Vom Kalibrierzertifikat zur digitalen Qualitätsinfrastruktur

– Ergebnisse aus GEMIMEG-II und anstehende Herausforderungen –

Jena Digital Innovation Hub Opening 2024

Tech:Talk Panel - Impulsvortrag

Dr. Thomas Engel

Jena, 13. August 2024

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The GEMIMEG-II Project in a Nutshell

Project start:	01.08.2020	
Funding budget:	11,2 M€	
Total project budget:	17,9 M€	
Project duration:	36 months	
Project end:	(31.07.2023) → 31.12.2023	
Project partners:	13	
	Industry:	8
	NMI:	PTB
	Applied Research:	1
	University:	3

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Digitize, Digitalisation and Digital Transformation

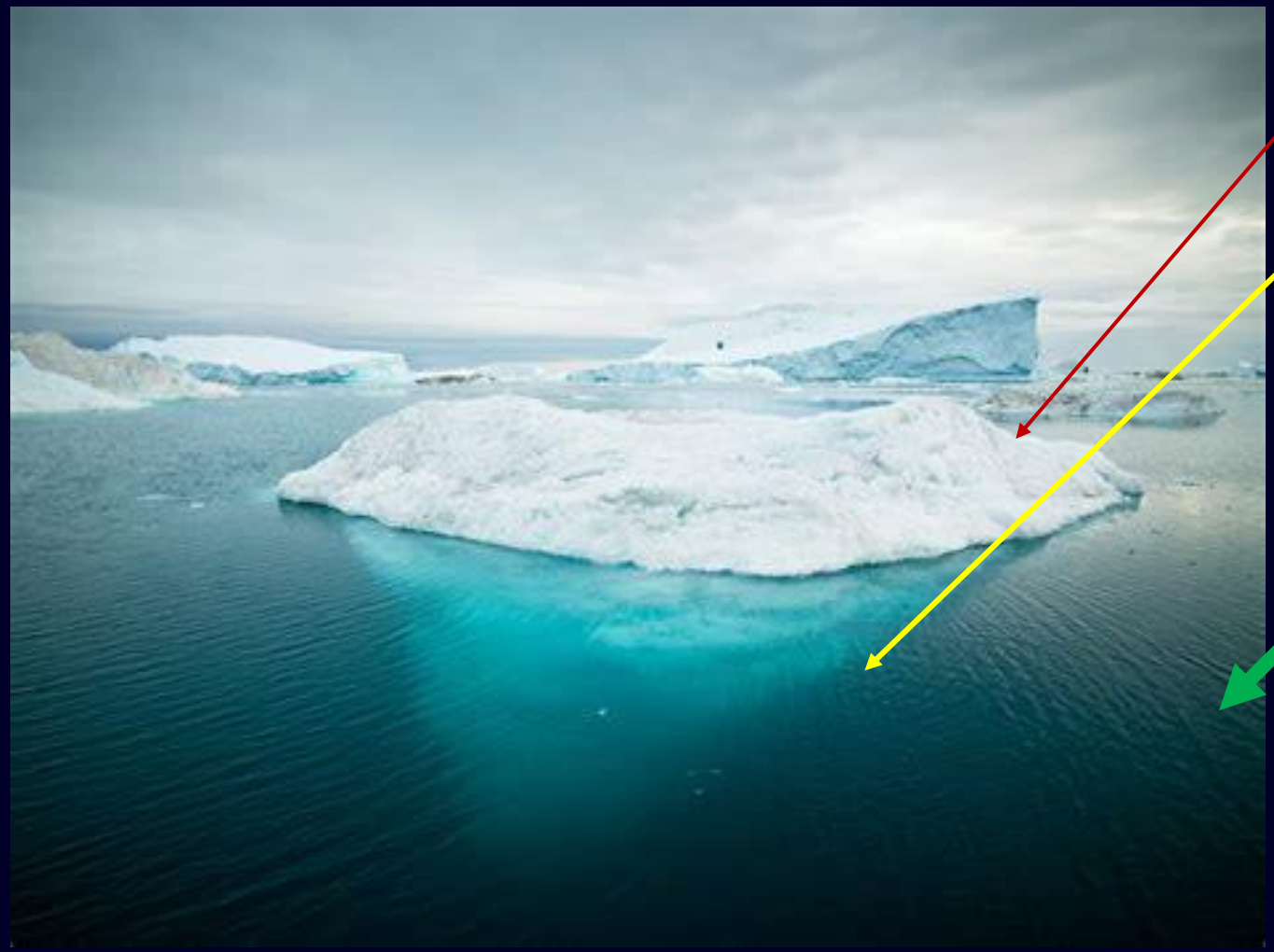

Foto: Alexander Hafemann; Mlenny/iStockphoto.com

Digitize:

- Documents available in digital format

Digitalization:

- Machine readable, machine understandable, machine actionable data / information
  - Related set of (basic) functions
- Semantics, Ontology, Quality information
- Data exchange, interface, platforms

Digital Transformation:

- New business opportunities – cost structure
  - Lower waste / higher first pass yield
  - Higher precission with larger tolerances
- Enabler: more presice data
- Business transformation from „economy of conformity“ to „economy of consistency“

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Digitize, Digitalisation and Digital Transformation

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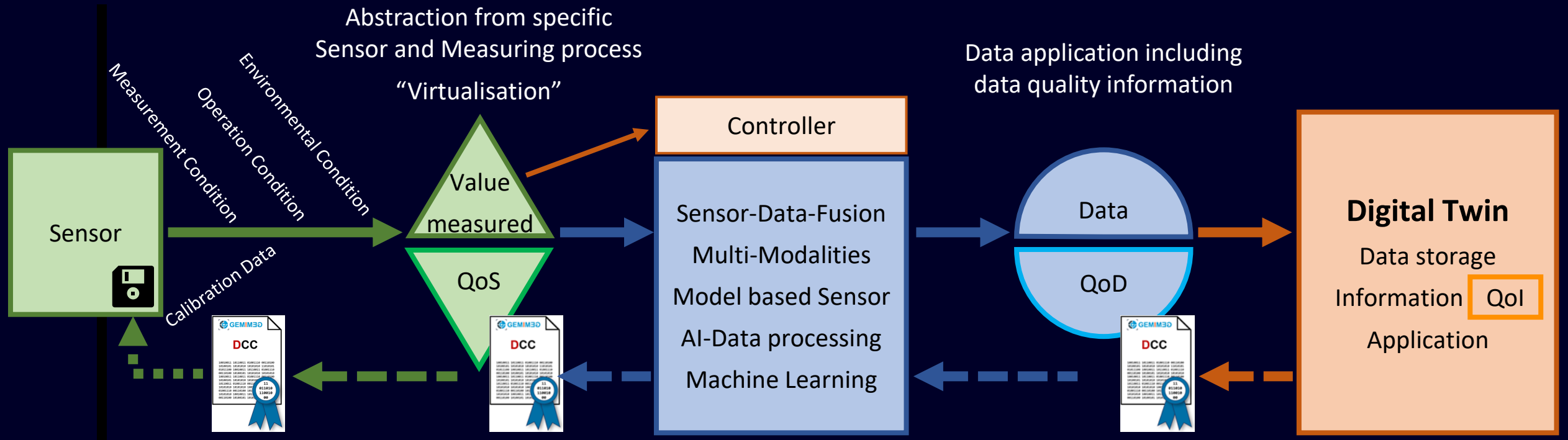
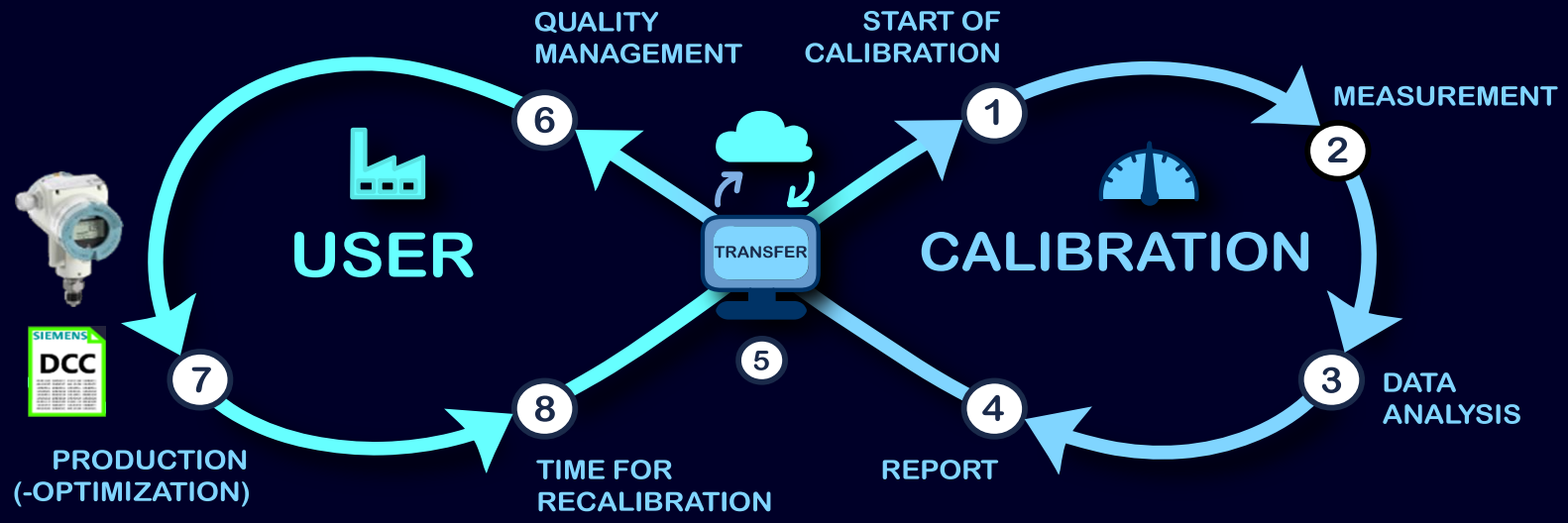
The GEMIMEG - Concept



Calibration Usecases

A) Production process

B) Process equipment with periodic recurring calibrations



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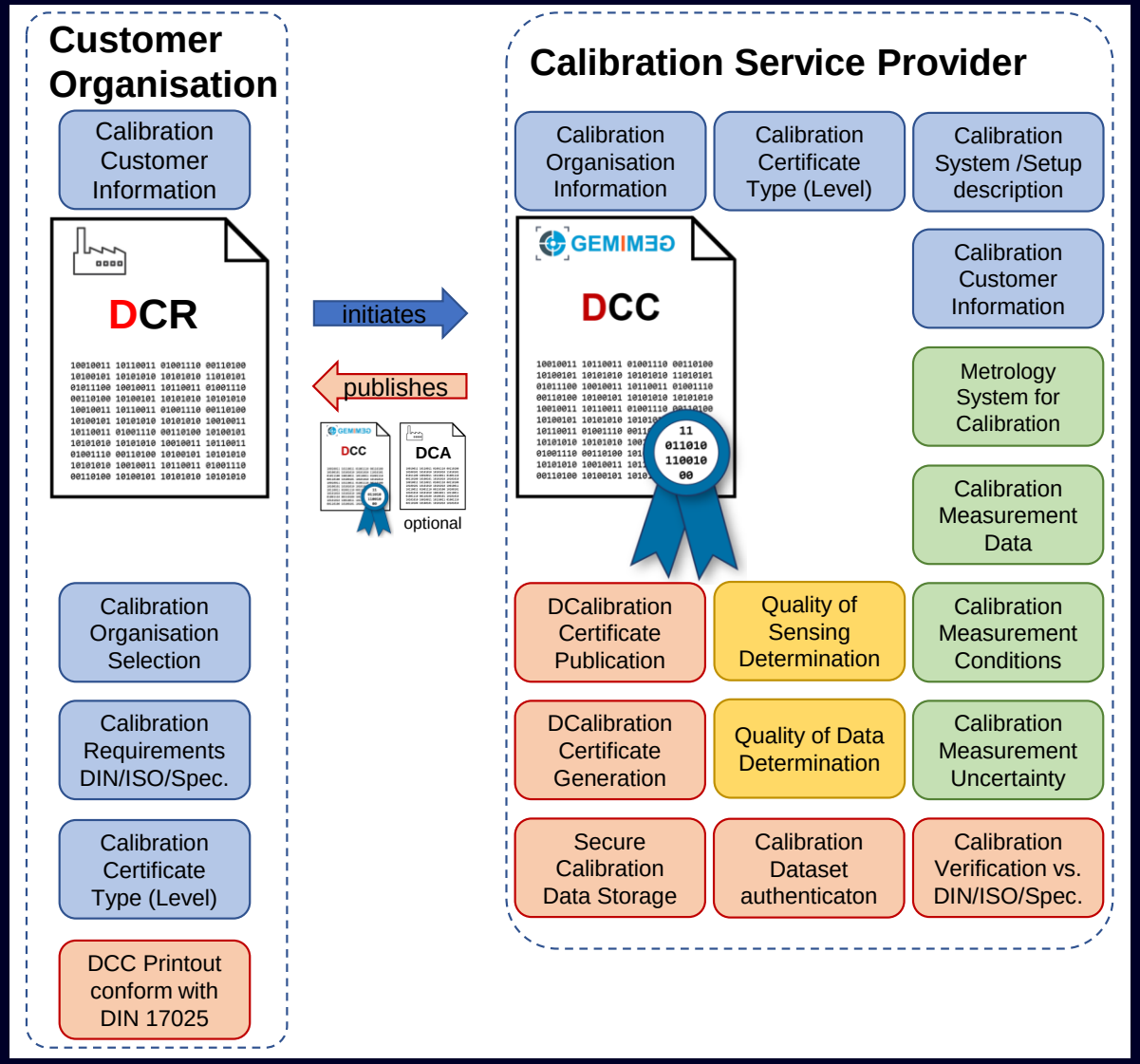
The DCC and its generic components



Calibration Certificate Type (Level)

(1) National Metrology Institute (NMI)
(2) Measurement Office
(3) Calibration Laboratory
(4) Testing Laboratory
(5) Inspection Bodies
(6) Company Level
  (1) Factory calibration
  (2) Acceptance Testing
  (3) Verification / Field Testing

DCC: Digital Calibration Certificate
DCR: Digital Calibration Request
DCA: Digital Calibration Answer

Calibration Data Type / Data representation
i. Platinum
ii. Gold
iii. Silver
iv. Bronze

Calibration System/Setup description

(1) Calibration instruments & artefacts inventory of organisation
  1. Concise list
  2. Unique identification and description
  3. Calibration / qualification status
  4. Validity of currrent calibration, history of previous calibrations
(2) Combination / Installation of indivicual instruments / artefacts in a „standard“ configuration for repetitive use in subsequent applications (e.g. gauge block set)

Calibration Measurement

Internal operational steps for metrology in respective calibration / verification organisation

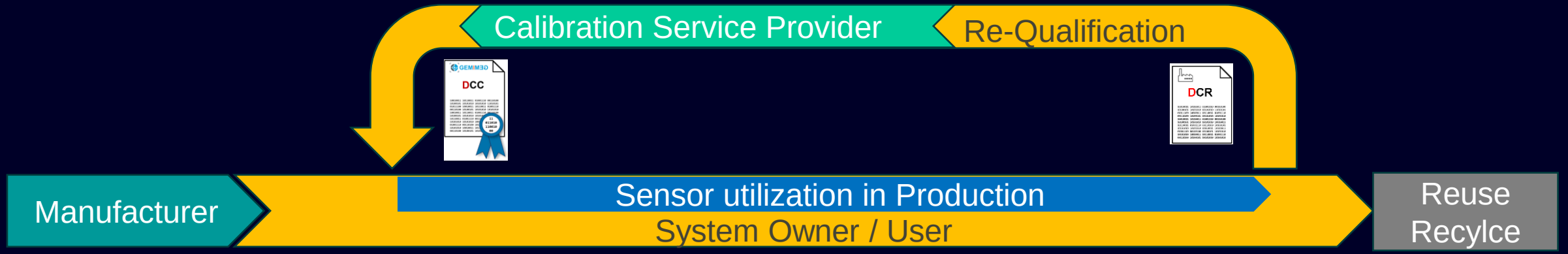
Calibration Documentation

Internal operation steps to fully document and qualify calibration measurement data and to issue DCC certificate – according to requirement for respective type of calibration

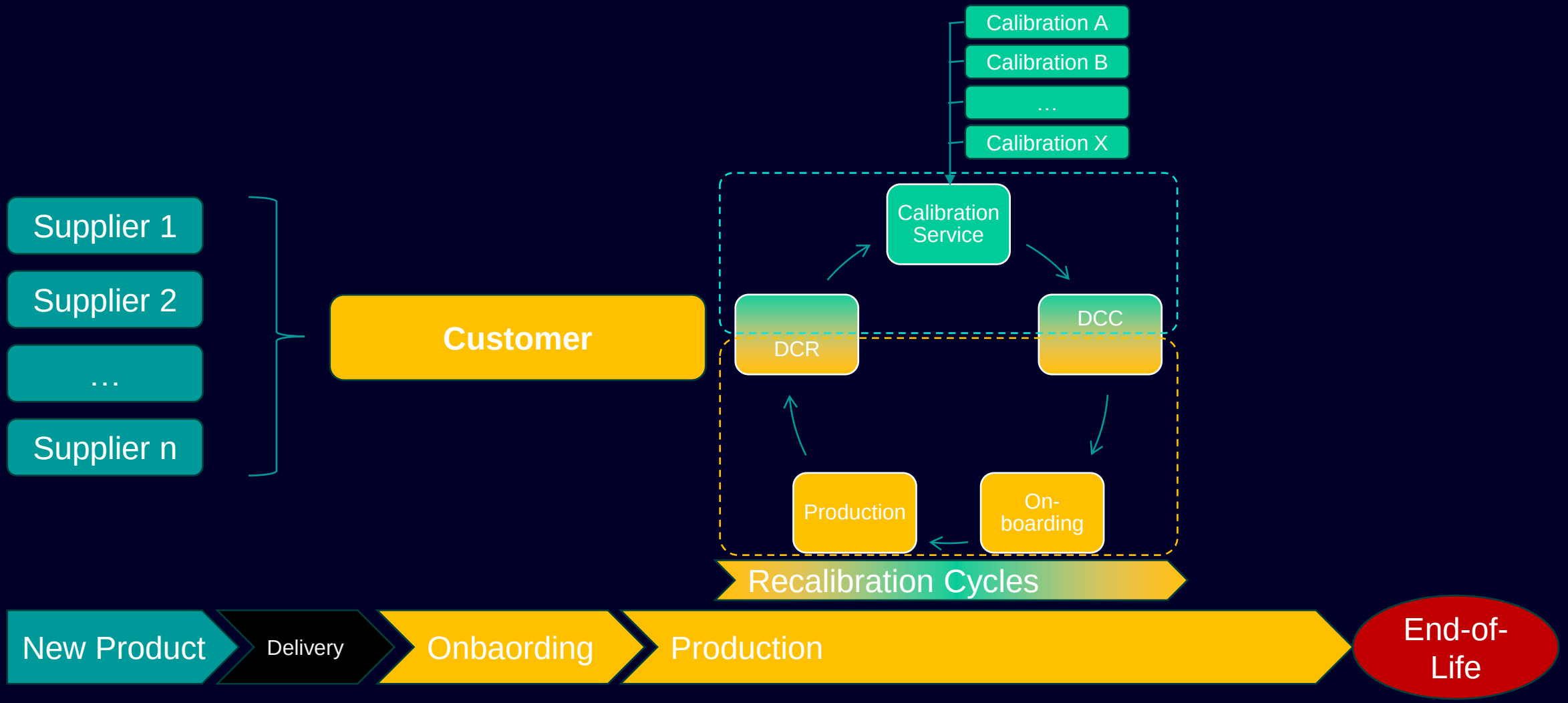
Quality Info Determination

Quality level determination for measurement values data generated by sensor as a physical or model based sensor entity

Productive Lifecycle of a Sensor in Industry



Productive Lifecycle of a Sensor in Industry



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Digitize, Digitalisation and Digital Transformation

Digitalization:

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Foto: Alexander Hafemann; Mlenny/iStockphoto.com

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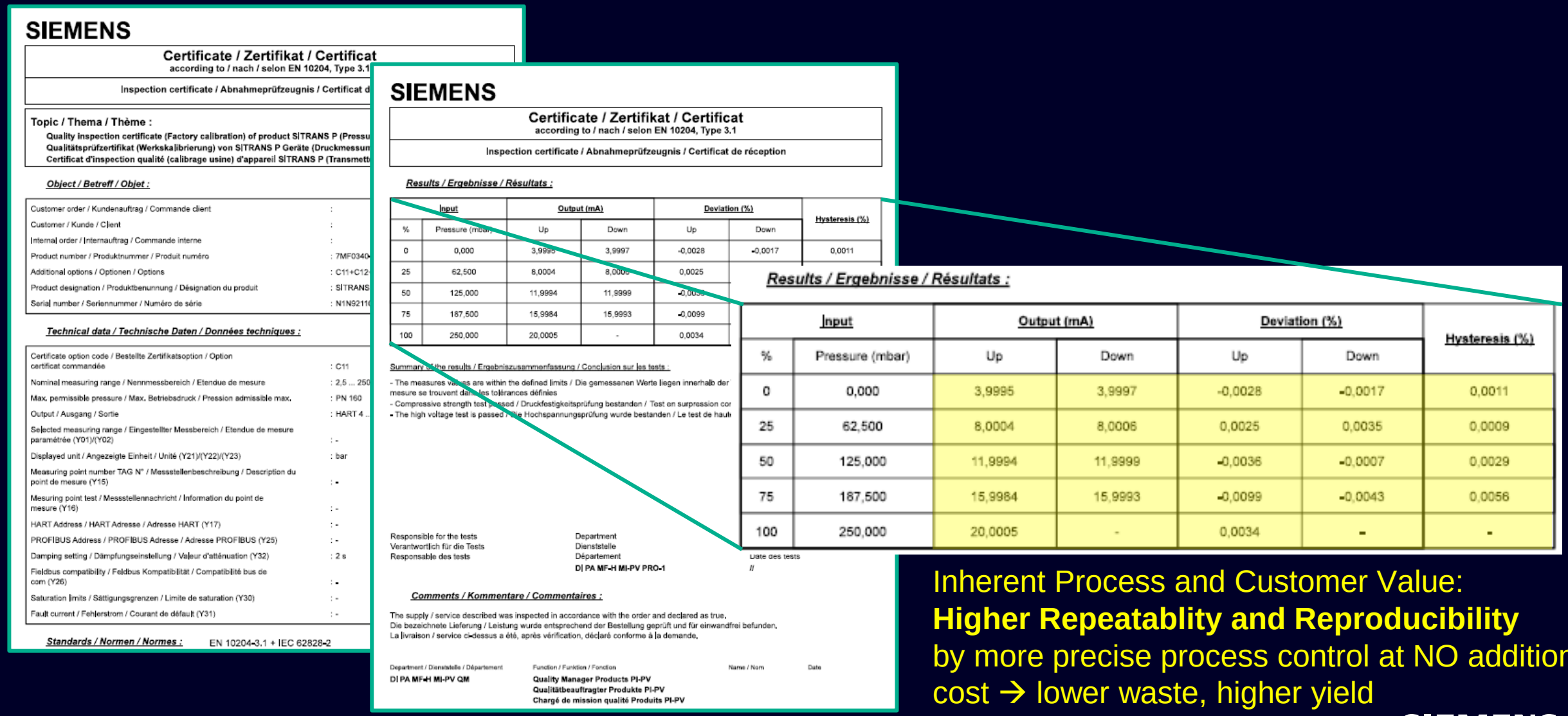
Example: Pressure Sensor with 4 – 20 mA Interface



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Certificate / Zertifikat / Certificat
according to / nach / selon EN 10204, Type 3.1

Inspection certificate / Abnahmeprüfzeugnis / Certificat de réception

Topic / Thema / Thème :
Quality inspection certificate (Factory calibration) of product SITRANS P (Pressu
Qualitätsprüfzertifikat (Werkskalibrierung) von SITRANS P Geräte (Druckmessun
Certificat d'inspection qualité (calibrage usine) d'appareil SITRANS P (Transmett

Object / Betreff / Objet :

Customer order / Kundenauftrag / Commande client	:
Customer / Kunde / Client	:
Internal order / Internauftrag / Commande interne	:
Product number / Produktnummer / Produit numéro	: 7MF0340
Additional options / Optionen / Options	: C11+C12
Product designation / Produktbenennung / Désignation du produit	: SITRANS
Serial number / Seriennummer / Numéro de série	: N1N9211

Technical data / Technische Daten / Données techniques :

Certificate option code / Bestellte Zertifikatsoption / Option certificat commandée	: C11
Nominal measuring range / Nennmessbereich / Etendue de mesure	: 2,5 ... 250
Max. permissible pressure / Max. Betriebsdruck / Pression admissible max.	: PN 160
Output / Ausgang / Sortie	: HART 4 ..
Selected measuring range / Eingestellter Messbereich / Etendue de mesure paramétrée (Y01)/(Y02)	: -
Displayed unit / Angezeigte Einheit / Unité (Y21)/(Y22)/(Y23)	: bar
Measuring point number TAG N° / Messstellenbeschreibung / Description du point de mesure (Y15)	: -
Mesuring point text / Messstellennachricht / Information du point de mesure (Y16)	: -
HART Address / HART Adresse / Adresse HART (Y17)	: -
PROFIBUS Address / PROFIBUS Adresse / Adresse PROFIBUS (Y25)	: -
Damping setting / Dämpfungseinstellung / Valeur d'atténuation (Y32)	: 2 s
Fieldbus compatibility / Feldbus Kompatibilität / Compatibilité bus de com (Y26)	: -
Saturation limits / Sättigungsgrenzen / Limite de saturation (Y30)	: -
Fault current / Fehlerstrom / Courant de défault (Y31)	: -

Standards / Normen / Normes : EN 10204-3.1 + IEC 62828-2

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Certificate / Zertifikat / Certificat
according to / nach / selon EN 10204, Type 3.1

Inspection certificate / Abnahmeprüfzeugnis / Certificat de réception

Results / Ergebnisse / Résultats :

Input		Output (mA)		Deviation (%)		Hysteresis (%)
%	Pressure (mbar)	Up	Down	Up	Down	
0	0,000	3,9995	3,9997	-0,0028	-0,0017	0,0011
25	62,500	8,0004	8,0006	0,0025		
50	125,000	11,9994	11,9999	-0,0036		
75	187,500	15,9984	15,9993	-0,0099		
100	250,000	20,0005	-	0,0034		

Summary of the results / Ergebniszusammenfassung / Conclusion sur les tests :
- The measures values are within the defined limits / Die gemessenen Werte liegen innerhalb der mesure se trouvent dans les tolérances définies
- Compressive strength test passed / Druckfestigkeitsprüfung bestanden / Test on surpression cor
- The high voltage test is passed / Die Hochspannungsprüfung wurde bestanden / Le test de haut

Responsible for the tests / Verantwortlich für die Tests / Responsable des tests
Department / Dienststelle / Département
DI PA MF-H MI-PV PRO-1
Date des tests
//

Comments / Kommentare / Commentaires :

The supply / service described was inspected in accordance with the order and declared as true.
Die bezeichnete Lieferung / Leistung wurde entsprechend der Bestellung geprüft und für einwandfrei befunden.
La livraison / service ci-dessus a été, après vérification, déclaré conforme à la demande.

Department / Dienststelle / Département	Function / Funktion / Fonction	Name / Nom	Date
DI PA MF-H MI-PV QM	Quality Manager Products PI-PV Qualitätbeauftragter Produkte PI-PV Chargé de mission qualité Produits PI-PV		

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50	125,000	11,9994	11,9999	-0,0036	-0,0007	0,0029
75	187,500	15,9984	15,9993	-0,0099	-0,0043	0,0056
100	250,000	20,0005	-	0,0034	-	-

Inherent Process and Customer Value:
Higher Repeatablity and Reproducibility
by more precise process control at NO additional cost → lower waste, higher yield

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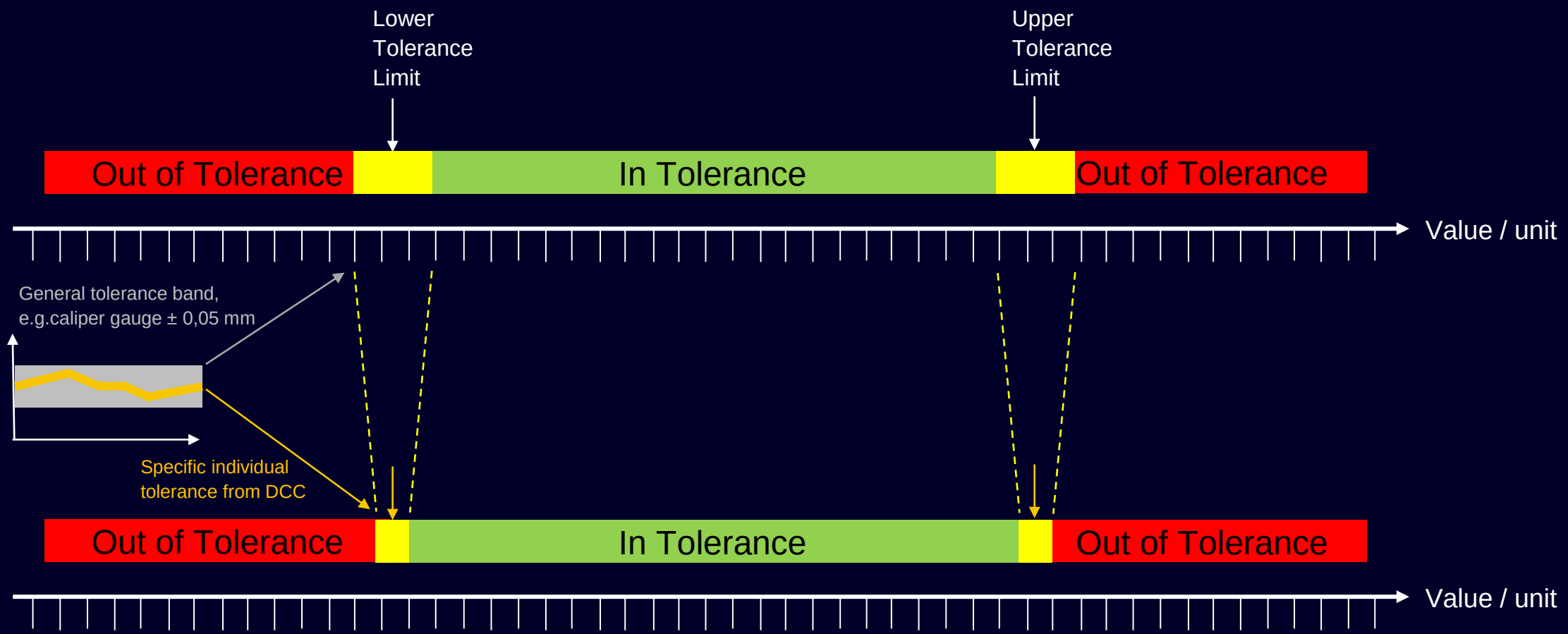
Benefits from Digital Calibration Certificate
DCC enables process yield in production processes

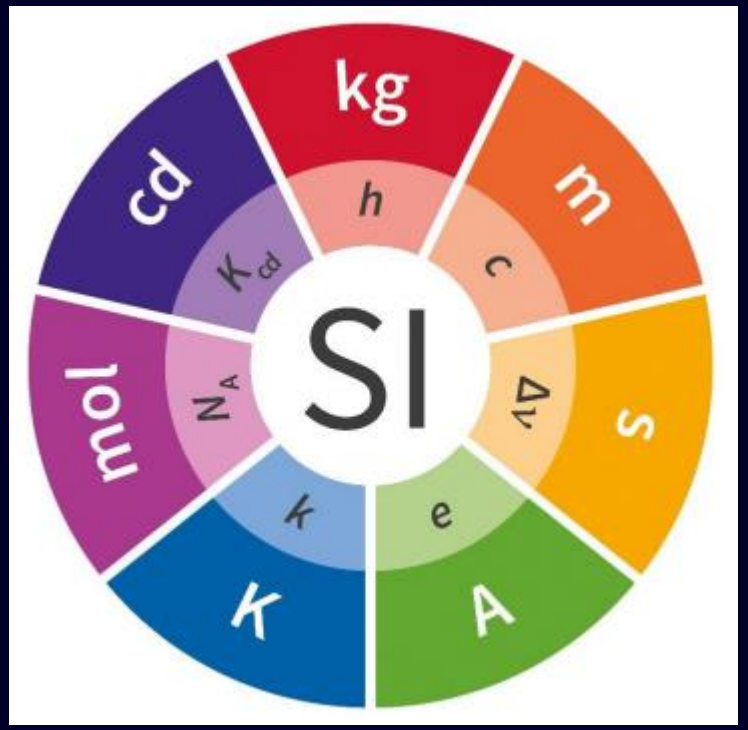


Precise and secure information about metrology system shrinks tolerance budgets !

The international digital System of Units: D-SI

A worldwide system of trading needs an internationaly accepted system of units.

7 Base Units



https://www.bipm.org/en/publications/si-brochure

22 derived units

Name	Symbol	Quantity	Equivalents	SI base unit equivalents
hertz	Hz	frequency	1/s	s^{-1}
radian	rad	angle	m/m	1
steradian	sr	solid angle	m^2/m^2	1
newton	N	force, weight	$kg{\cdot}m/s^2$	$kg{\cdot}m{\cdot}s^{-2}$
pascal	Pa	pressure, stress	N/m^2	$kg{\cdot}m^{-1}{\cdot}s^{-2}$
joule	J	energy, work, heat	m·N, C·V, W·s	$kg{\cdot}m^2{\cdot}s^{-2}$
watt	W	power, radiant flux	J/s, V·A	$kg{\cdot}m^2{\cdot}s^{-3}$
coulomb	C	electric	s·A, F·V	s·A
volt	V	voltage, electrical	W/A, J/C	$kg{\cdot}m^2{\cdot}s^{-3}{\cdot}A^{-1}$
farad	F	electrical capacitance	C/V, s/Ω	$kg^{-1}{\cdot}m^{-2}{\cdot}s^4{\cdot}A^2$
ohm	Ω	electrical	1/S, V/A	$kg{\cdot}m^2{\cdot}s^{-3}{\cdot}A^{-2}$
siemens	S	electrical conductance	1/Ω, A/V	$kg^{-1}{\cdot}m^{-2}{\cdot}s^3{\cdot}A^2$
weber	Wb	magnetic flux	J/A, $T{\cdot}m^2$, V·s	$kg{\cdot}m^2{\cdot}s^{-2}{\cdot}A^{-1}$
tesla	T	magnetic	$V{\cdot}s/m^2$, Wb/m^2,	$kg{\cdot}s^{-2}{\cdot}A^{-1}$
henry	H	electrical inductance	V·s/A, Ω·s, Wb/A	$kg{\cdot}m^2{\cdot}s^{-2}{\cdot}A^{-2}$
degree Celsius	°C	temperature relative	K	K
lumen	lm	luminous flux	cd·sr	cd
lux	lx	illuminance	lm/m^2	$cd{\cdot}m^{-2}$
becquerel	Bq	radioactivity (decays	1/s	s^{-1}
gray	Gy	absorbed	J/kg	$m^2{\cdot}s^{-2}$
sievert	Sv	equivalent	J/kg	$m^2{\cdot}s^{-2}$
katal	kat	catalytic activity	mol/s	$s^{-1}{\cdot}mol.$

+ numerous „traditional“ units (mm Hg, bar, …)
+ numerous imperial units (inch, pound, gallon, …)

and their digital representation in an XML-structure:

```
<si:listUnit>\siemens</si:listUnit>
  <si:listUnivariateUnc>
    <si:expandedUnc>
      <si:uncertainty>0.01</si:uncertainty>
      <si:coverageFactor>2</si:coverageFactor>
      <si:coverageProbability>0.95</si:coverageProbability>
      <si:distribution>normal</si:distribution>
    </si:expandedUnc>
  </si:listUnivariateUnc>
<si:real>
  <si:value>113.5</si:value>
</si:real>
```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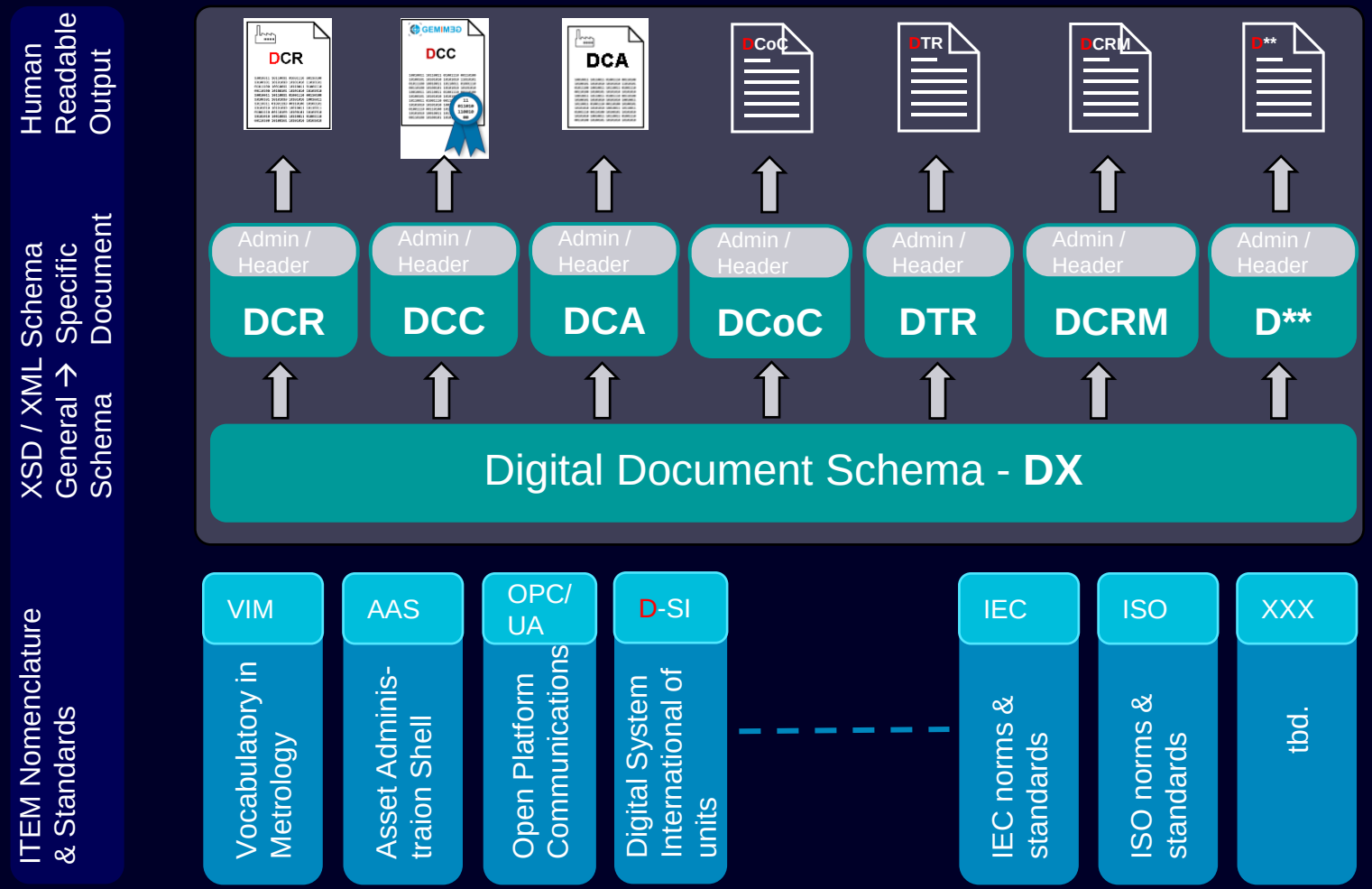
The Digital Calibration Document „Ecosystem“
A generic view…



Concept:
One common DX-Schema with Semantics
(as XSD / XML-Schema as parent schema)

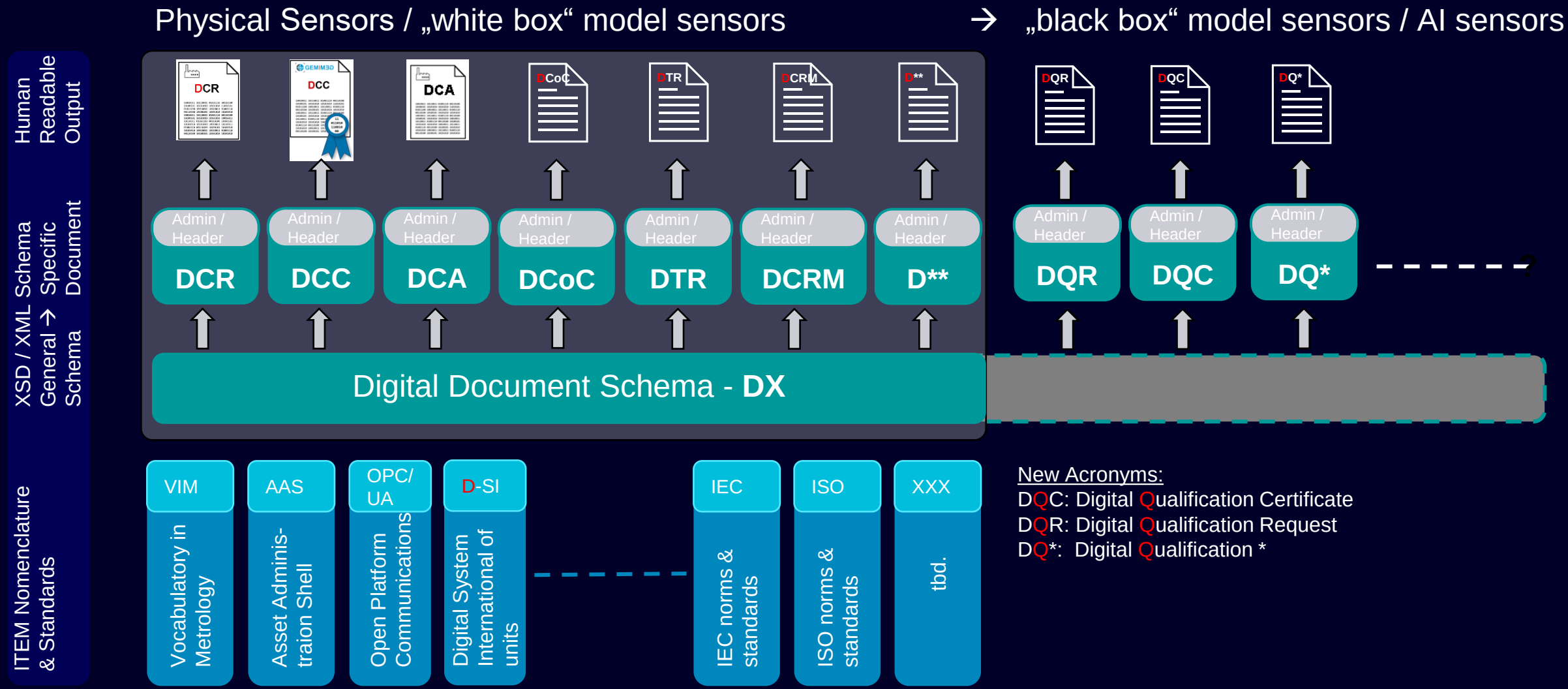
Multiple different sub-schemata of DX as children / branches for

- DCR Digital Calibration Request
- DCC Digital Calibration Certificate [1]
  DCA Digital Calibration Answer
- DCoC Digital Certificate of Conformity [1]
- DTR Digital Test Report
- DCRM Digital Certificate for Reference Material [1]
- D** … and many more digital documents

[1] governed by ISO 17xxx standards

HRO: Multi-language available → automatic conversion / generation from (signed/qualified) D**.XML file

The Digital Calibration Document „Ecosystem“
A generic view…



Building Blocks for a Digital Quality Document

Semantic Model

- Terms
- Definitions

(plus Ontology)

\+ Multi-lingual Translations

Implementation

- XSD Schema

Potentially others:

- JSON Schema
- …

Digital Quality Document

- DCC.xxx
- DCoC.xxx
- DTR.xxx
- DCRM.xxx
- …

(xxx: xml, json, ...)

Tools

- GEMIMEG Tool*
- Schema Validation*
- PyDCC **
- …

* PTB ** Open Source

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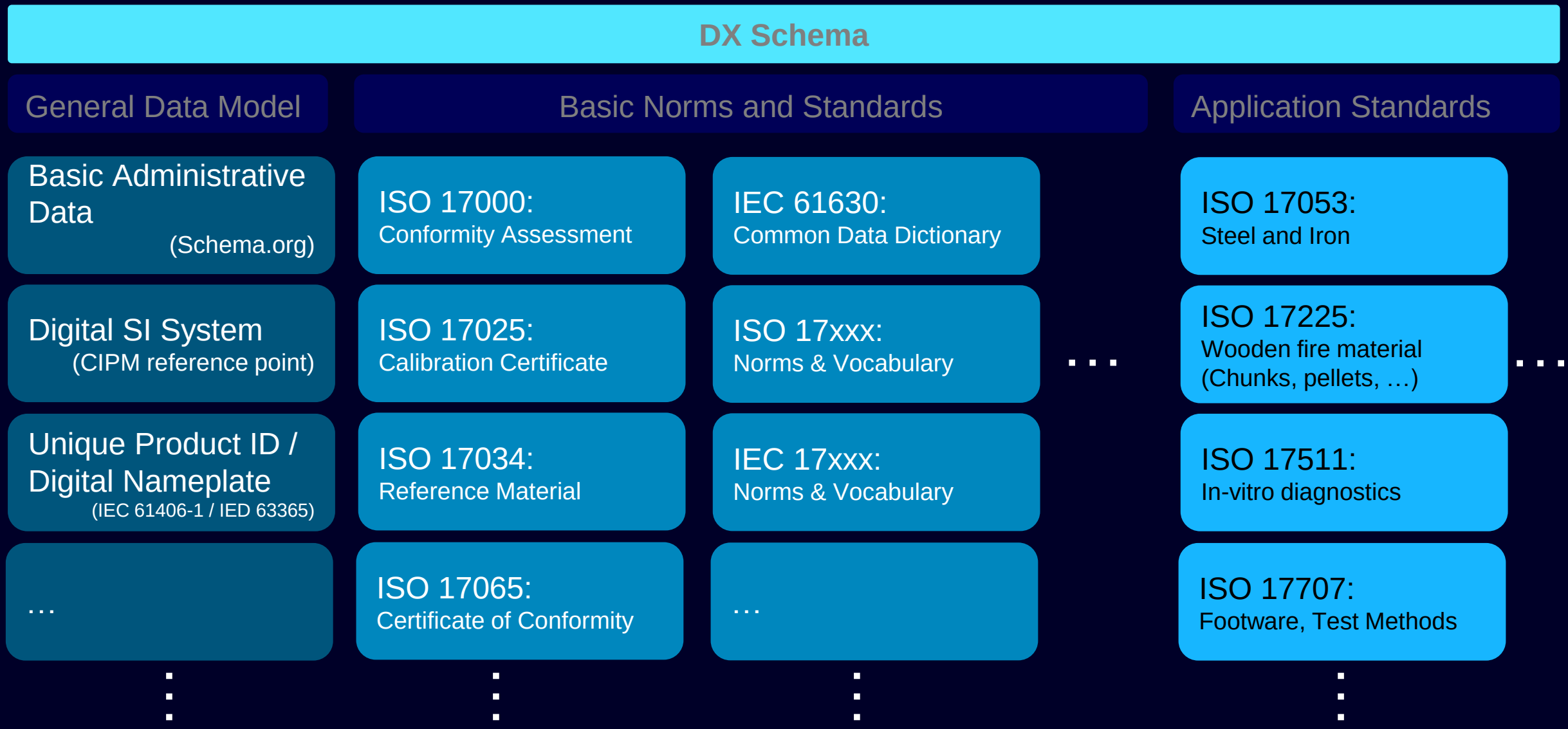
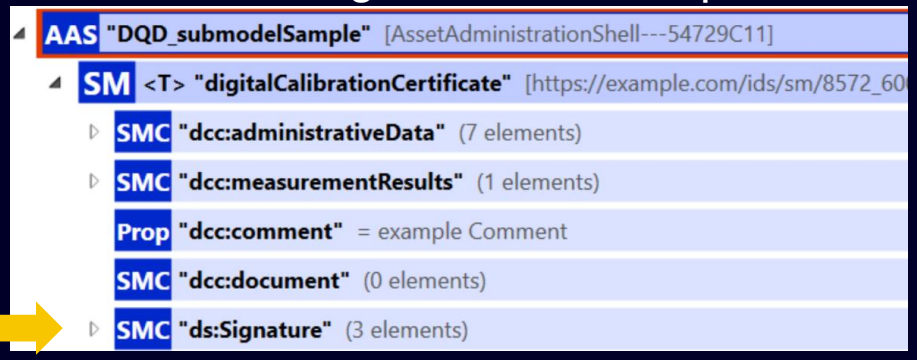
Suggestion for modular structure of Semantic Model for DX-Schema



Asset Administration Shell
Submodel: Digital Quality Documents

Digital Quality Documents characterize the *performance of a system / product* over its *entire life span* via the following documents by recurring tests over time:

- Calibration (DCC)
- Conformity asessment (DCoC)
- Legal metrology (DCC, DCoC)
- Test reports (DTC)
  - Acceptance tests
  - Field Tests
  - Check lists e.g. function / completeness



Signed document for
Originality and Authenticity

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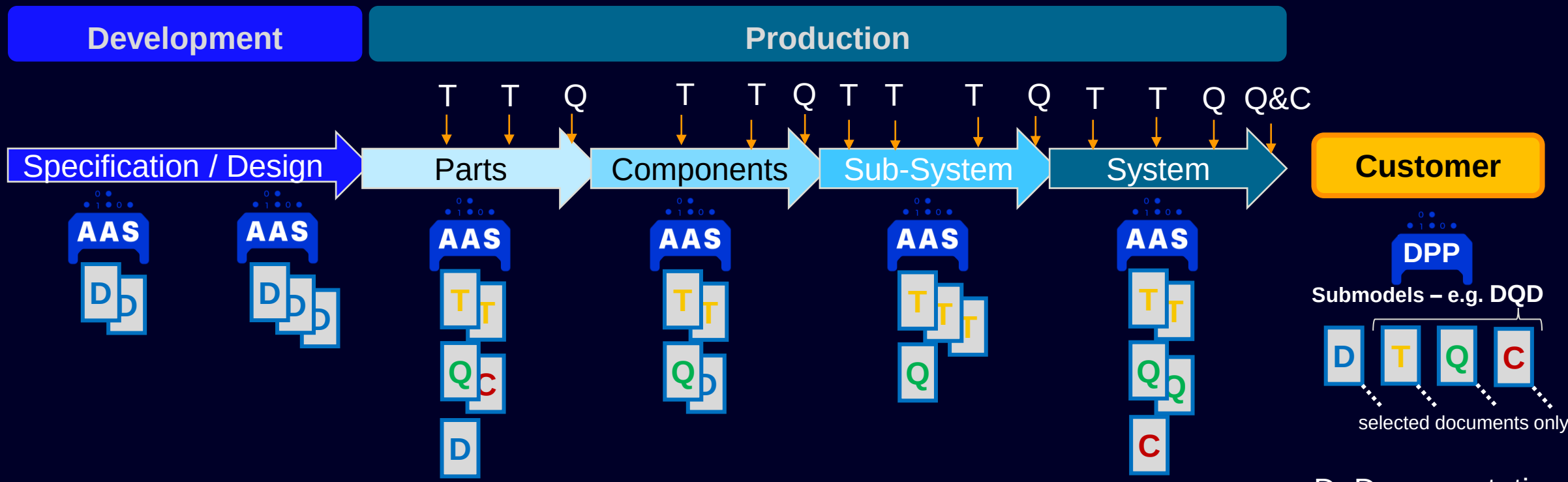
Product Lifecycle from Craddle to Gate for Digtial Quality Documents
AAS - DPP - DQD



D: Documentation
T: Test
Q: Qualification
C: Calibration

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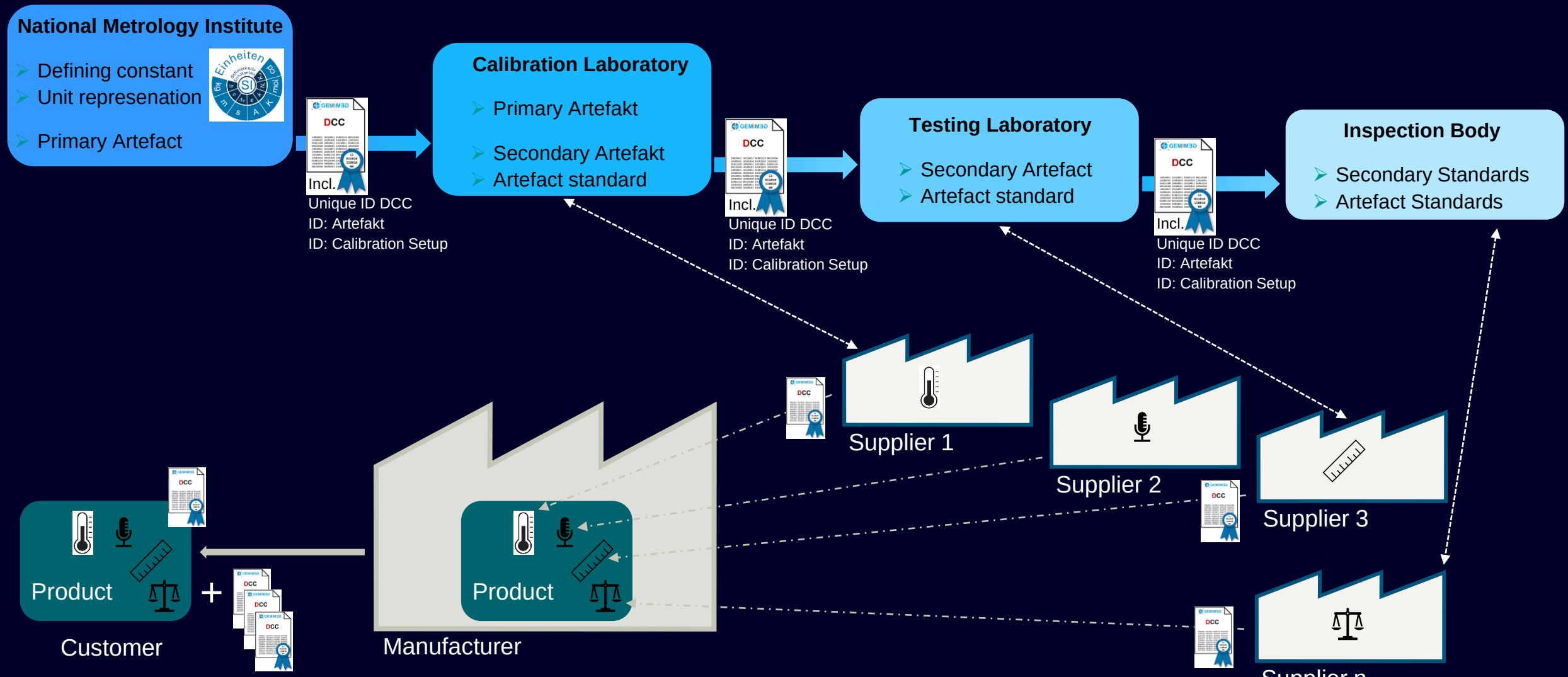
Usecase: System Integration of industrial products and industrial production systems



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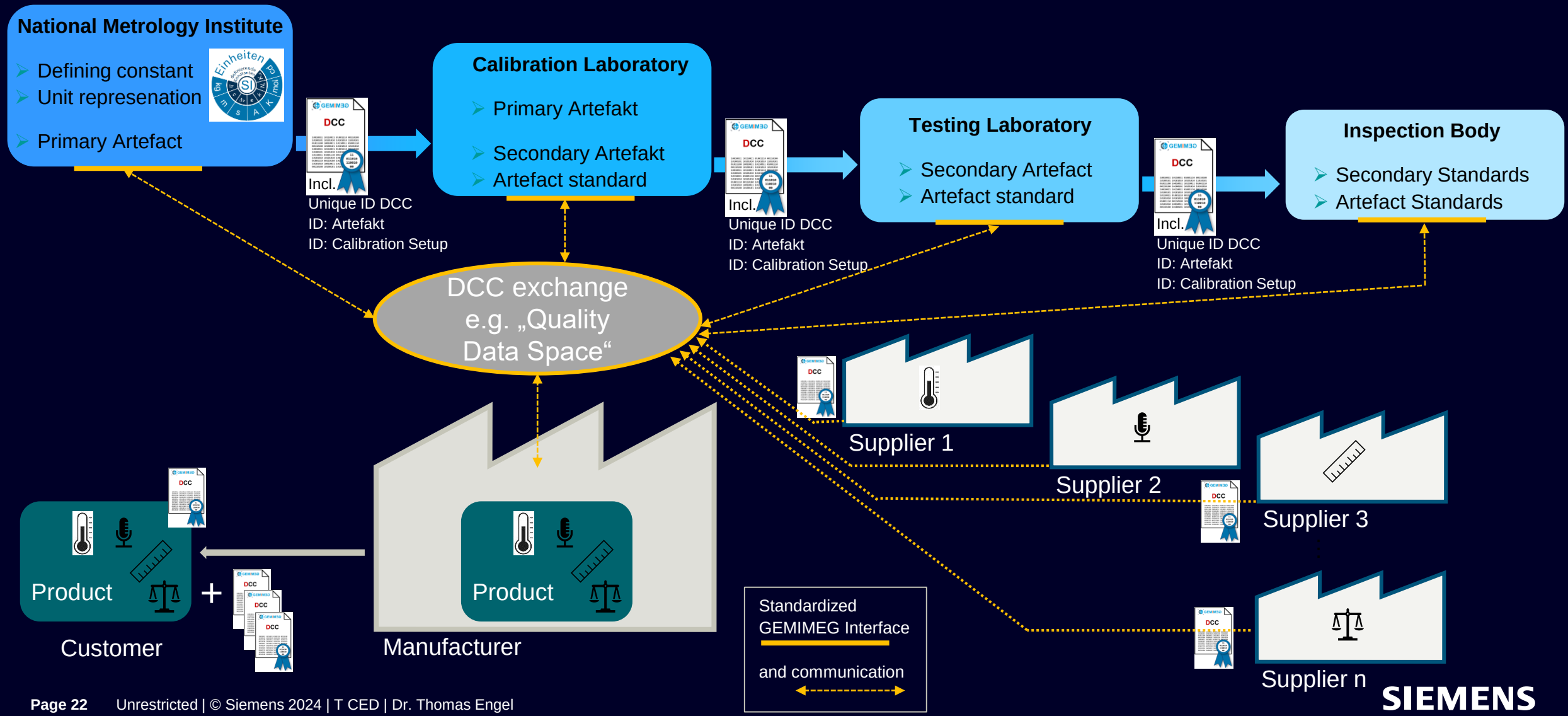

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Foto: Alexander Hafemann; Mlenny/iStockphoto.com

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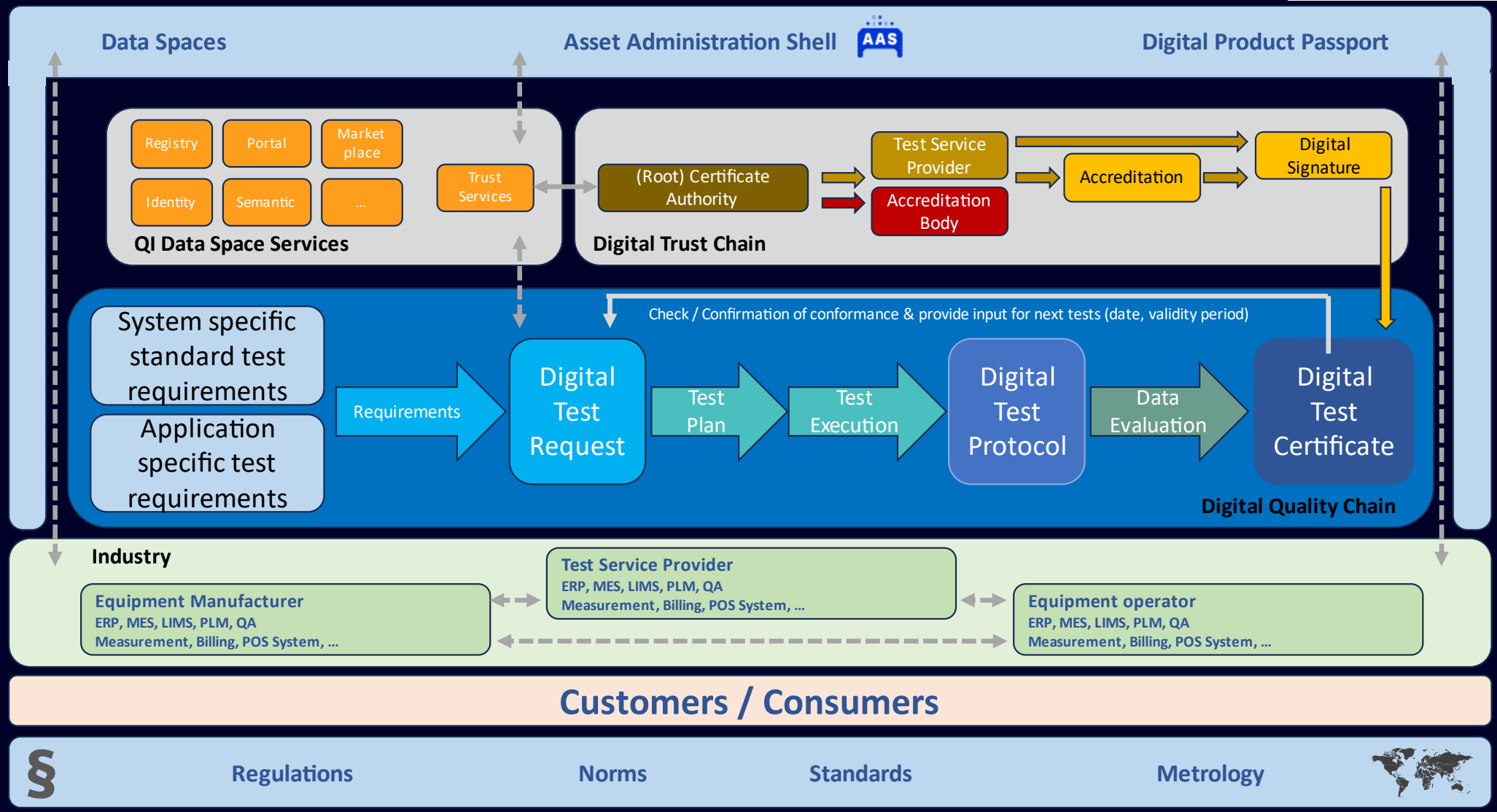
The Future: GEMIMEG-X ? (Project proposal submitted to BMWK, under evaluation)



Summary: Benefits from DCC in a Stakeholder perspective

Sensor owner

Asset Administration
- Full Automation
- Correct Data
- Full Traceability

DCR standardize calibration requirements

Consistency in DCC information content

Calibration Tracking
- Due date
- Intervals
- Perfomance

Resilience

Calibration Service

Standard calibration requirements in DCR
- Data Handling
- Adminstrative Data
- Order Clarification

DCC based on DCR
* DCR is „DCC template“

Full process automation

Secure data provisioning in platform / data space: DCR / DCC / revocation

Industry 4.0 compliant

New digital Businesses

Sensor User

Full process automation
- Instant data availability
- Reduced error margin
- Accurate data improve process yield

Consitent DCC data
- Across calibration service providers

Secure data availablity in platform / data space: DCR / DCC / revocation

Sensor data lifetime / type evaluation – recal. interval

Industry 4.0 compliant

Legal / Regulatory

Full data traceability
- Instant & long term data availability
- DCR / DCC / DCA
- Calibration laboratory accreditation
- Transparent process quality chain with all stakeholders in a quality process

Automated (Pre-)Auditing

Secure data availablity in platform / data space:
- DCR / DCC / revocation
- Independent audit trail

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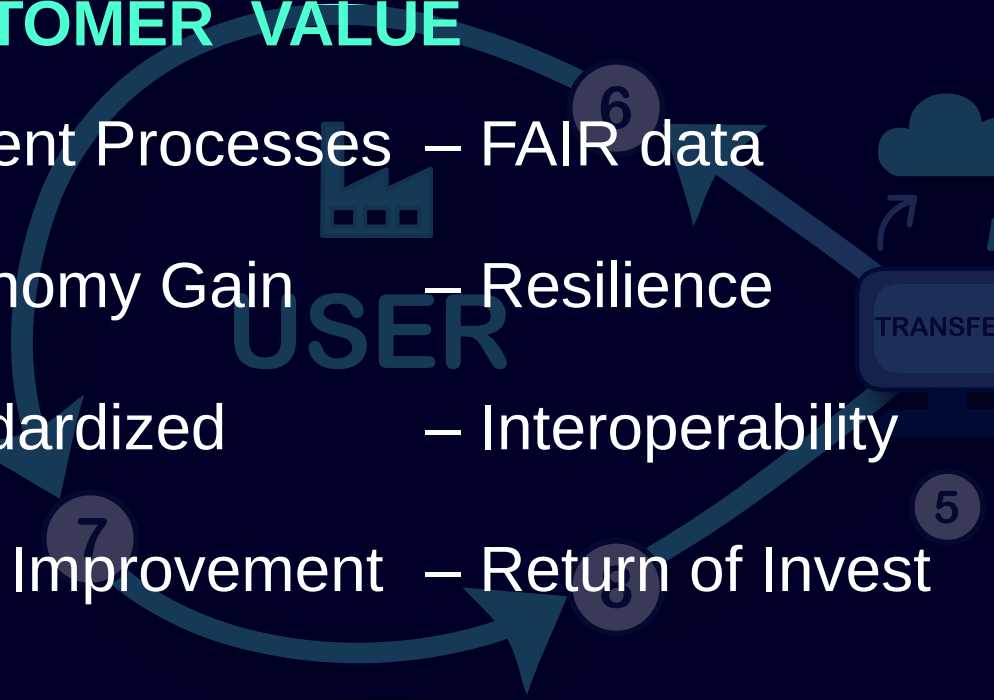
The value behind the GEMIMEG concept for industrial processes



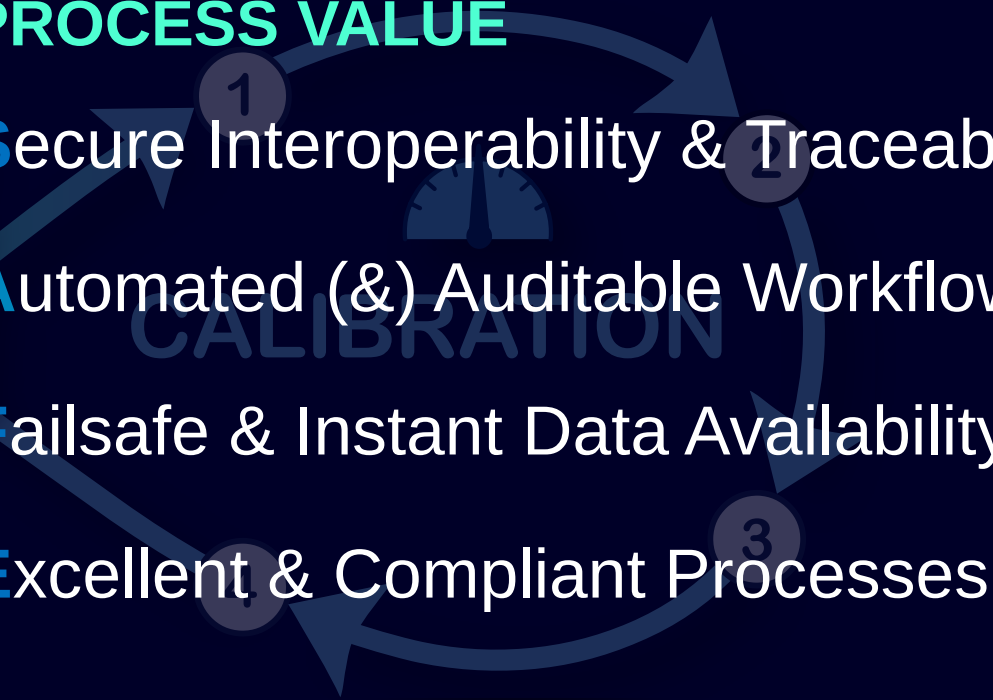
CUSTOMER VALUE

Efficient Processes – FAIR data

Autonomy Gain – Resilience

Standardized – Interoperability

Yield Improvement – Return of Invest



PROCESS VALUE

Secure Interoperability & Traceability

Automated (&) Auditable Workflows

Failsafe & Instant Data Availability

Excellent & Compliant Processes

→ Sustainable, circular processes!

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More content:

GEMIMEG-II — How metrology can go digital…
https://iopscience.iop.org/article/10.1088/1361-6501/ace468/meta

PyDCC
https://github.com/siemens/pydcc/

Contributions to previous international DCC conferences

Presentation and paper @ IMEKO 2024 end of August

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