT • Mixing of materials with high/low density/Zeff
Size-independent discrimination	No size discrimination, but material identification	• For CT (and transmission X-ray) size is a very dominant discriminating factor • XDi could sum up all voxels of identical material even if not connected
Material identification	positive identification of other substances (Li-batteries, drugs, currency)	• XRD3500 has already been used at customs (Heathrow) • Study on counterfeit medicine

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XDi – application 1

	Feature	Comment
Orthogonal technology to CT / X-ray	**XDi is the only method with high penetration, which probes different features than CT**	• XDi can be (and is) applied to resolve CT false alarms without just repeating the measurement • As ultimate solution a combination of CT and XDi features can be used for extreme low-false alarm method

Automatic alarm resolution (System of systems)

0,5 m/s

0,2 m/s

FA-bags

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XDi – application 2

	Feature	Comment
Density-independent discrimination	**Detection of lighter materials** **Detection of materials with varying density and Zeff**	• Home-made explosives using varying recipes → Recent test @ ICT • Mixing of materials with high/low density/Zeff
Size-independent discrimination	**No size discrimination, but material identification**	• For CT (and transmission X-ray) size is a very dominant discriminating factor • XDi could sum up all voxels of identical material even if not connected

- XDi „high security" product for checkpoint or HBS
  - Stand-alone or in SoS config
  - Speed 10cm/s – 20cm/s
    (→ May become mainstream?)

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XDi – Status

CBS: Three XDi prototypes operational

- Hamburg, TSL (DHS), Israel (on its way to Soreq)

HBS: One prototype

- Developed under a DHS-funded project

Features:

- Dual energy dual view x-ray images for visual inspection of prohibited items
- Operator workstation and re-check station

Certifications / data collections:

- ECAC C1 achieved, C2 WiP, C1+/C4 prepared
- XDi-HBS DC's and detection algorithms delivered

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XDi – Technical Challenges

- It is (and will always be?): photon statistics translating into speed
  - XDi works in full-bag mode between 10cm/s (today) and 20cm/s
  - Too fast speed "only" generates more dark alarms („photon starvation alarms")
  - Let's have the coded aperture vs. strong collimation discussion now or after the talk

- Detection potholes exist for diffraction as for any other technique, but different and maybe less?

- Technical challenges are decreasing
  - It used to be the detectors, but CZT, CdTe and low-noise electronics work
  - Multi-focus has shown it works @140kV and 180kV
  - Supply chain exists
  - Still: power consumption (~5 – 10kW)

- Cost is comparable or higher than CT

- Usefulness (and therefore success) of XDi depends on application scenario: „fast vs. accurate" (also to consider human factor vs. machine learning)

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Further work: Towards the "real strength"

- Focused experimental tests addressing future security demands
  - Extended threat lists including relevant HMEs
  - Other masses
  - Camouflaged scenarios

- First tests carried out at ICT, Germany

- Working with EU-regulators on proving performance on future standards

- Tests planned for Soreq, Israel, and US test-site

→ **First results show that material-specific detection starts to pay back!**

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Challenges: „You just haven't earned it yet, Baby"

Technology development

- Minimizing technology risk, but less so market risk
- Public Funding opportunities

The sea of no return

Product development

- Decision based on market opportunities & risk
- Internal Funding

!

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Product Development – yes or no?

- Market opportunities are measured in terms of incoming orders in the next *x* years (*x* is a small number)

- Incoming order forecasts are requested from customers

- Estimates are particularly difficult for non-incremental new products, which require change of procedures, ConOps, even lane concepts etc.

- This gives bias towards incremental changes and leaves opportunities for „disruptive improvements" behind

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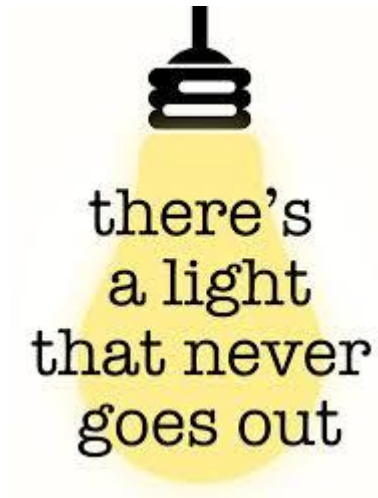
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XDi deployment status

- Technology readiness would enable to develop as a product
  - XDi – CBS within 2-3 years
    - X-ray tube industrialization still defines the critical path
  - XDi – HBS within 3-4 years
    - Continuation of DHS-project would be required
  - (XDi – Cargo within 4-5 years)
    - Patents and concepts exist

- Smiths Detection has decided to discontinue all XDi developments

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Thank you for your attention!

Part of this work was funded by the DHS under contract HSHQDC-11-C-00014

Thanks a lot!

there's
a light
that never
goes out

References

- All image copyrights are with Smiths Detection except

  - Slide 2, hand X-ray:
  https://en.wikipedia.org/wiki/Wilhelm_R%C3%B6ntgen
  - Slide 2, DNA diffractogram:
  http://www.bbc.com/news/health-18041884
  - Slide 2, Helical structure:
  http://banaszakdiabms.weebly.com/genetics.html
  - Slide 11: Sailing fleet:
  Jens-Peter Schlomka, 2017
  - Slide 14: light bulb:
  https://www.touts.com.br/arts/318-there-s-a-light-that-never-goes-out

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