Digital TILSAM systems

– providing FAIR data and SI traceability to smart sensor networks for air quality monitoring

Jan C. Petersen[1], Federico Grasso Toro[2], and Olav Werhahn[3,*]

[1] Danish Fundamental Metrology (DFM), Denmark
[2] GRASSO TORO (GT Digital Solutions), Switzerland
[3] Physikalisch-Technische Bundesanstalt (PTB), Germany

*currently with the Bureau International des Poids et Mesures (BIPM)

Introduction to the method: **TILSAM***

- Laser spectroscopy (TDLAS, QCLAS,CRDS, others) as primary method directly applied;
- Delivered amount fraction results directly traceable to the international systems of units (SI);
- Using a full physical model (first principles) for the measurement process;
- Technical protocol for TILSAM online available [Link] and presented at CIM 2020 [Link];
- TILSAM method allows for the implementation of Optical Gas Standards (OGS);
- Realized OGS, e.g., demonstrated (published) on HCl, NH_3, NO_2, CO, CO_2, and H_2O;

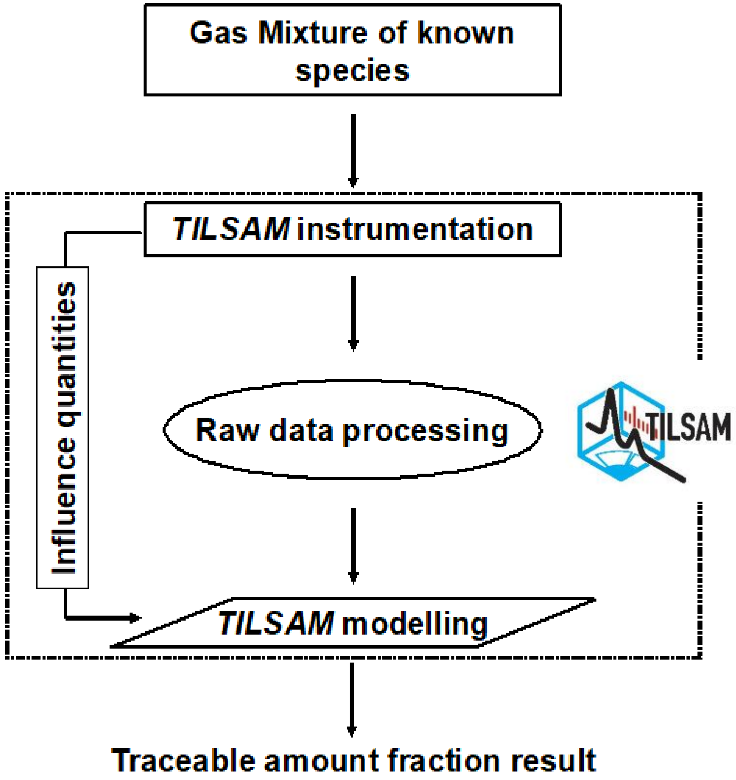
- A similar instrument as laser hygrometer (H_2O) has been autonomously operated onboard the research aircraft HALO during measurement campaigns …

TILSAM

***TILSAM**: **T**raceable **I**nfrared **L**aser-**S**pectrometric **A**mount fraction **M**easurement

In Situ and Spaceborne Observations of Atmospheric Water Vapor and Temperature II, paper A54C-06, https://agu.confex.com/agu/fm14/meetingapp.cgi#Paper/19528

Introduction to the method: **TILSAM**



Input:

- Laser tuning data
- Optical path length calibration data
- Pressure sensor calibration data
- Temperature sensor calibration data
- Spectral molecular line data

In situ measurements:

- Total gas pressure
- Gas temperature
- Transmitted laser radiation / detector signal / spectra

Delivered output data:

- Species amount fraction and uncertainty
- Meta data incl. raw data / spectra

EURAMET 1498 bilateral comparison on 100 µmol/mol HCl in nitrogen, final report online available [Link]

Digitally transforming the method: **TILSAM**

FAIR-Certificate manageable input

Input:
- Laser tuning data
- Optical path length calibration data
- Pressure sensor calibration data
- Temperature sensor calibration data
- Spectral molecular line data

***In situ* database queries**

Online comparison to external data

In situ measurements:
- Total gas pressure
- Gas temperature
- Transmitted laser radiation / detector signal / spectra

FAIR-Certificate manageable output

Delivered output data:
- Species amount fraction and uncertainty
- Meta data incl. raw data / spectra

Digitally transforming the method: **TILSAM**

FAIR-Certificate
manageable inp…

In s…

FAIR-Certifica…
manageable output

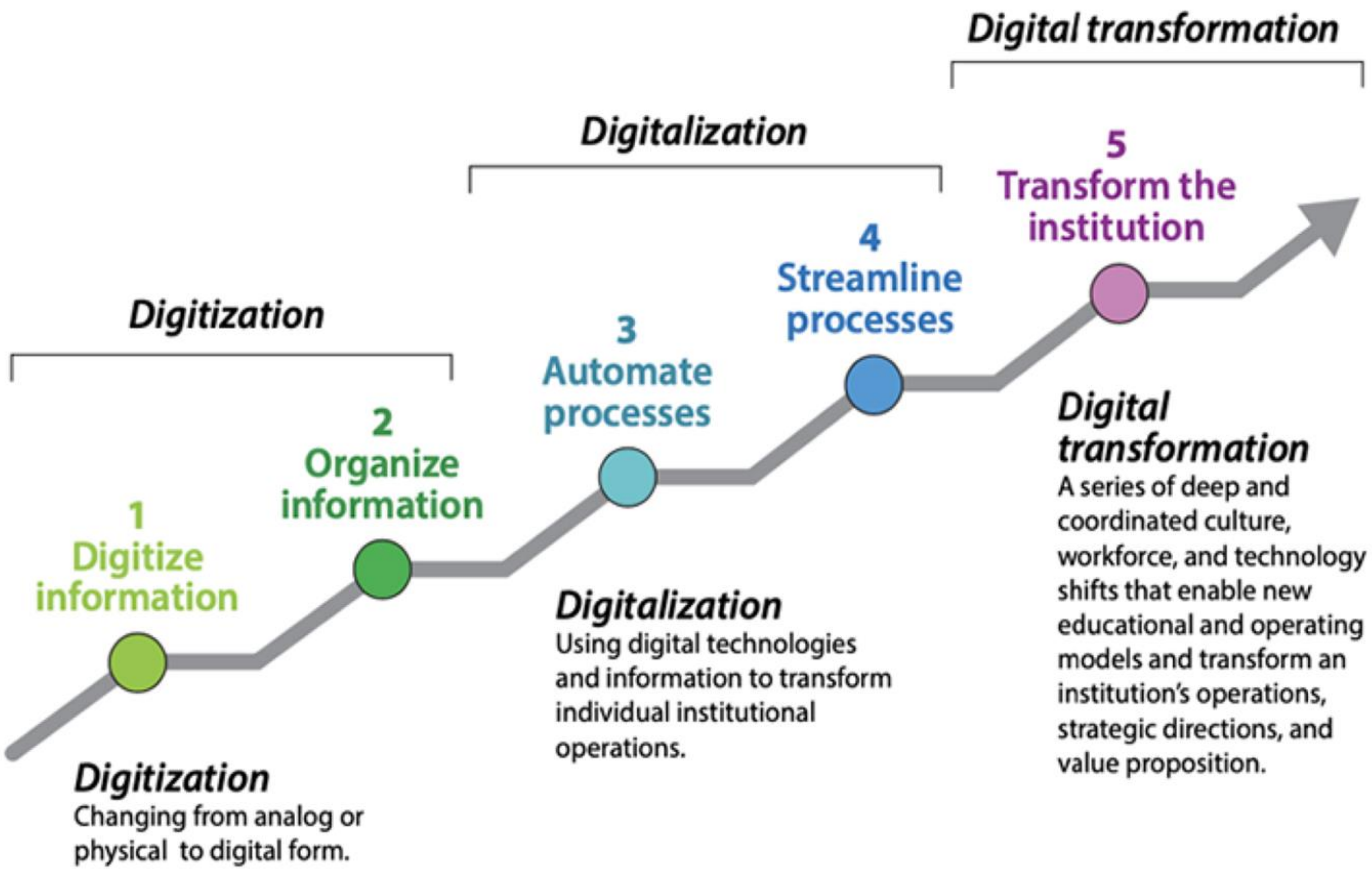
Digital documentary standard
repository / DIN / ISO

CIPM KCDB

BIPM IRMM

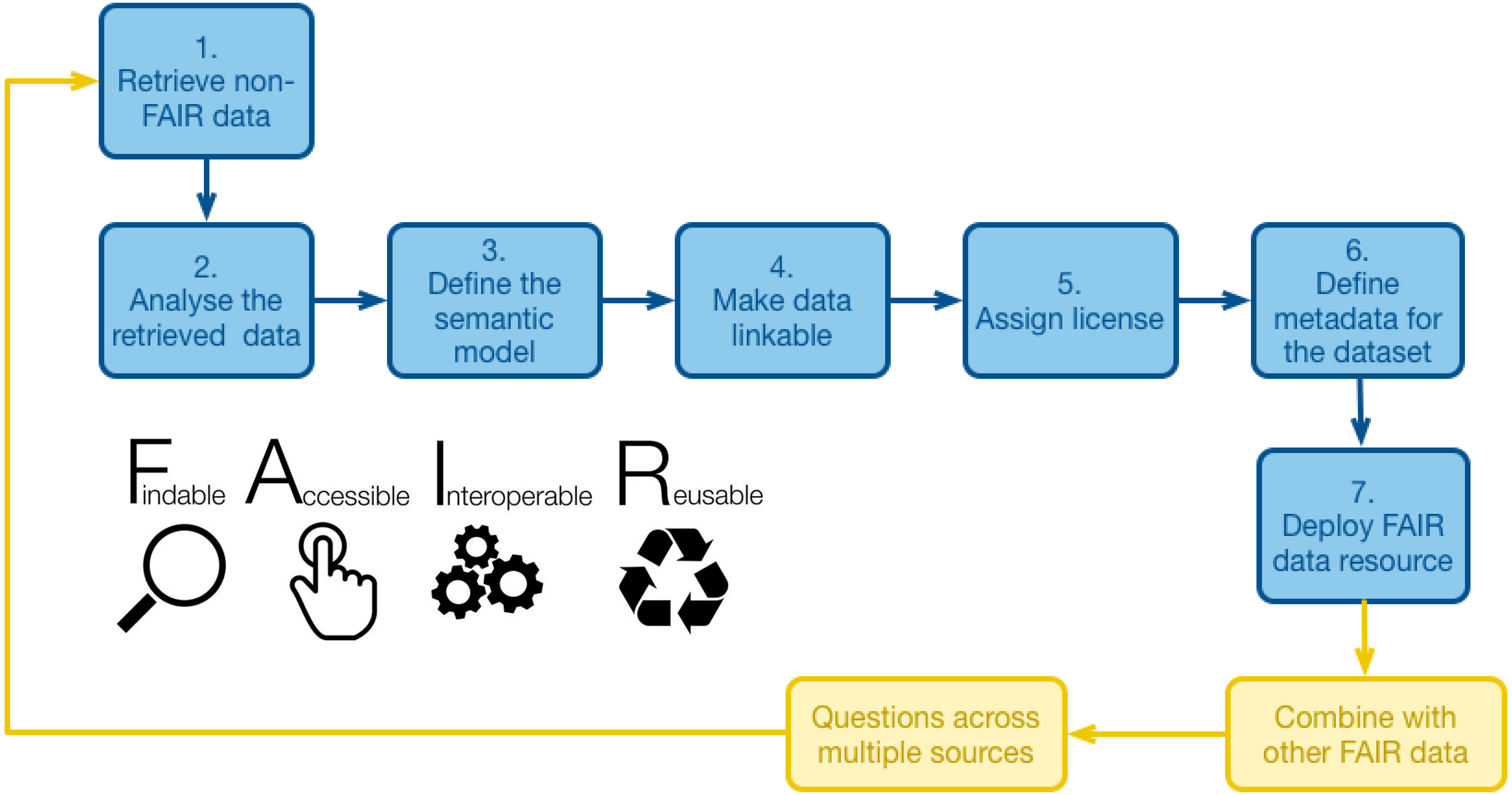
HITRAN

Towards digitalisation of the method: **d-TILSAM** by FAIRification



[Infographic: Differentiating digital transformation from digitization and digitalization]

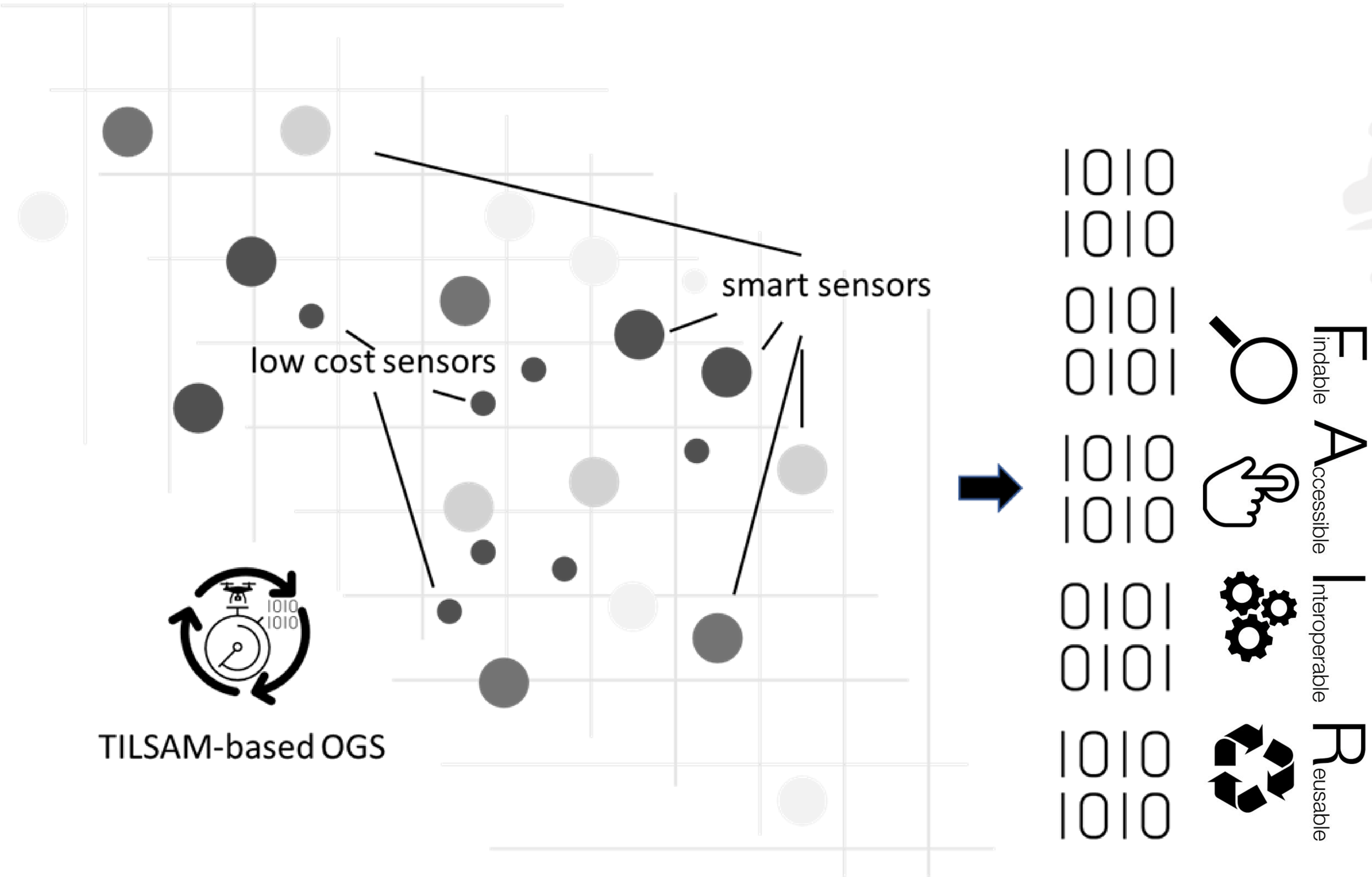
Towards digitalisation of the method: **FAIRification process**

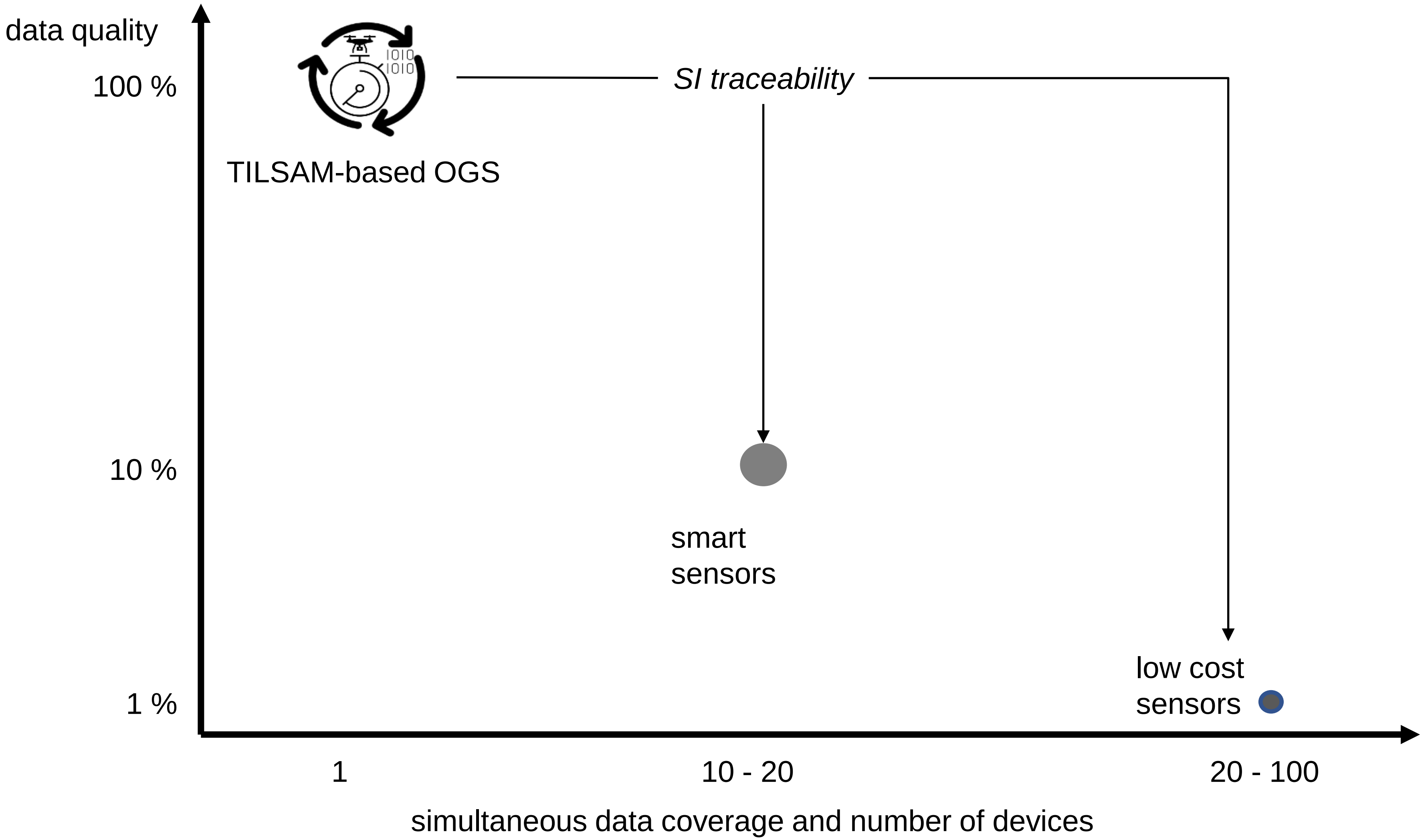


https://www.go-fair.org/fair-principles/fairification-process /

Sensor networks: *Smart City Modules for Air Quality Monitoring*

Hofman J, Peters J, Stroobants C, Elst E, Baeyens B, Van Laer J, Spruyt M, Van Essche W, Delbare E, Roels B, Cochez A, Gillijns E, Van Poppel M. Air Quality Sensor Networks for Evidence-Based Policy Making: Best Practices for Actionable Insights. *Atmosphere*. 2022; 13(6):944. https://doi.org/10.3390/atmos13060944


smart sensors
low cost sensors
TILSAM-based OGS
1010
1010
0101
0101
1010
1010
0101
0101
1010
1010
Findable
Accessible
Interoperable
Reusable


data quality
100 %
10 %
1 %
TILSAM-based OGS
SI traceability
smart
sensors
low cost
sensors
1
10 - 20
20 - 100
simultaneous data coverage and number of devices

The d-TILSAM method for *decentralized monitoring networks*

The proposed D-TILSAM method has several **advantages** over currently used calibration methods for Low Cost Sensor (LCS) Networks and Smart Sensor Networks:

- A single OGS device can be used for *in situ* calibration of a sensor network for a large range of molecular species - with known absorption line strength;
- Certified reference gases are generally not required – only for not yet tabulated molecular line strength;
- Sensors do not need to go back to a laboratory for calibration – which is very time consuming and expensive; and
- Calibration intervals can be easily adjusted, according to dynamic needs from the system – LCS Networks usually require frequent calibration.

Conclusions and further steps for advanced Air Quality Monitoring

*In a recent WMO report it is mentioned that **sensor calibrations and sensor stabilities need to be checked routinely by a sensor network operator**. For example, related to **decision-making** from air quality monitoring.*

R.E. Peltier (ed.), "An update on low-cost sensors for the measurement of atmospheric composition", WMO_No. 1215, World Meteorological Organization, Geneva 2021, ISBN 978-92-63-11215-6

Required Normative efforts

- Standardization and harmonization of "low" cost sensor networks
- SI-traceable calibration procedures *in situ* by TILSAM-based OSG
- Trust thresholds for validated and verified monitoring, towards decision-making

Required Digitalisation efforts

- Fully **FAIRified d-TILSAM** for M2M communication.
- Automation and streamlining of calibration *in situ*