

SMART SENSORS

Smart sensors in process analytical technology applications of the future

Tobias Eifert, [Kristina Eisen](#), Michael Maiwald, Christoph Herwig

3rd European Forum on New technologies – Plant of the Future, EFCE

WHO WE ARE

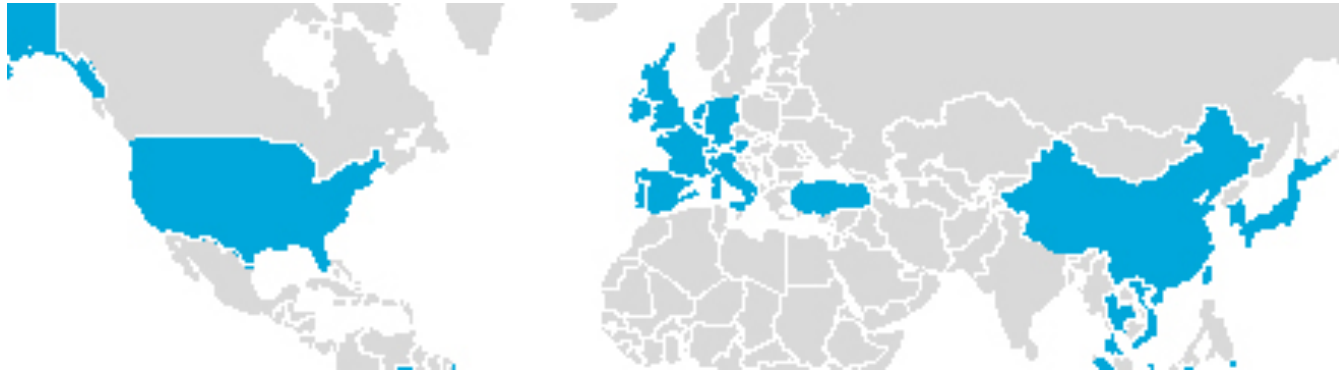
Working group Process Analytical Technology by GdCh and Dechema:

- **Topical leader** in the field of process analysis and process analytical technology in the DACH region
- **Experts** from three sectors: user, manufacturer, and academia
- Knowledgeable **network**
- **Professional start** into PAT especially for young analysts

We support process analysis by:

- Subject-specific **education** and training
- **Networking**
- Support and spreading of **new technologies**
- Support of technological **market access**
- Establishment of **new applications**

DAIICHI SANKYO EUROPE GMBH



- Global pharmaceutical company based in Japan
- 15.000 employees
- New and generic medicines
- New methods of drug discovery and delivery
- Passion for innovation, compassion for patients
- Global production and development site in Pfaffenhofen a.d. Ilm
- More than 80 million blister and about two billion tablets each year, soon also oncology products



COMPLEX INDUSTRIAL NEEDS

- Shorter product cycles
- Flexible production
- Direct assessment of
 - product quality attributes
 - raw material attributes
- Transparent life cycles
- Efficient and sustainable production
- General need of SMART production strategies
- Particular need of new and holistic process analytical technologies (PAT) concepts

PUBLICATIONS IN ABC

Analytical and Bioanalytical Chemistry
<https://doi.org/10.1007/s00216-020-02420-2>

FEATURE ARTICLE



Current and future requirements to industrial analytical infrastructure—part 1: process analytical laboratories

Kristina Eisen^{1,2} · Tobias Eifert^{1,3} · Christoph Herwig^{1,4} · Michael Maiwald^{1,5}

Eisen, K., Eifert, T., Herwig, C. et al. Current and future requirements to industrial analytical infrastructure - part 1: process analytical laboratories. *Anal Bioanal Chem* **412**, 2027–2035 (2020).
<https://doi.org/10.1007/s00216-020-02420-2>

Analytical and Bioanalytical Chemistry
<https://doi.org/10.1007/s00216-020-02421-1>

FEATURE ARTICLE

Check for updates

Current and future requirements to industrial analytical infrastructure—part 2: smart sensors

Tobias Eifert^{1,2} · Kristina Eisen^{1,3} · Michael Maiwald^{1,4} · Christoph Herwig^{1,5}

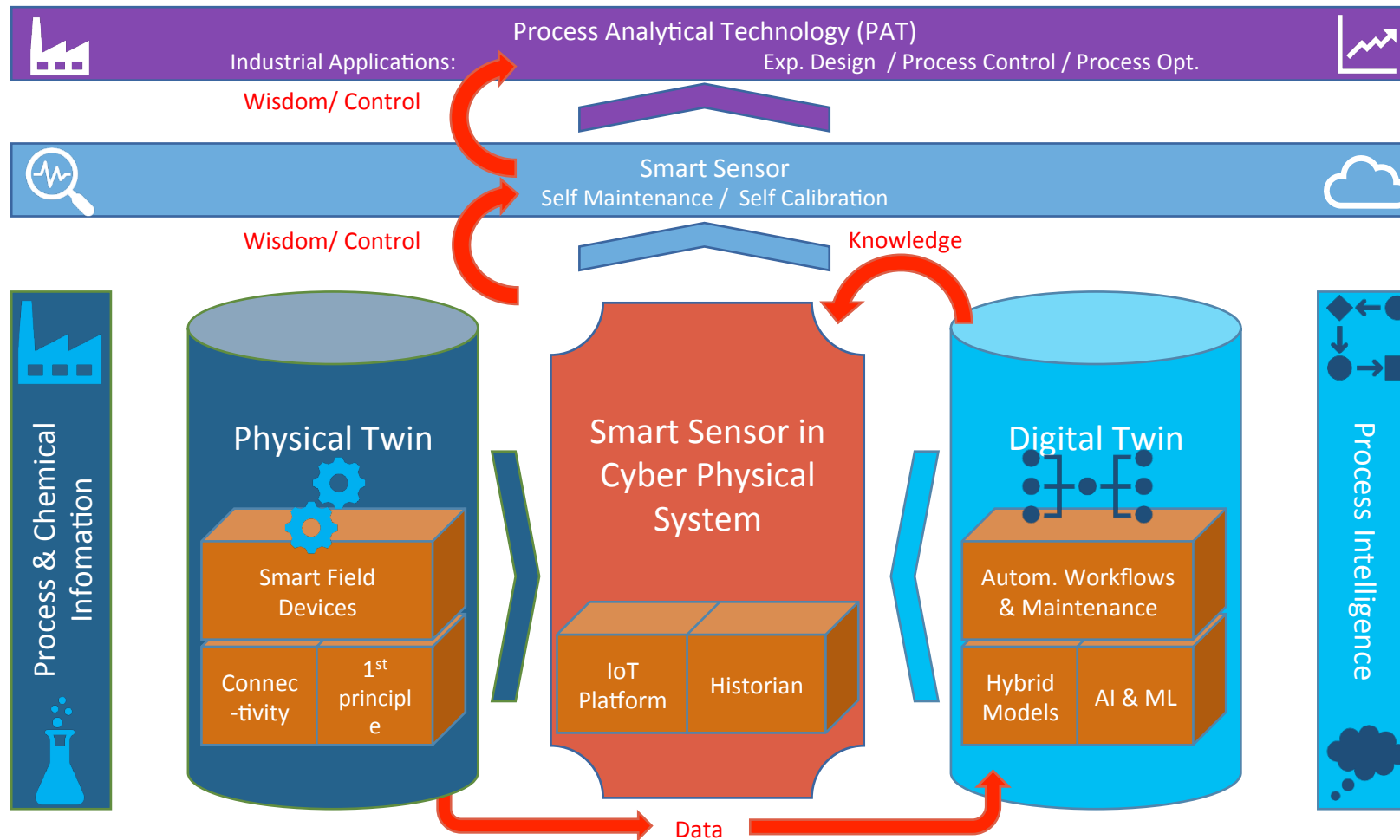
Eifert, T., Eisen, K., Maiwald, M. et al. Current and future requirements to industrial analytical infrastructure - part 2: smart sensors. *Anal Bioanal Chem* **412**, 2037–2045 (2020).
<https://doi.org/10.1007/s00216-020-02421-1>



FUTURE SMART SENSOR - PROPERTIES

- Multiple component measurement
 - Self-calibrating
 - Self-optimizing
 - Straightforward process integration
 - Autonomous operation
 - Smart
 - Predictive
- Flexible, target-oriented predictive control strategy
- Compensation of process and raw material variations

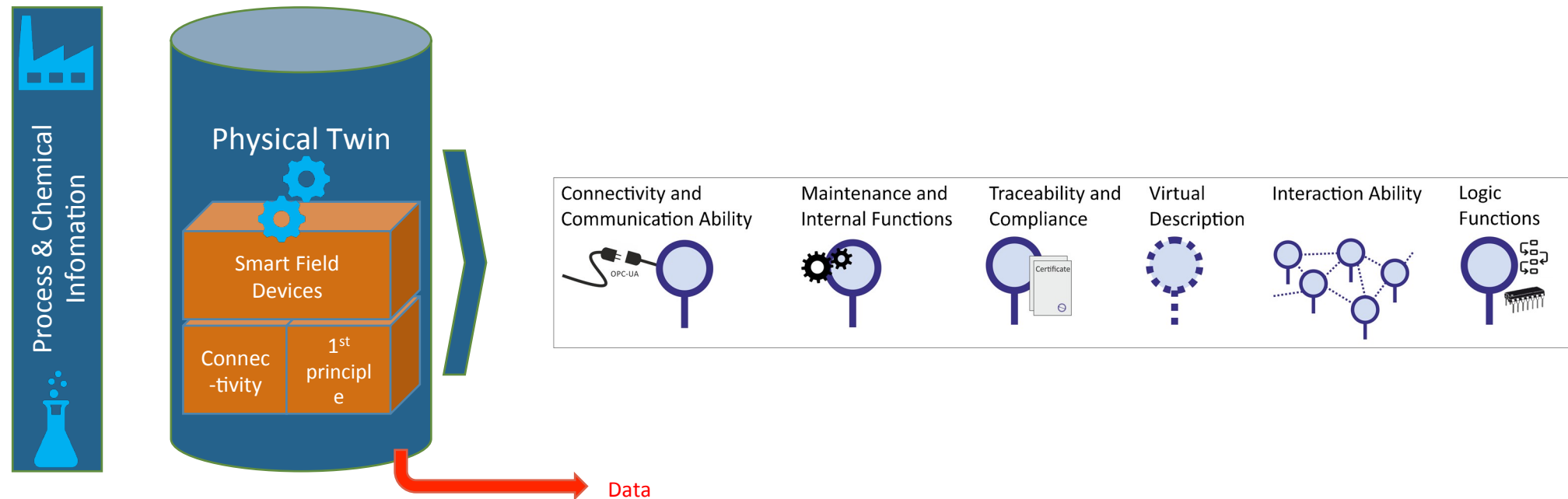
FUTURE SMART SENSORS - CONCEPT



Eifert, T., Eisen, K., Maiwald, M. et al., Anal Bioanal Chem 412, 2037–2045 (2020).

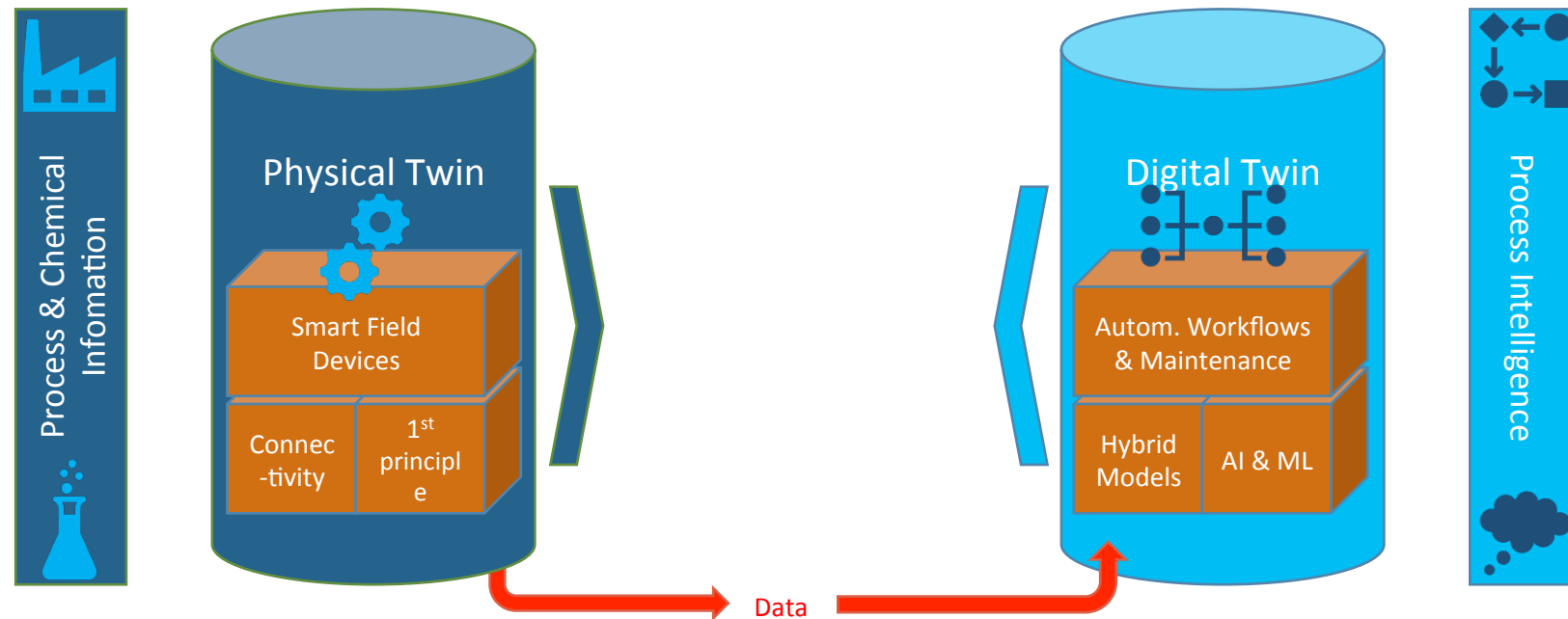
FUTURE SMART SENSORS - CONCEPT

Data from the physical twin: smart field devices for chemical and process information



FUTURE SMART SENSORS - CONCEPT

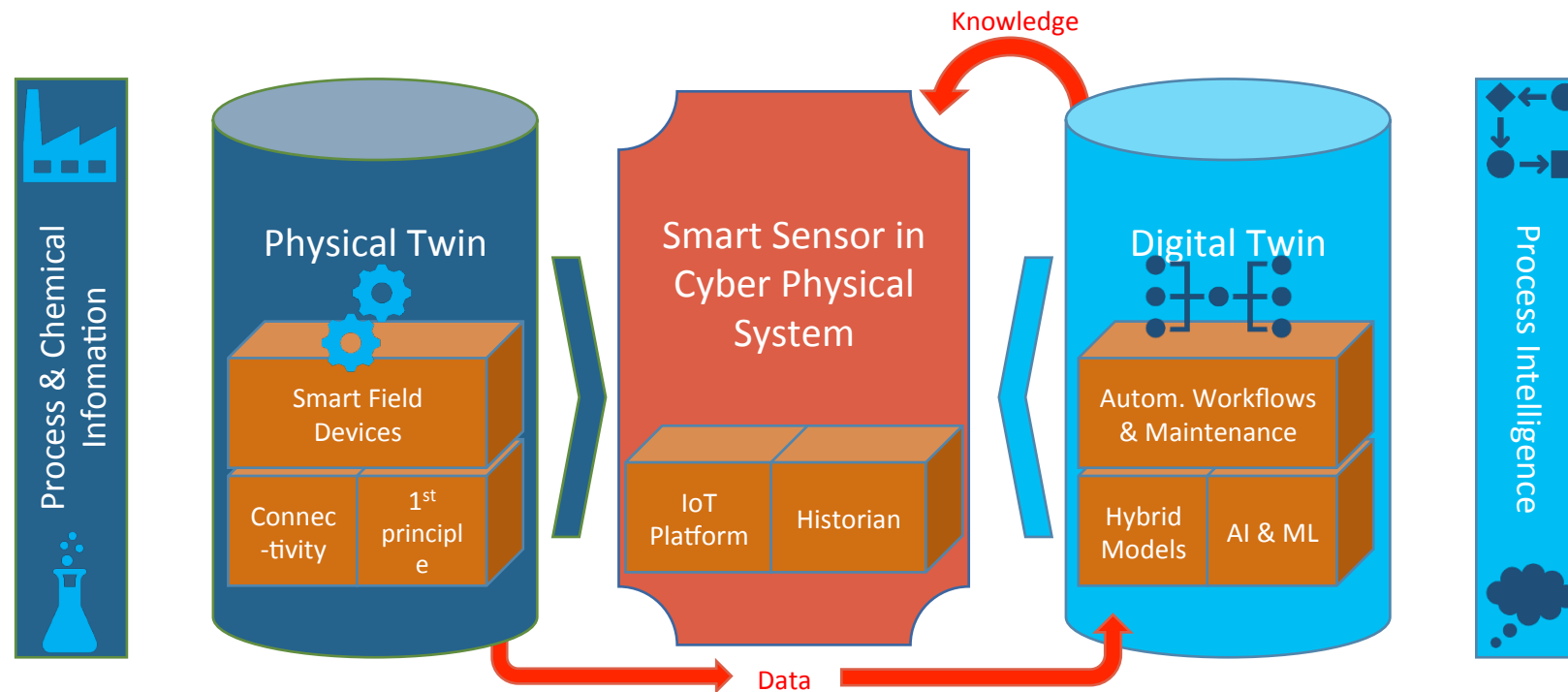
Digital twin: process intelligence by data modelling/process simulation



Eifert, T., Eisen, K., Maiwald, M. et al., Anal Bioanal Chem 412, 2037–2045 (2020).

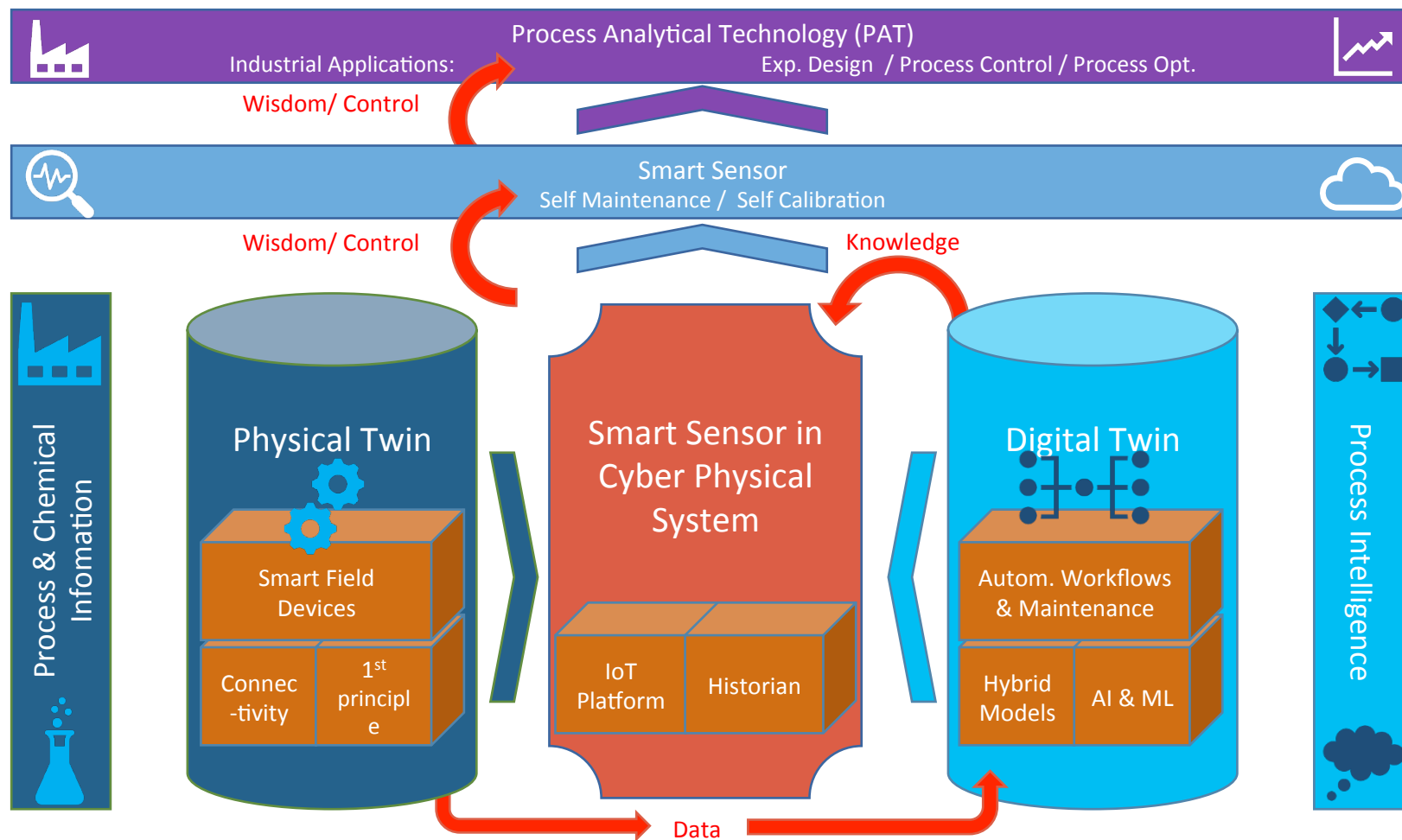
FUTURE SMART SENSORS - CONCEPT

The integration of the twins in cyber-physical systems



Eifert, T., Eisen, K., Maiwald, M. et al., Anal Bioanal Chem 412, 2037–2045 (2020).

FUTURE SMART SENSORS - CONCEPT



Eifert, T., Eisen, K., Maiwald, M. et al., Anal Bioanal Chem 412, 2037–2045 (2020).

FUTURE SMART SENSOR - APPLICATIONS



- Smart sensor applications
 - Sensor optimization
 - Self-maintenance/management
 - Self-calibration
- Smart sensor-facilitated PAT applications
 - Digital twin-based experimental design
 - Digital twin-based optimum control
 - Continued process verification
 - Golden batch controls

FUTURE SMART SENSORS – FEATURES

- Smart sensors shall be simple to use, maintain and calibrate
 - Supervised by digital twin intelligence
 - Plug-and-play integration in a CPS
- Requirements
 - Standardization
 - Modular design of process connection and connectivity

LEVELS OF INTEGRATION

- Software agility: DevOps techniques
- Data agility: SaaS cloud solutions
- Holistic data management and data analysis
- Model and digital twin agility
- Interdisciplinary curricula

TAKE HOME

- Smart sensors are key enabler for intelligent PAT applications and smart manufacturing
- The smart sensor consists of
 - chemical and process information (**physical twin**) → smart field devices, multi-component-measurements, integration in IIoT 4.0 environment
 - process intelligence (**digital twin**) → generate knowledge from multi-sensor and multi-dimensional data
 - Combination in a cyber-physical system (CPS) → intelligent PAT applications
- Require standardization or modularization of interfaces and data modelling
- Different levels of integration turning individual sensors to smart sensors



QUESTIONS FOUND IN GOOGLE AUTOCOMPLETE

WHY DO WHALES JUMP
WHY ARE WITCHES GREEN
WHY ARE THERE MIRRORS ABOVE BEDS
WHY DO I SAY UH
WHY IS SEA SALT BETTER
WHY ARE THERE TREES IN THE MIDDLE OF FIELDS
WHY IS THERE NOT A POKEMON MMO
WHY IS THERE LAUGHING IN TV SHOWS
WHY ARE THERE DOORS ON THE FREEWAY
WHY ARE THERE SO MANY SMOGHOSTS
WHY AREN'T THERE ANY COUNTRIES IN ANTARCTICA
WHY ARE THERE SCARY SOUNDS IN MINECRAFT
WHY IS THERE KICKING IN MY STOMACH
WHY ARE THERE TWO SLASHES AFTER HTTP
WHY ARE THERE CELEBRITIES
WHY DO SNAKES EXIST
WHY DO OYSTERS HAVE PEARLS
WHY ARE DUCKS CALLED DUCKS
WHY DO THEY CALL IT THE CLAP
WHY ARE KYLE AND CARTMAN FRIENDS
WHY IS THERE AN ARROW ON AANG'S HEAD
WHY ARE TEXT MESSAGES BLUE
WHY ARE THERE MUSTACHES ON CLOTHES
WHY ARE THERE MUSTACHES EVERYWHERE
WHY ARE THERE SO MANY BIRDS IN OHIO
WHY IS THERE SO MUCH RAIN IN OHIO
WHY IS OHIO WEATHER SO WEIRD
WHY ARE THERE MALE AND FEMALE BIKES
WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE BRIDGES ANYMORE
WHY ARE OLD KINGDOMS DIFFERENT

WHY DO TESTICLES MOVE
WHY ARE THERE PSYCHICS
WHY ARE HATS SO EXPENSIVE
WHY IS THERE COFFEINE IN MY SHAMPOO
WHY DO YOUR BOOBS HURT

WHY ARE THERE SLAVES IN THE BIBLE
WHY DO TWINS HAVE DIFFERENT FINGERPRINTS
WHY ARE AMERICANS AFRAID OF DRAGONS
WHY IS HTTPS CROSSED OUT IN RED
WHY IS THERE A LINE THROUGH HTTPS
WHY IS THERE A RED LINE THROUGH HTTPS ON FACEBOOK
WHY IS HTTPS IMPORTANT

WHY AREN'T MY ARMS GROWING

WHY AREN'T ECONOMISTS RICH
WHY DO AMERICANS CALL IT SOCCER
WHY ARE MY EARS RINGING
WHY ARE THERE SO MANY AVENGERS
WHY ARE THE AVENGERS FIGHTING THE X MEN
WHY IS WOLVERINE NOT IN THE AVENGERS

WHY ARE THERE ANTS IN MY LAPTOP
WHY IS EARTH TILTED
WHY IS SPACE BLACK
WHY IS OUTER SPACE SO COLD
WHY ARE THERE PYRAMIDS ON THE MOON
WHY IS NASA SHUTTING DOWN

WHY ARE THERE GHOSTS
WHY IS THERE AN OWL IN MY BACKYARD
WHY IS THERE AN OWL OUTSIDE MY WINDOW
WHY IS THERE AN OWL ON THE DOLLAR BILL
WHY DO OWLS ATTACK PEOPLE
WHY ARE AK 47s SO EXPENSIVE
WHY ARE THERE HELICOPTERS CIRCLING MY HOUSE
WHY ARE THERE GODS
WHY ARE THERE TWO SPOOKS
WHY IS MT VESUVIUS THERE
WHY DO THEY SAY T MINUS
WHY ARE THERE OBELISKS
WHY ARE WRESTLERS ALWAYS WET
WHY ARE OCEANS BECOMING MORE ACIDIC
WHY IS ARWEN DYING
WHY AREN'T MY QUAIL LAYING EGGS
WHY AREN'T MY QUAIL EGGS HATCHING
WHY AREN'T THERE ANY FOREIGN MILITARY BASES IN AMERICA

WHY ARE THERE SO MANY CROWS IN ROCHESTER, MN
WHY IS PSYCHIC WEAK TO BUG
WHY DO CHILDREN GET CANCER
WHY IS POSEIDON ANGRY WITH ODYSSEUS
WHY IS THERE ICE IN SPACE
WHY ARE DOGS AFRAID OF FIREWORKS
WHY IS THERE NO KING IN ENGLAND

WHY ARE THERE LIES
WHY DO I FEEL DIZZY

WHY ARE THERE TINY SPIDERS IN MY HOUSE
WHY DO SPIDERS COME INSIDE
WHY ARE THERE HUGE SPIDERS IN MY HOUSE
WHY ARE THERE LOTS OF SPIDERS IN MY HOUSE
WHY ARE THERE SPIDERS IN MY ROOM
WHY ARE THERE SO MANY SPIDERS IN MY ROOM
WHY DO SPIDER BITES ITCH
WHY IS DYING SO SCARY
WHY IS THERE NO GPS IN LAPTOPS
WHY DO KNEES CLICK
WHY AREN'T THERE E GRADES
WHY IS ISOLATION BAD
WHY DO BOYS LIKE ME
WHY DON'T BOYS LIKE ME
WHY IS THERE ALWAYS A 3PWA UPDATE
WHY ARE THERE RED DOTS ON MY TIGHS
WHY IS LYING GOOD

WHY ARE THERE GHOSTS

WHY ARE THERE FEMALE MR NINES

WHY IS SEX SO IMPORTANT

WHY AREN'T THERE GUNS IN HARRY POTTER

WHY ARE ULTRASOUNDS IMPORTANT
WHY ARE ULTRASOUND MACHINES EXPENSIVE
WHY IS STEALING WRONG
WHY DO GOOD PEOPLE DIE

WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE BRIDGES ANYMORE
WHY ARE OLD KINGDOMS DIFFERENT

WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE BRIDGES ANYMORE
WHY ARE OLD KINGDOMS DIFFERENT

WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE BRIDGES ANYMORE
WHY ARE OLD KINGDOMS DIFFERENT

WHY ARE THERE BRIDESMAIDS
WHY DO DYING PEOPLE REACH UP
WHY AREN'T THERE BRIDGES ANYMORE
WHY ARE OLD KINGDOMS DIFFERENT

<https://doi.org/10.1007/s00216-020-02420-2>

<https://doi.org/10.1007/s00216-020-02421-1>