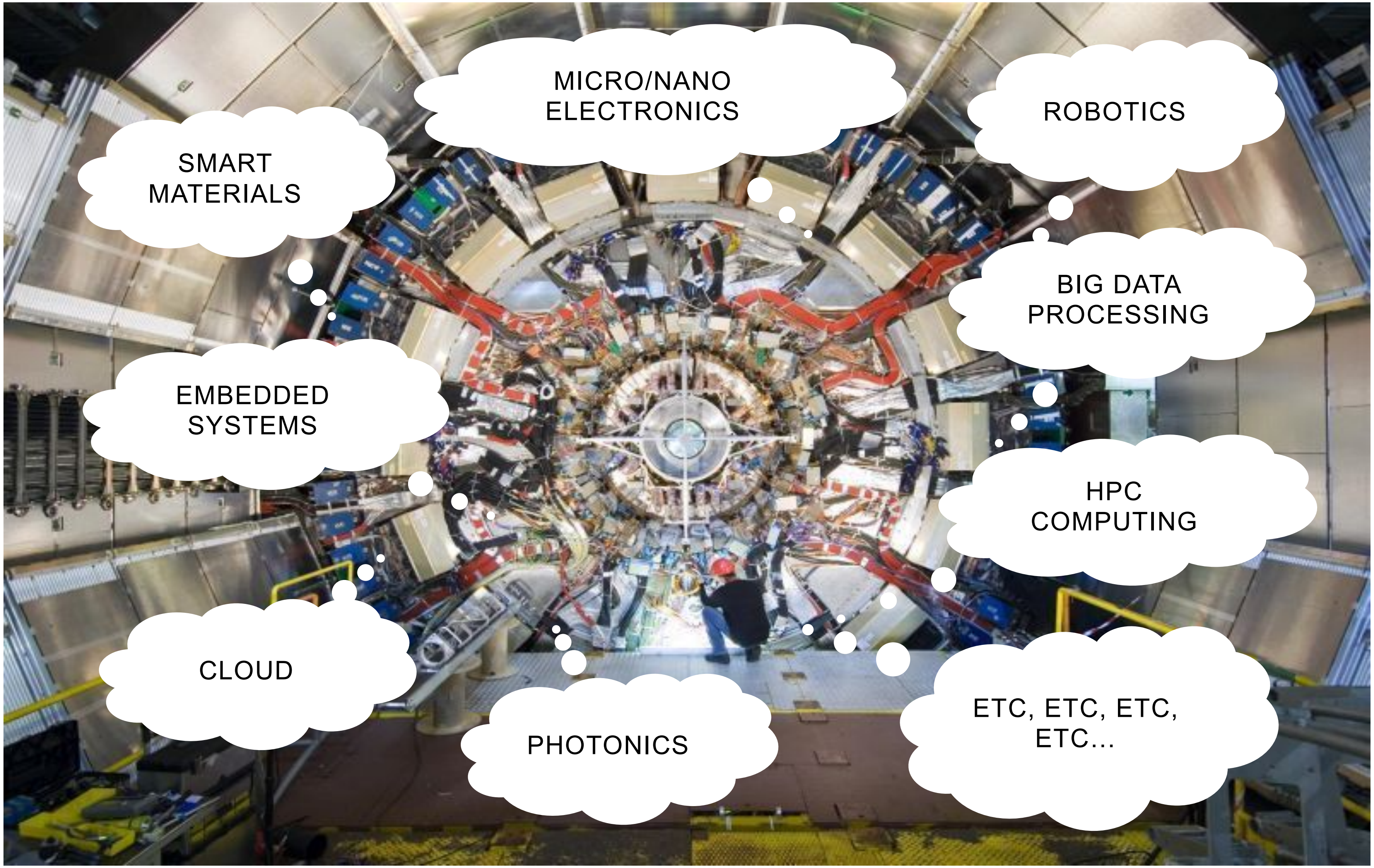
SOME EXAMPLES OF SCIENTIFIC, INDUSTRIAL AND SOCIETAL VALUE OF **DETECTION AND IMAGING TECHNOLOGIES**

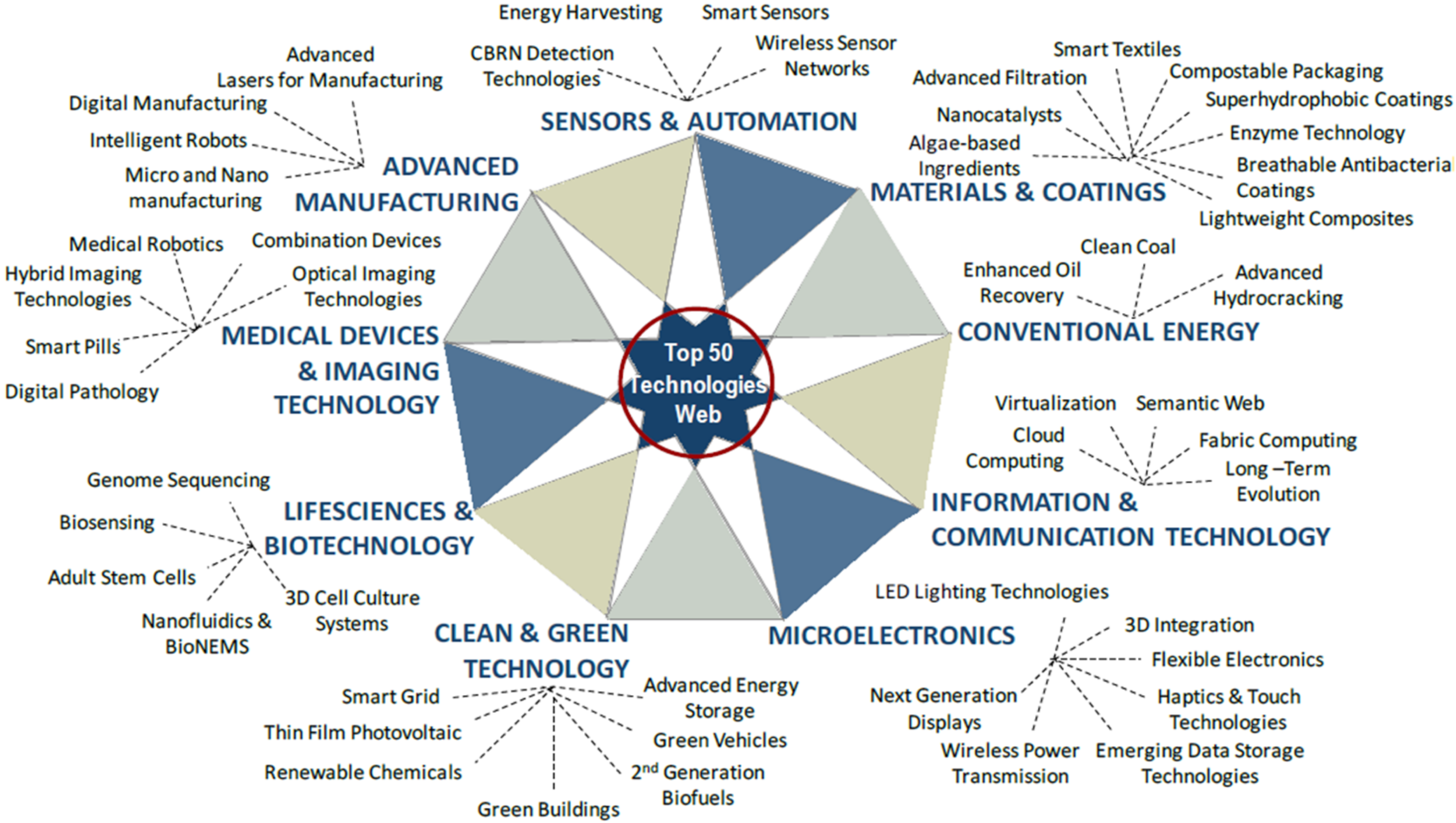
Aalto University | CERN | eirma | EMBL | ESADE Universitat Ramon Llull | ESO | ESRF The European Synchrotron | European XFEL | ILL Neutrons for Science Institut Laue-Langevin

When we consider detection and imaging technologies… What do we talk about?



Example ATLAS Detector, CERN

Difficult to think on a technology not in connection with detection and imaging



Source: Frost & Sullivan, Megatrends in Technology Convergence

4 ideas to illustrate

detection and imaging technologies

...are the backbone for expanding the frontiers of fundamental research

...are and will be fundamental for ourselves and our society

...are at the core of European industrial competitiveness

...translate in direct economic and wealth value in Europe

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FIRST IDEA…
… RESEARCH ENABLERS

A good perspective is considering technological challenges

Frontier research needs breakthrough technologies

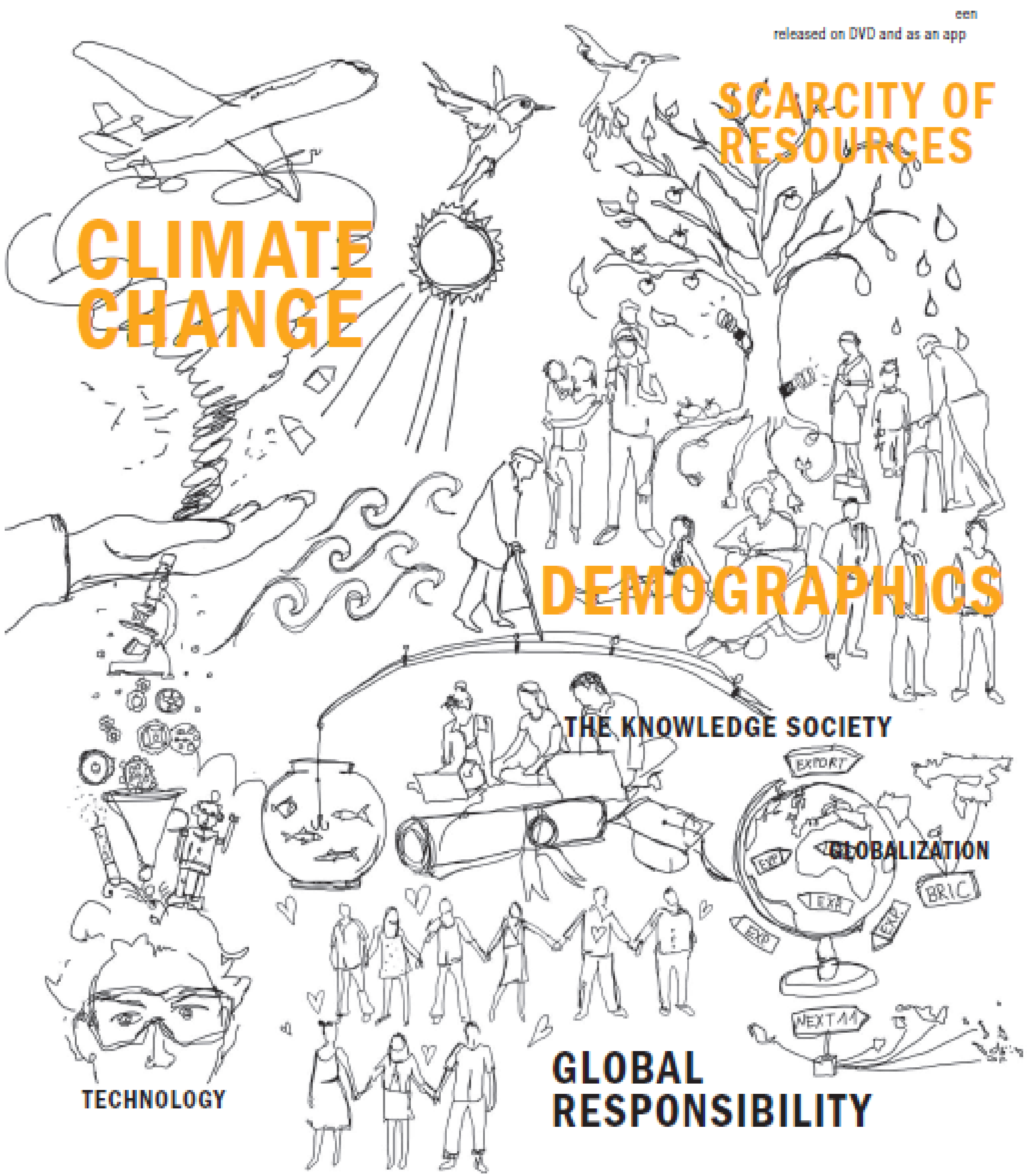
REQUERIMENTS AMONGST FIELDS USING RADIATION DETECTORS

	HEP	SYNC	Neutron ESS	Beam monitoring	Astronomy	Hadron Therapy	Medical Imaging Pre-clinical Imaging	Electron Microscopy	Environmental radiation monitoring IAEA
Radiation type	p, n, y	X-rays	n	p, n, y, e	λ=300nm to 28μm	N, p, y, light ions (protons to oxygen)	X-rays	e	y
Max Intensity	12x10^{15} ncm^{-2}	2700 pulses	10^2 ncm^{-2}	10^{17} ncm^{-2} (p, n) 10MGy (e)	from 1 photon/hour/pixel to 1E9 photons/s/pixel	Conventional Accelerator up to 10^10 ions/s Laser > 10^7/cm2 (ps pulses, low repetition rate ~1/s)	CT: 10^2 $g/mm^3/s$, General X-ray: 10^2 $g/mm^2/s$ Angeiogaphy: 10^2 $g/mm^2/s$ Mammography: 10^2 $g/mm^2/s$	20 Mrads	100μSv/h (~100,000 cts/s)
timing	25ns	4.5 MHz	1us	Sub ns	from 2000 frames/s to 1 frame/hour	Up to MHz (singles rate)	CT: 5000 frames/s General X-ray: - Angeiogaphy: 1-60 frames/s Mammography: -	1000 frames/s	
Pixel size (Min)	50x50 um^2	10x10 um^2	50x50 um^2	50x50 um^2	10μmx10μm	50 um	CT: 10000 mm General X-ray: 150-200 mm Angeiogaphy: 150-200 mm Mammography: 85 mm	10x10 um^2	
Spectral resolution	yes	yes	no	yes	no, moderate possible with APD	yes	Today: not used Future: yes	yes	<1.5% @ 662 keV
Detector size (max)	2500 m^2 (ILC cal)		80 m^2	100 cm^2	Optical 9Kx9K NIR 4Kx4K	40x40 cm^2	CT: 10x100 cm^2 (segmented) General X-ray: 43x43 cm^2 Angeiogaphy: 30x40 cm^2 Mammography: 24x30 cm^2	8Kx8K pixels	6 cm^2

Cinzia Da Via, ERDIT – Freiburg im Breisgau 7-8 April 2014

The table summarises some of the great challenges identified by the basic research communities

European Radiation Detection and Imaging Technology Platform http://erdit.eu/



SECOND IDEA… SOCIETAL VALUE

A good societal perspective is considering megatrends

Megatrend: Connectivity & data traffic

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By 2020

80 billion connected devices

9 billion mobile phones

5 billion internet users

5 connected devices per individual

10 connected devices per household

500 devices with digital IDs per square kilometer

Challenge

How to take advantage of the Data Deluge?

How to deal with data traffic?

Detection and imaging technologies

Today

Hardware & Software technologies developed at European Research Infrastructures today are capable of analyzing terabytes of data each year

They are the equivalent of the content in:

- 7 km of CD-ROMs stacked on top of each other
- 600 years of listening to songs

Tomorrow?

Megatrend: Personalised medicine

By 2020

The number of people who develop cancers in Europe is expected to grow to 3.4 million each year by 2020, a 20% increase from 2002

…by 2050, healthcare spending will double, claiming 20-30% of GDP for some economies

Challenge

How to accurately predict, prevent, personalize?

Detection and imaging technologies

Today

European Research Infrastructures Chip technology has been applied in X-ray CT, in prototype systems for digital mammography, and for beta and gamma autoradiography of biological samples

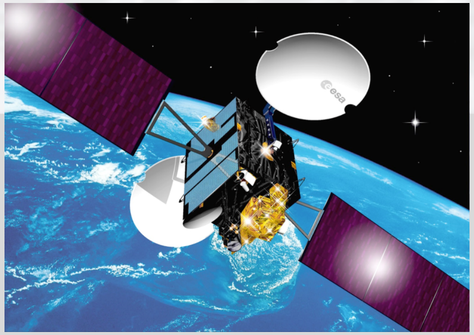
Tomorrow?

Megatrend: Space use

By 2020

By 2020, there will be approximately 927 newly launched Satellites (Communication – 405; Earth Observation – 151; Navigation – 85; Reconnaissance – 212 and R&D 75)

Challenge



How to increase life time (Space Jam), reliability and performance?

Detection and imaging technologies

Today

Radiation hard ASICS and FPGA technology developed at European Research Infrastructures can be one of the keys

Tomorrow?

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Megatrend: Air mobility

By 2020

Over the 2009-2028 period, world passenger traffic is expected to increase by 4.7% per annum,

(Airbus 2009-2028 Global Market Forecast)

Traffic demand will nearly triple, and

airlines will more than double their fleets

Challenge

How to keep technology leadership of Europe's Aeronautical Industry?

Detection and imaging technologies

Today

Optoelectronics sensing technology developed for fundamental research allows for innovative real time in flight aircraft health structure monitoring.

Tomorrow?

Megatrend: Zero emissions

By 2020

In 2002, the global data center Footprint was 76 MtCO2e and this is expected to more than triple by 2020 making it the fastest-growing contributor to the ICT sector's carbon footprint.

Challenge

How to achieve a zero emission ICT industry and contribute to reduce CO_2 footprint in other industrial sectors?

Detection and imaging technologies

Today

Hardware (i.e. micro-cooled ASICS) and software (i.e. cloud computing) technologies developed for large RI instruments can be put to work for reducing global CO_2 footprint.

Tomorrow?

THIRD IDEA…
INDUSTRIAL COMPETITIVENESS

A good industrial perspective is considering examples of applications

Data management and real time monitoring of gas turbines

Modules

Online-Data: ca. 5,000 variables / s

Real-time Data Analysis (1,000 Neural Models)

Database: Input data and model results

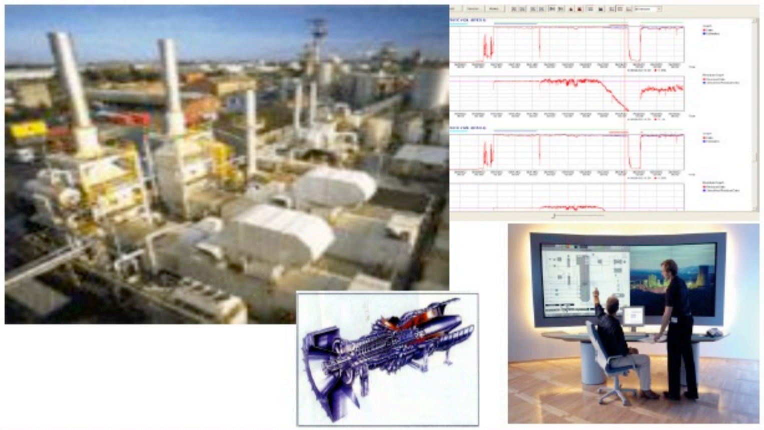
Complete Data and Dependency Analysis
plus Learning Optimization

Benefits

- Improved turbine ramp-up with less vibrations (lower maintenance needs)
- Reduced NOx Emissions
- Increase of turbine efficiency
- Guiding turbine development process

SIEMENS

Real time monitoring of power plants



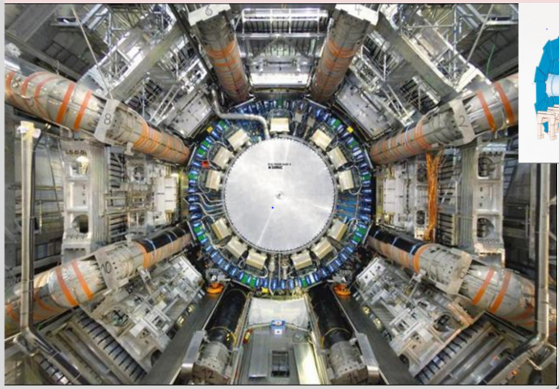
Condition monitoring platform that predicts failures by
- learning from historical data and trends
- incorporating it with user defined rules and knowledge

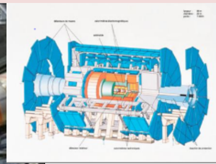
Benefits

- Detect failures and fatigue in advance
- Alert service operators upfront before damage occurs
- Mitigate the risk of long term service contracts
- Increase the efficiency of remote monitoring operations

Detection and imaging technologies

- ✓ *Enabling **cost & production cycle time** reduction*
- ✓ *Enhance **in-service inspection** capabilities*
- ✓ *Quality assessment of **adhesive bonding***





From Big Science, e.g. Optronics developed at CERN…

S

M

L

2020

- **Quality assessment of adhesive bonding in composite structures**
- **Reduced NDT: Process Health Monitoring**
- **NDT Modelling for cost reduction**

2017

- **Low power, one-sided inspection**

2014-16

- **Fast inspection of complex CFRP structures**
- **Quick impact assessment after accidental damage in CFRP**
- **Structure Health Monitoring for accidental damage**
- **NDT techniques for CFRP repair**
- **Waviness characterisation and detection techniques**

2015

- **X-ray Computed Tomography**
- **Online Maintenance Assistance**

… to applied technologies in short-, mid- and long-term development

Slide courtesy of Airbus

Airbus product needs

Today	2015	2020	2025	2030	Beyond 2030

** Project studies*

e.g. opto-electronics for sensoring

e.g. opto-electronics breaking ground

e.g. next generation of opto-electronics

e.g. sensing structure

R&T stream:

Today

Introduce mature solutions and technologies

- **Get improve-ments in RC** reduction
- Correct in service problems

Short-term

Introduce mature solutions and technologies

- Secure route to performance target
- Support ramp-up
- Get improve-ments in RC reduction

Mid-term

TRL6 target 2016-2018

Develop **incremental derivatives offering better performance** introducing

- Low cost technologies
- Low weight solutions
- Short ROI
- High volume production

Long-term

TRL6 target beyond 2020

Explore **new configurations for a game changer**

- New architecture
- New propulsion system
- New passenger experience

Airbus is highly active on "translating" Big Science into Applied Technology!

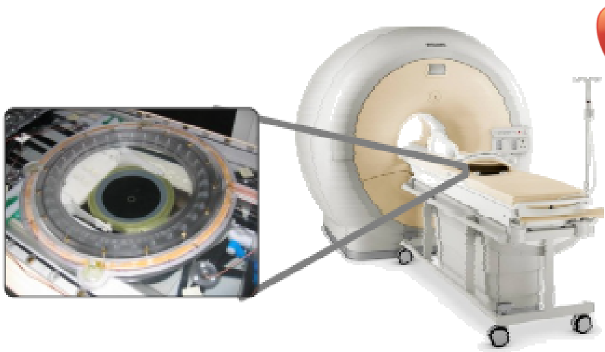
Slide courtesy of Airbus

RC: recurring cost; ROI: return of investment

PHILIPS

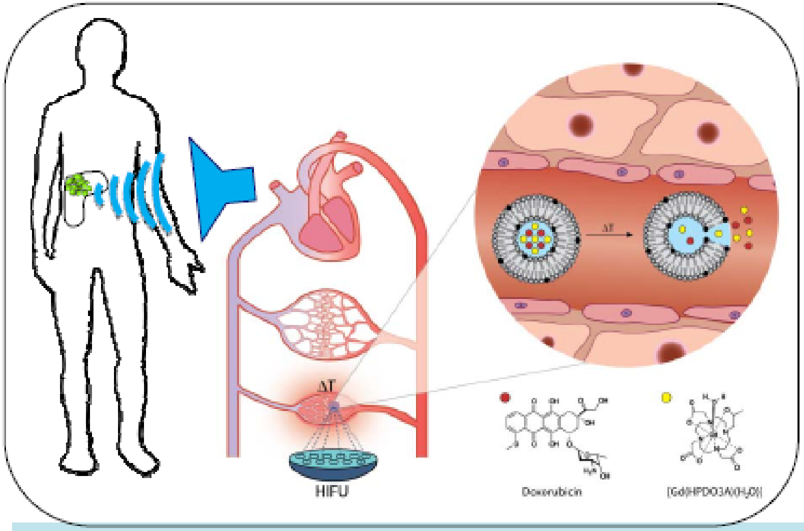
Convergence of technologies

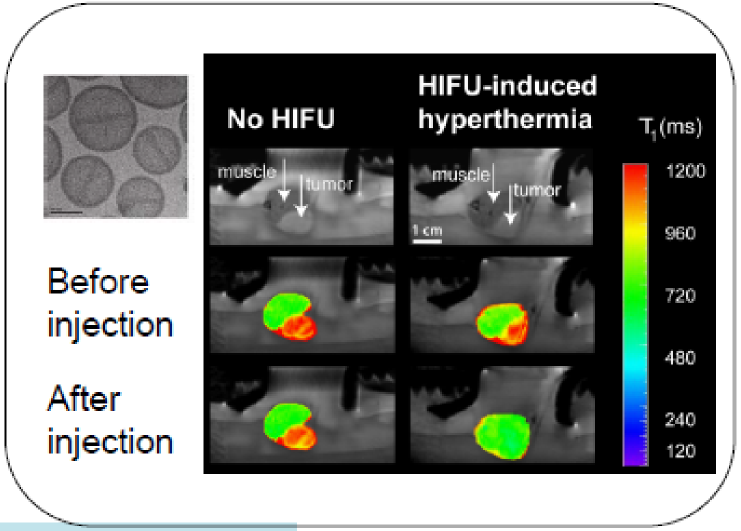
Bio + Nano = Nanomedicine



Local Tumor Therapy using MR-HIFU

- *Thermal ablation at temperatures of >65 ºC*
- Local hyperthermia at 42 ºC in combination with local delivery of drug in temperature sensitive liposomes





- **New therapeutic options**
- **10-20 x higher drug concentrations in the tumor**
- **Improved efficacy at equal or reduced side effects**

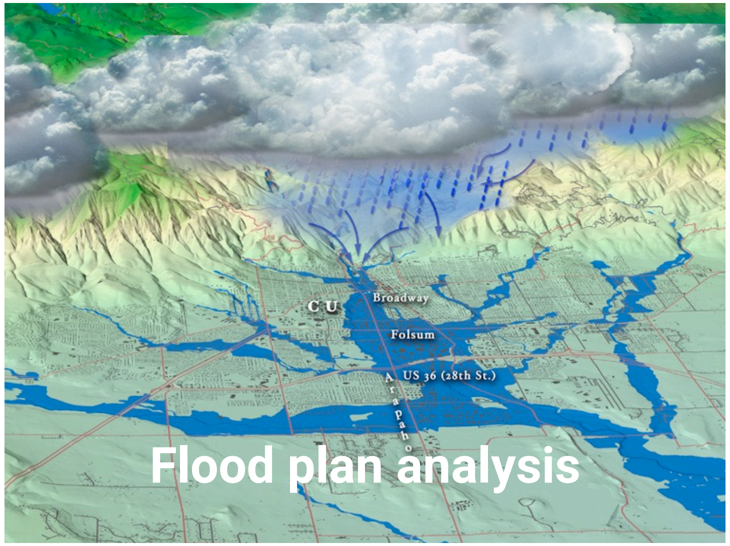
TU/e Technische Universiteit Eindhoven University of Technology

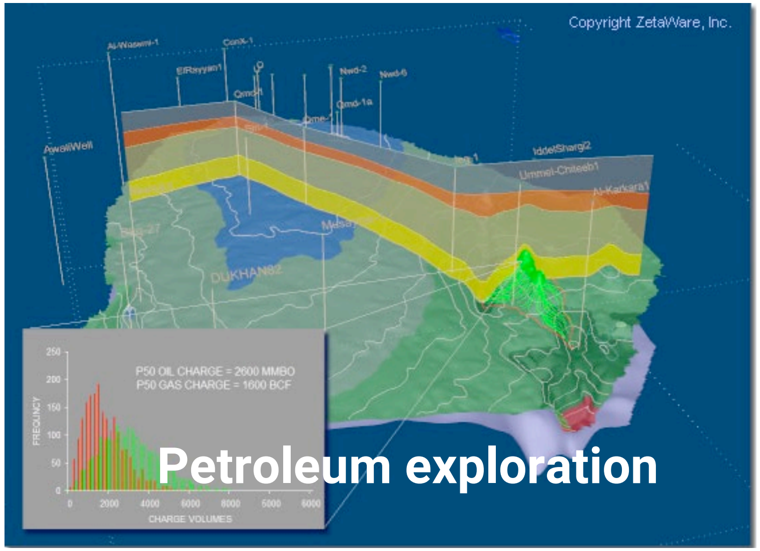
SONODRUGS

Sonalleve MR-HIFU is a medical system developed by Philips Healthcare. The system uses non-invasive high-intensity focused ultrasound (HIFU) guided by magnetic resonance (MR)

Data coming from sensing & imaging needs to become information

Example of treatment of geospatial data

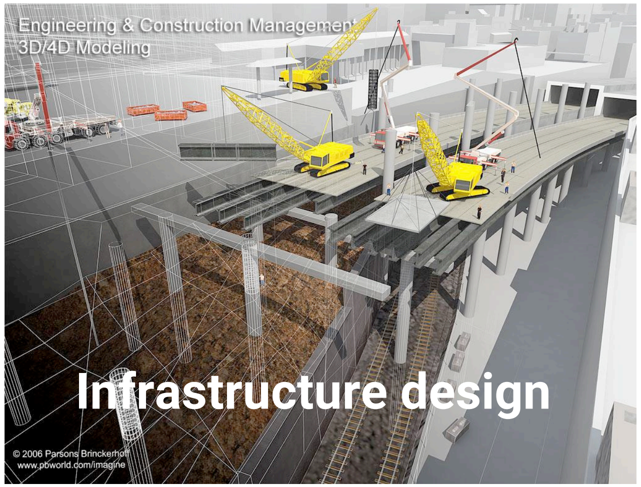




Oracle Spatial 11g

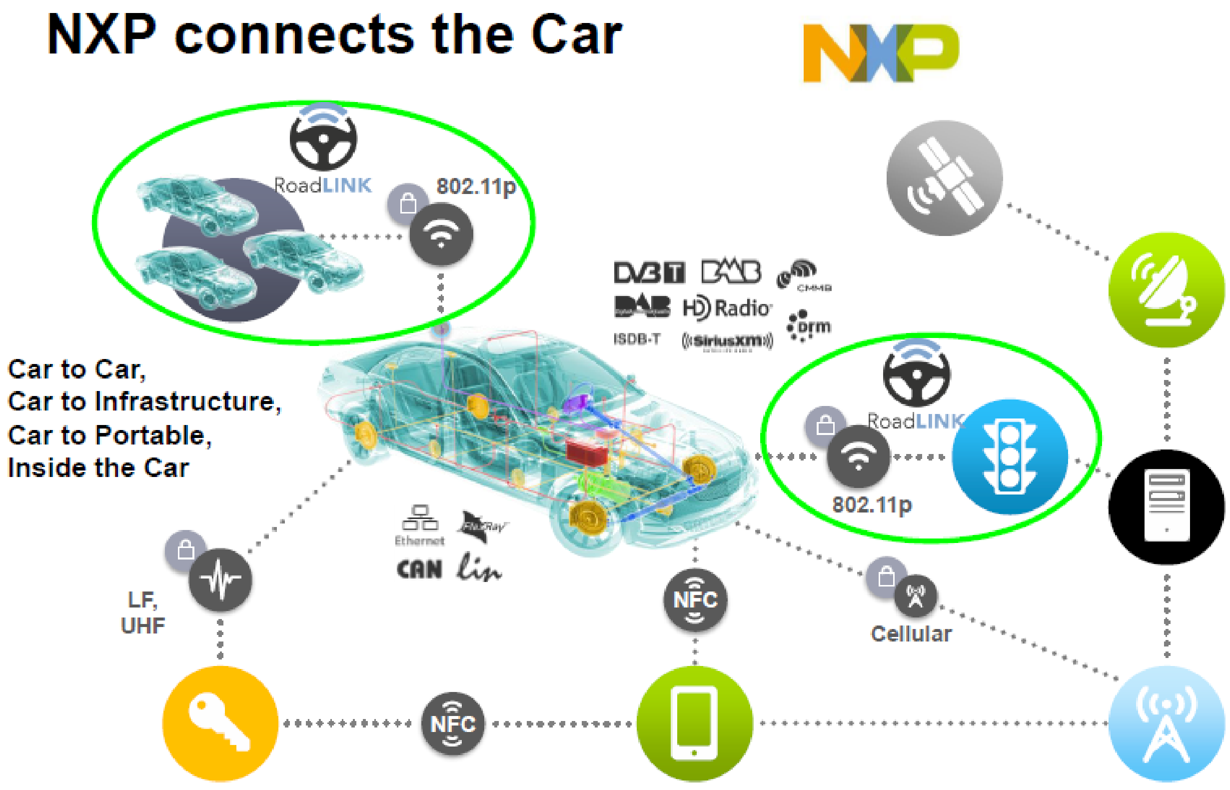
3D applications

- Location-based services
    - Augmented reality
- GIS Analytical modeling
    - Terrain (2.5D) and 3D objects
- City planning/administration
- Infrastructure design
    - Accurate descriptions of objects



Towards Intelligent Transport Systems (ITS)

Example



Example of **key challenges** directly related to **sensing and imaging technologies**

- Car-car and car-infrastructure communication network
- Safety
- Traffic/energy management & emissions reduction

GE
Sensing & Inspection Technologies

ATTRACT

Example oil & gas large infrastructures

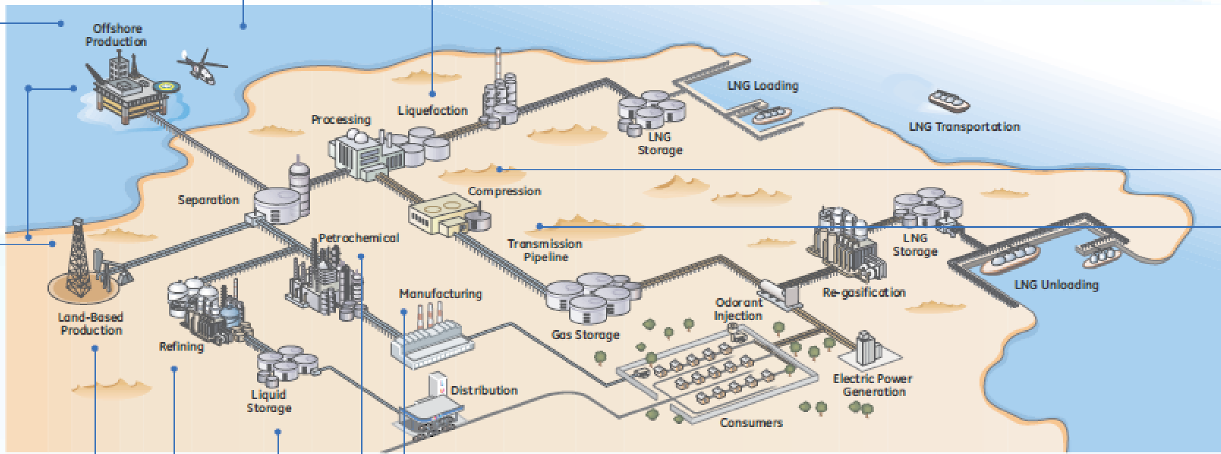
GE
Inspection Technologies

Subsea pipelines
Our radiographic, eddy current and ultrasounic devices are often deployed by clients working subsea to assess the in-service integrity of pipes and risers.

Liquefied Natural Gas (LNG) liquefaction
Rotating equipment requires regular non-intrusive inspections to help ensure the safe working of the machines. GE provides a comprehensive suite of remote visual and eddy current systems and unique software tools to provide improved quality of inspections and immediate reporting. For new LNG projects, a large number of welds need to be inspected to ensure weld quality. GE provides a full suite of radiography and ultrasonic systems for high quality weld inspection.

Compression stations
Rotating equipment requires regular non-intrusive inspections to ensure the safe working of the machines. GE provides a comprehensive suite of remote visual inspection and eddy current systems and unique software tools to provide improved quality of inspections and immediate reporting.

Re-injection stations
Rotating equipment requires regular non-intrusive inspections to help ensure the safe working of the machines. We provide a comprehensive suite of remote visual inspection, eddy current systems and unique software tools to provide improved quality of inspections and immediate reporting.



Offshore and land-based production
Asset integrity management and asset life extensions require inspection to provide assurance of component integrity and regulatory compliance. We have a complete portfolio of inspection technologies, including continuous erosion/corrosion monitoring, remote visual inspection, digital radiography, ultrasonic thickness gauges and flow detectors, X-ray technology and eddy current to inspect pipes, vessels and parts of a rotating plant.

Transmission pipeline
From upstream through downstream, we have a range of testing and inspection products for transmission pipelines. In the pipe mill, we provide testing machines to ensure material and weld quality. In the construction phase, we provide automated ultrasonic and portable X-ray and digital/film solutions. For in-service inspection, we offer continuous monitoring, portable ultrasonic and remote visual inspection devices.

Reservoir engineering
With high resolution CT, the spatial distribution of the pore network in a drilling core can be visualized and analyzed. Clear knowledge of such a pore system is of utmost importance in the field of reservoir engineering.

Manufacturing
We design, manufacture and support a full range of testing machines for plate, billet, bar and pipe inspection using ultrasonic and X-ray technology.

Petrochemical
Nondestructive testing and inspection are a critical part of maintenance and process management to optimize the safe operation of a petrochemical facility. Our solutions offer high temperature corrosion monitoring of critical locations and piping, vessel and rotating plant inspections using ultrasonics, remote visual inspection, eddy current, digital radiography and X-ray.

Liquid storage
Storage tanks require inspection to help ensure they operate safely and within the regulatory standards. We have tools for large area remote visual inspection and ultrasound technology for checking remaining wall thickness and weld quality.

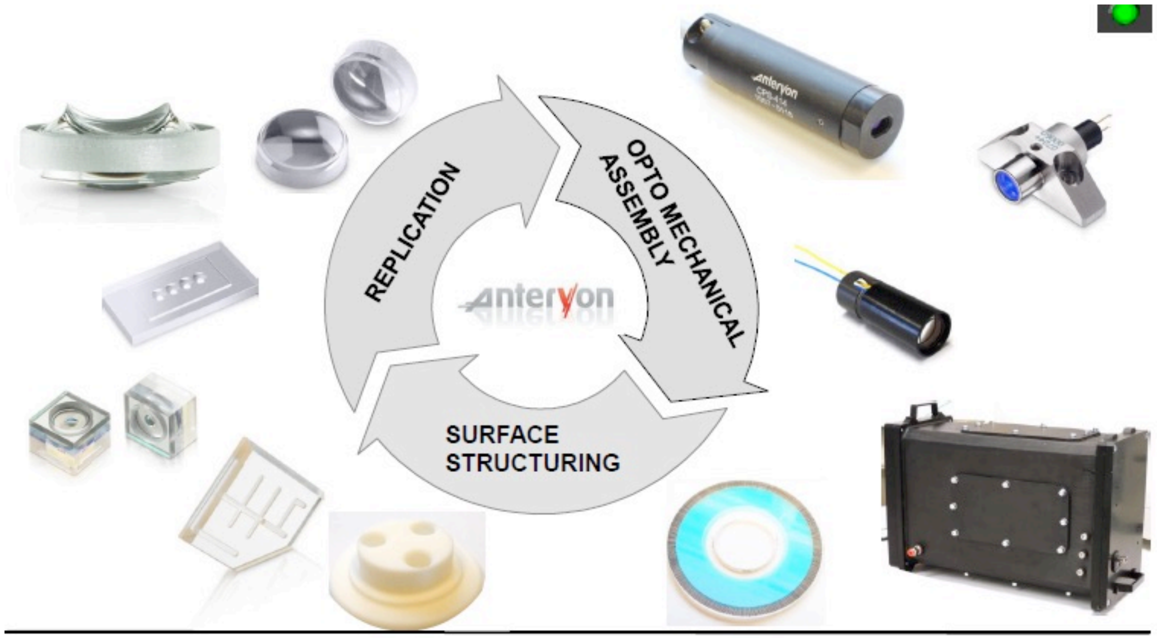
Refining
Inspection is a critical aspect of maintenance and process management to help enable the safe and optimized operation of an oil refinery. We provide inspection technologies for high temperature corrosion monitoring of critical locations and piping, vessel and rotating plant inspections using ultrasonics, remote

Example sensing & imaging for industrial manufacturing

Monitor wear debris contamination by detecting the particle size, shape, and elemental composition

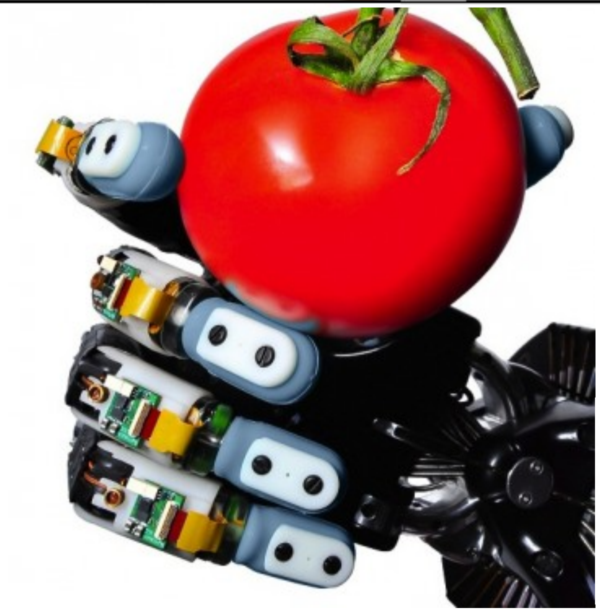
The ability to monitor wear debris contamination in oils and other fluids can result in **longer and more efficient engine function**

SMEs are key as well in manufacturing advanced sensing and imaging technology



Example Anteryon

- Optical components
- Opto-mechanical assemblies
- Etc



Shadow Dexterous Hand has 20 actuated degrees of freedom, position and force sensors, and ultra sensitive touch sensors on the fingertips

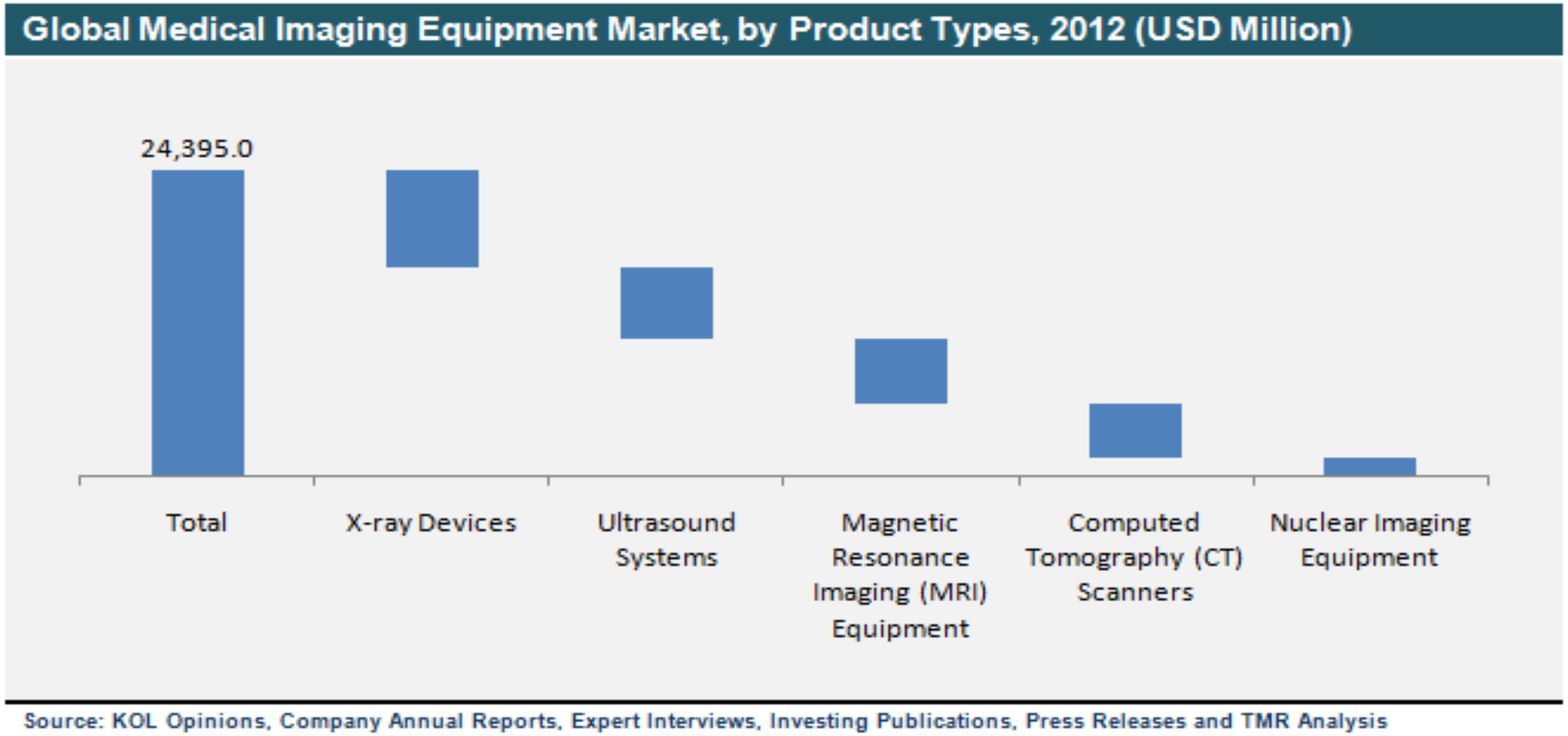
Shadow
Robot Company

FOURTH IDEA…
ECONOMIC AND WEALTH VALUE

A good perspective is considering markets

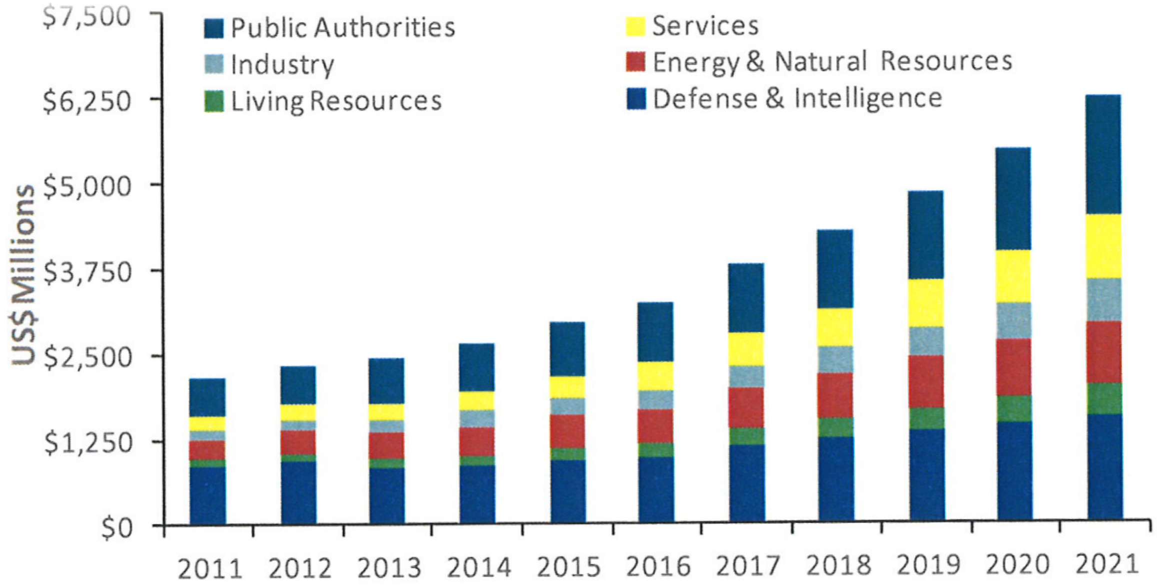
Example: Medical imaging

- The global medical imaging equipment market in 2012 was valued at USD 24.39 billion
- Expected to reach a market value of USD 35.35 billion by 2019
- Siemens Healthcare, Philips Healthcare and GE Healthcare accounted for more than 50% of the total market

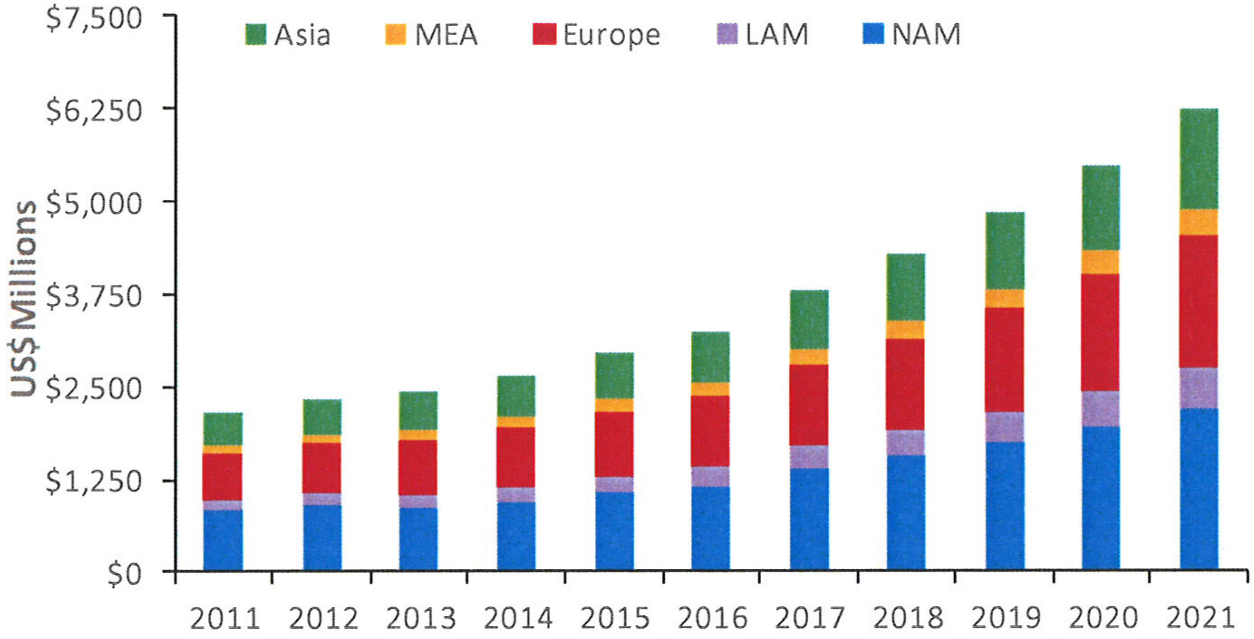


Source: Transparency Market Research published new "Medical Imaging Equipment Market - Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2013 - 2019" http://www.transparencymarketresearch.com/medical-imaging-equipment-market.html

Example: Satellite imaging, Earth observation



Global Satellite Earth Observation projected to reach 6.2 USD billion in 2021 from 2.1 USD billion in 2011



Expected growth in Europe similar than North America (NAM)

Source: Northern Sky Report 2012

Example: Open data (1)

Completely open — More liquid — Completely closed

	Completely open	Completely closed
Degree of access	Everyone has access	Access to data is to a subset of individuals or organizations
Machine readability	Available in formats that can be easily retrieved and processed by computers	Data in formats not easily retrieved and processed by computers
Cost	No cost to obtain	Offered only at a significant fee
Rights	Unlimited rights to reuse and redistribute data	Re-use, republishing, or distribution of data is forbidden

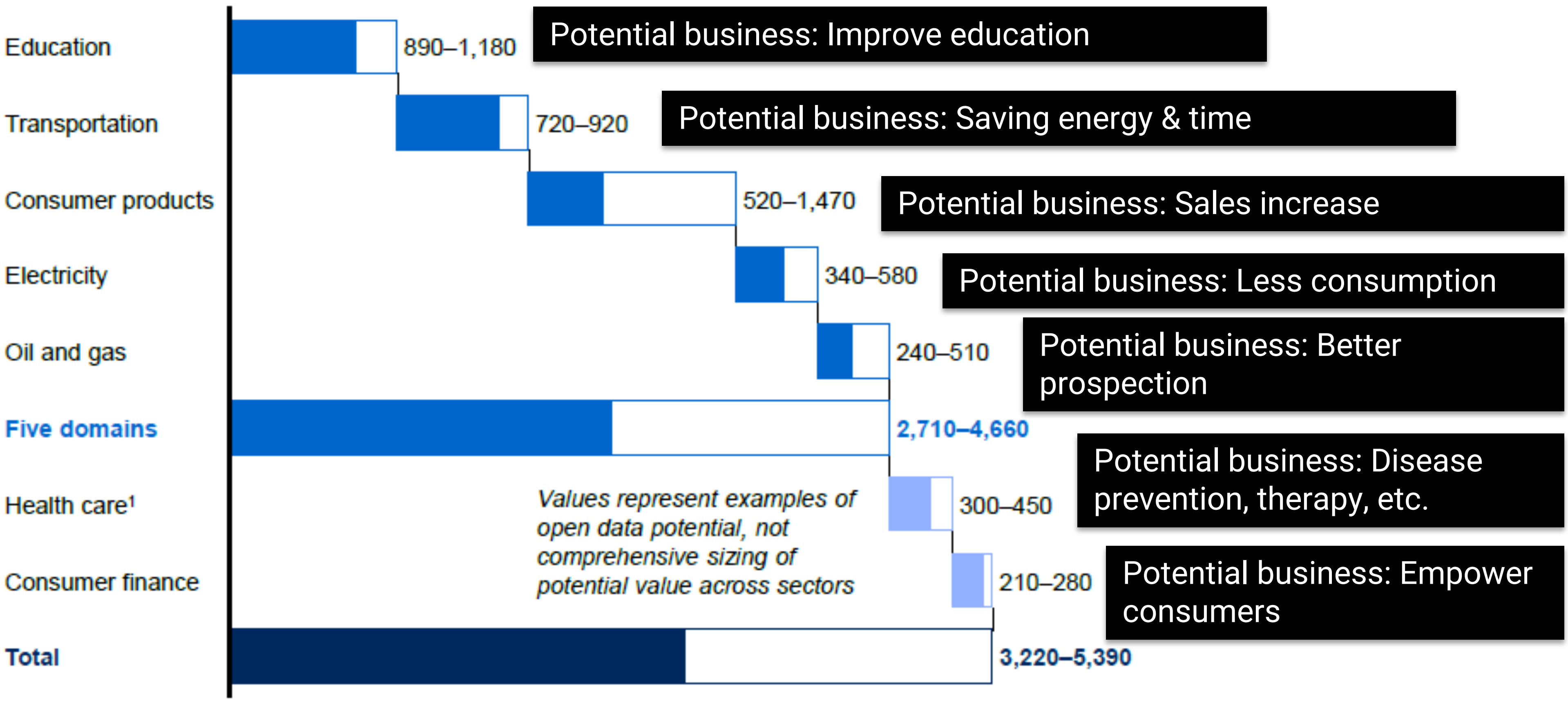
SOURCE: McKinsey Global Institute analysis

Europe counts with strong players like SAP, Atos, Telefonica, etc. but
we need to keep innovating!

Example: Open data (2)

Open data can help unlock $3.2 trillion to $5.4 trillion in economic value per year across seven "domains"

$ billion



1 Includes US values only.

NOTE: Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

Conclusions

Detection and imaging technologies are key enablers for reaching Europe's 2020 Agenda goals

- …are fundamental frontier research enablers
- …are and will be fundamental for ourselves and our society
- …are at the core of European industrial competitiveness
- …translate in direct economic and wealth value in Europe