Lab of the Future and Future of the Lab in Scientific Metrology

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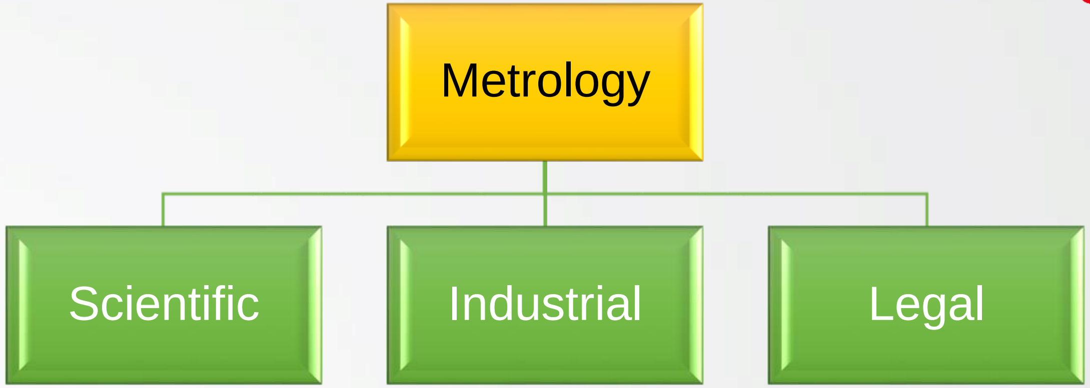
October 21, 2022

Metrology

Metrology has three sub branch

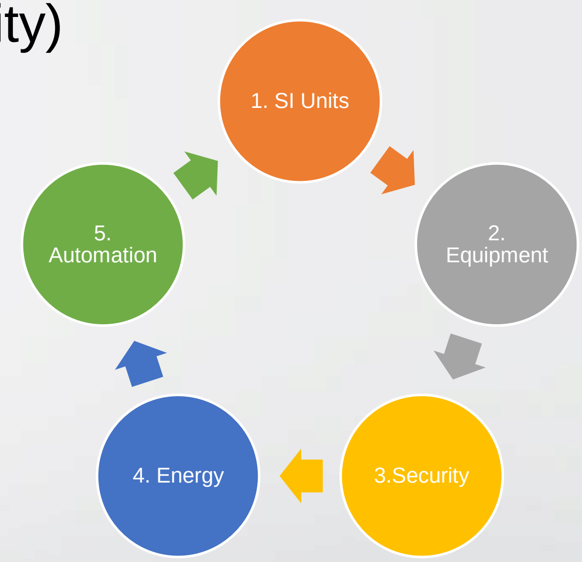
- Scientific metrology
- Industrial metrology
- Legal metrology



- ❑ Scientific Metrology; to measurand identification, setting up and maintaining primary and secondary level measurand assemblies,
- ❑ Industrial metrology; the certification of products, their testing before they are put on the market, and the accreditation processes of testing laboratories.
- ❑ Legal metrology; the activities of determining the rules to be followed based on measurement in the country, taking into account the rights of consumers.

Content

1. Changes that will occur with the redefinition of the measurement variables (SI Units Definition)
2. Changes in measurement methods as a result of developments in measuring devices (Equipment)
3. Changes in processes regarding the safety of measurement results (Security)
4. Changes in terms of energy efficiency of laboratory (Energy)
5. Changes in terms of automation of laboratories (Automation)



1. SI Units Definition

TÜBİTAK UME

kilogram

candela

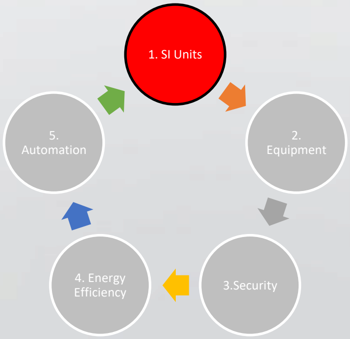
meter

mol

second

kelvin

amper



1. SI Units Definition

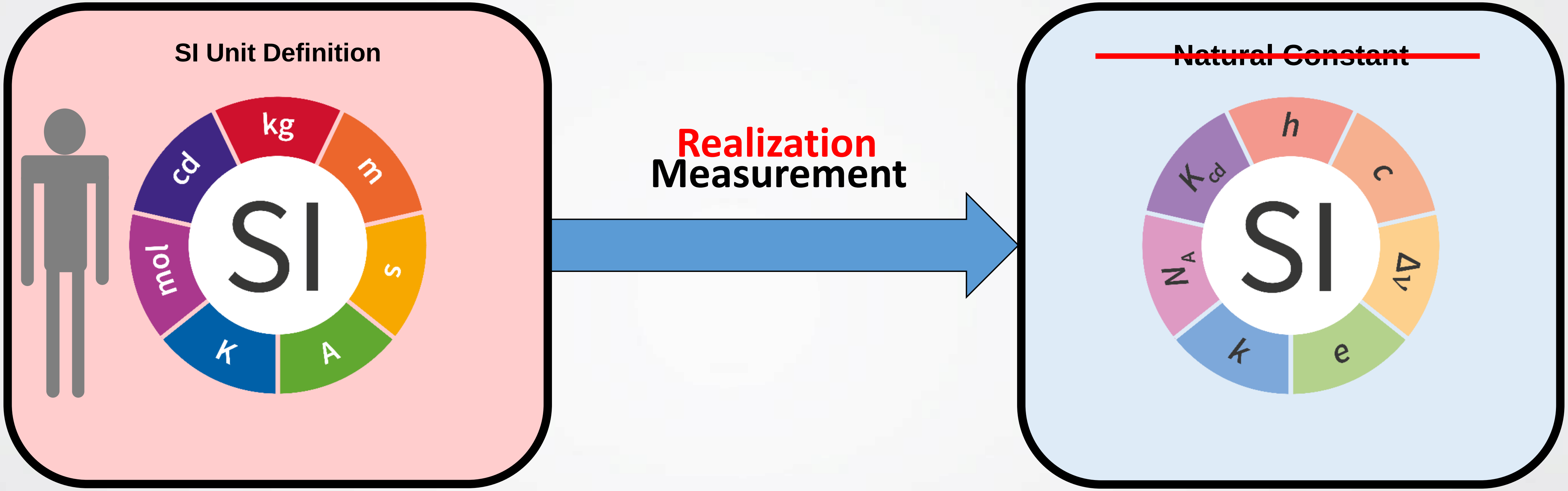
TÜBİTAK UME

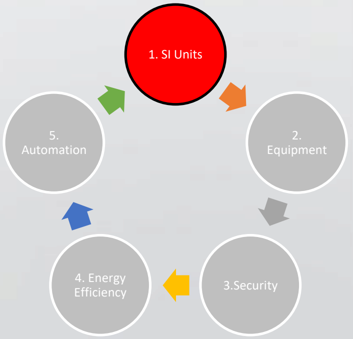
At the 26th General Conference on Weights and Measures (CGPM), hosted by the International Bureau of Weights and Measures (BIPM) on 14-16 November 2018 in Versailles, France, the changes in the definitions of kilograms, ampere, kelvin and mole were unanimously adopted. .

Changes that will end the use of physical objects to define units of measurement come into effect from May 20, 2019.

1. SI Units Definition

SI Unit Definition



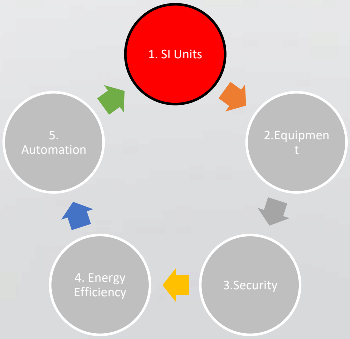


1. SI Units Definition

Natural Constants

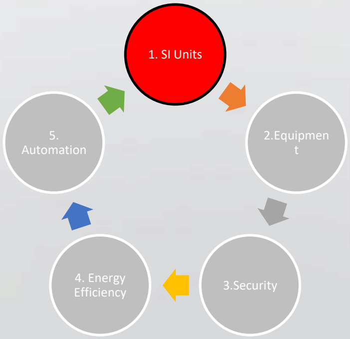
Natural Constant Name	Symbol	Value
Vakumdaki ışık hızı	c	299 792 458 m / s,
Planck constant	h	6.626 070 15 × 10^{-34} J s
Electron charge	e	1.602 176 634 × 10^{-19} C
Boltzmann constant	k	1.380 649 × 10^{-23} J / K
Avagadro's constant	N_A	6.022 140 76 × 10^{23} mol^{-1}
Extremely fine transition frequency of Cs 133 atoms	$\Delta\nu_{Cs}$	9 192 631 770 Hz
Light intensity	K_{cd}	Luminous efficiency of monochromatic radiation with a frequency of 540 × 10^{12} Hz, 683 lm / W

https://www.bipm.org/utils/en/pdf/si-revised-brochure/Draft-SI-Brochure-2019.pdf

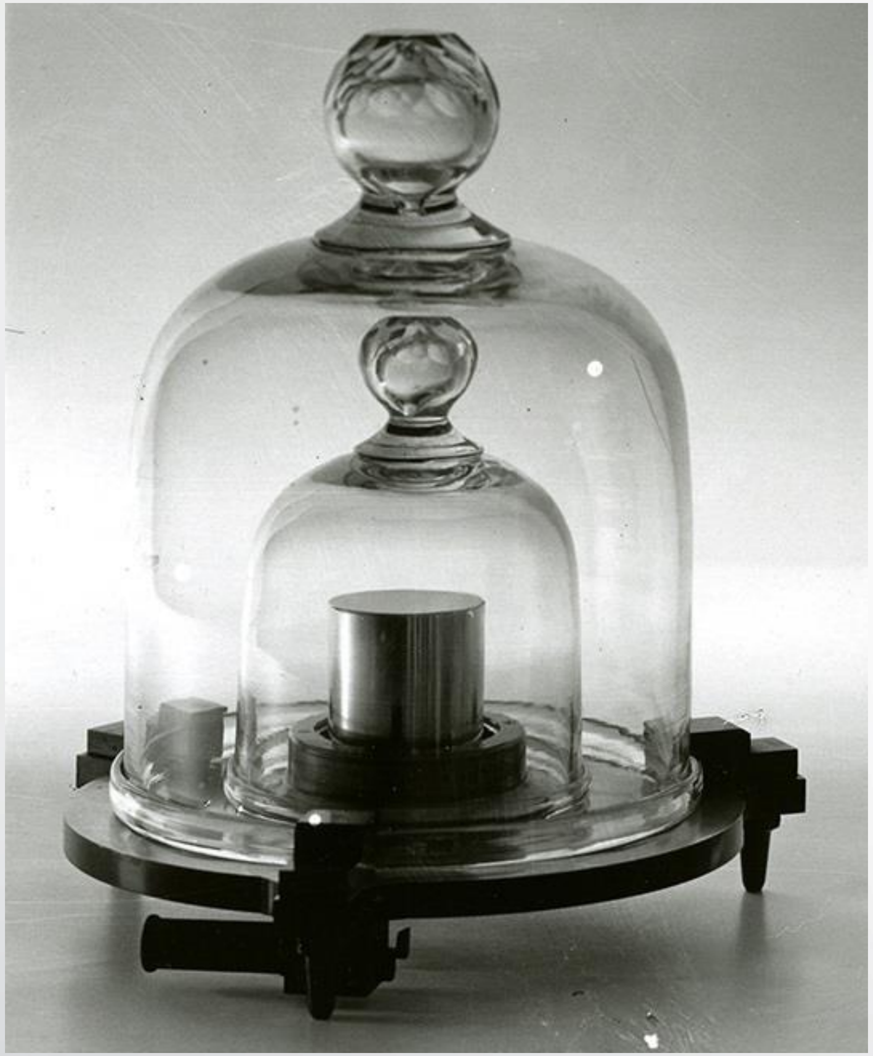


MASS

KILOGRAM

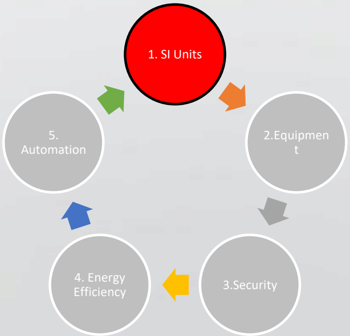


Old Definition of Kilogram



The unit of mass is the kilogram and is equal to the mass of the international prototype of the kilogram (CGPM, 1901).

- ❑It defines the mass of H_20 at a maximum density of 1 dm^3 at 4 °C.
- ❑90% Platinum, 10% Iridium (1878, Johnson-Mathey)
- ❑Cylinder shape, h= 39 mm and Ø = 39 mm
- ❑It is stored in BIPM under controlled environmental conditions.
- ❑6 legal copies and working standards



New Kg Definition

TÜBİTAK UME

2018 November 16

26. CGPM Meeting

SI unit of mass kilogram (kg) is defined by using Planck constant (h)

$h = 6.626\,070\,150(69) \times 10^{-34}$ J s

2019 May 20

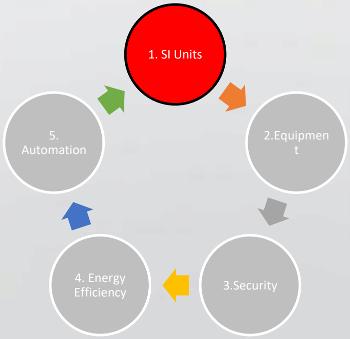
h

kg

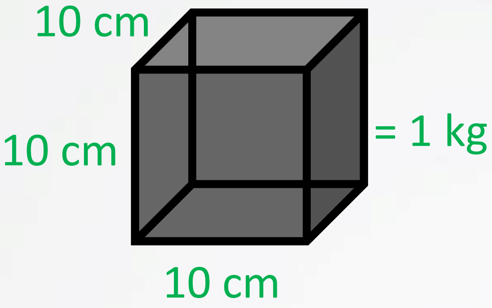
$h = 6.626\,070\,150(69) \times 10^{-34}$ kg m^2 s^{-1}

This definition is valid after May 20 2019

- h → Planck Constant
- 6.626 070 150(69) x 10^{-34} → CODATA 2017
- kg → Kilogram Unit
- m^2 → Light velocity in vacuum
- s^{-1} → Extremely fine transition frequency of Cs 133 atoms



New Kg Definition

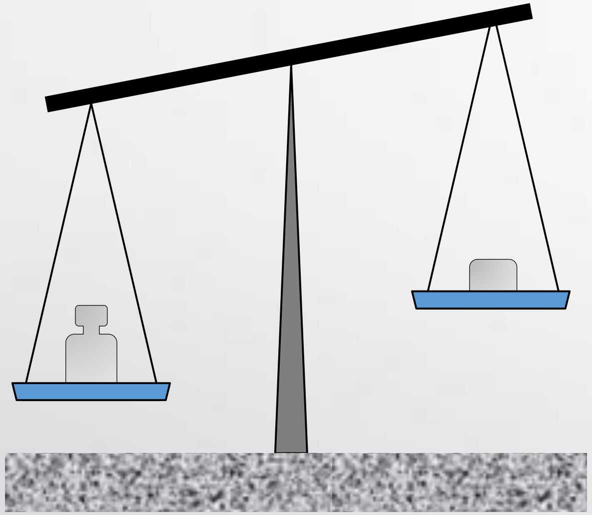


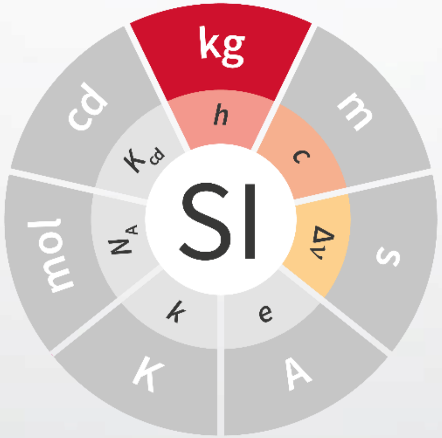
Old Definition…

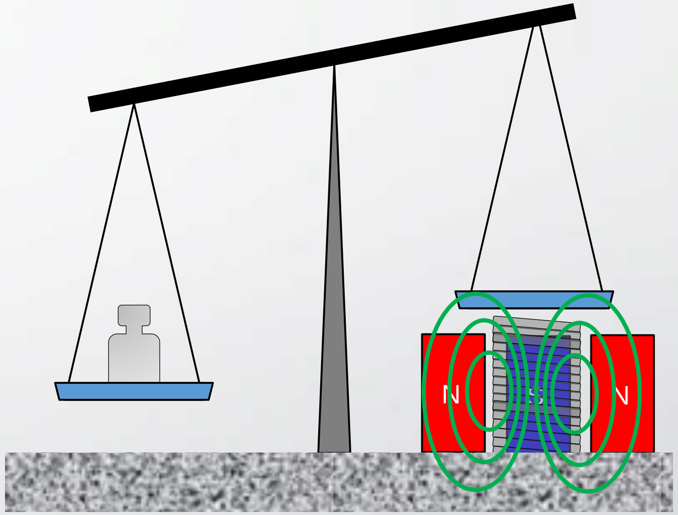
- International kilogam prototype (IPK)
- Standard kilograms is compared with IPK

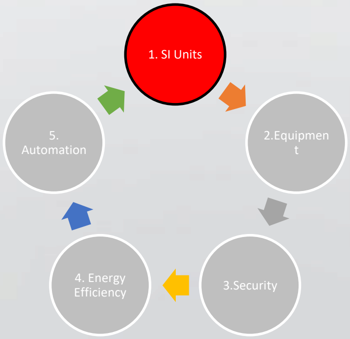
New Definition…

- h = 6.626 070 15 · 10^{-34} kg m^2 s^{-1}
- Garvity is compared with magnetic force
- Calculation formula: $\frac{h\Delta\nu_{Cs}}{c^2}$

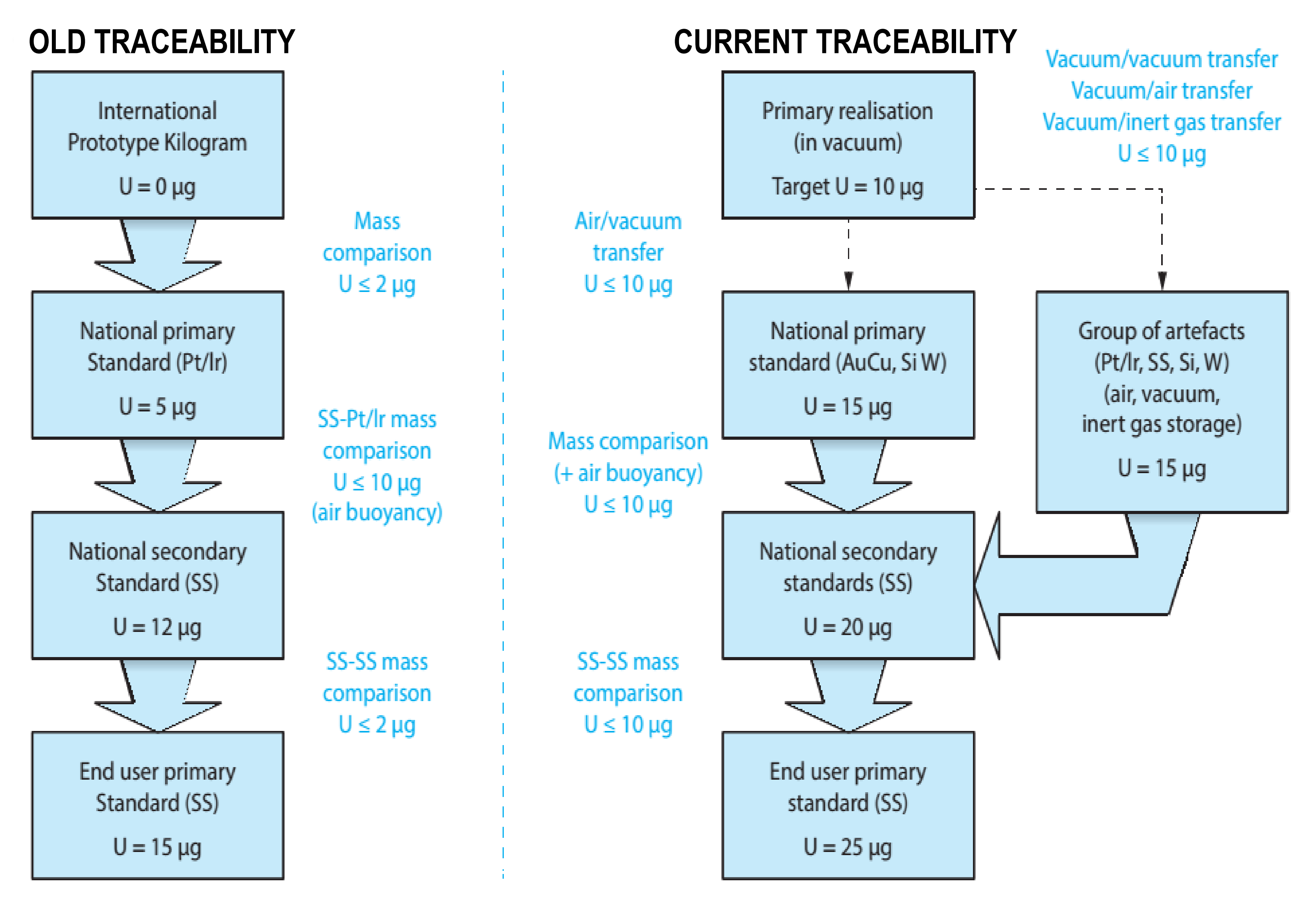


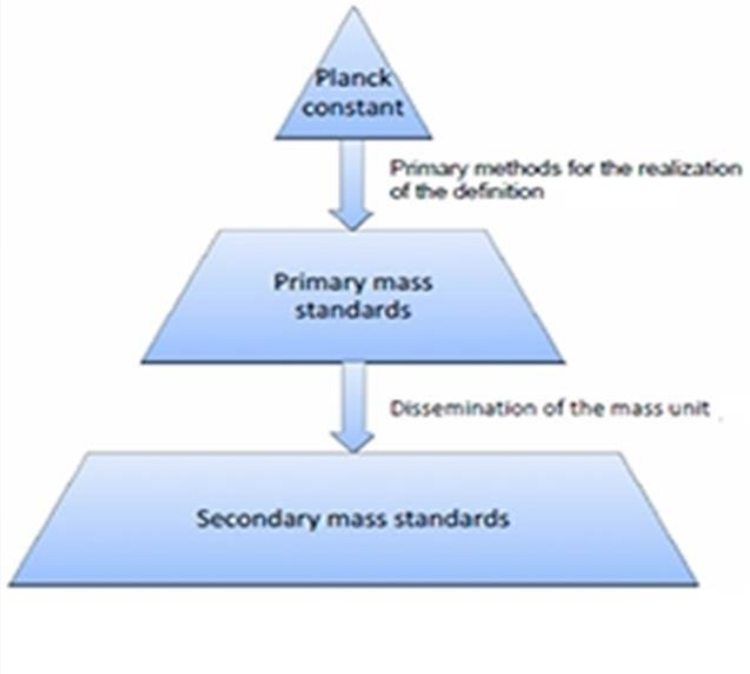


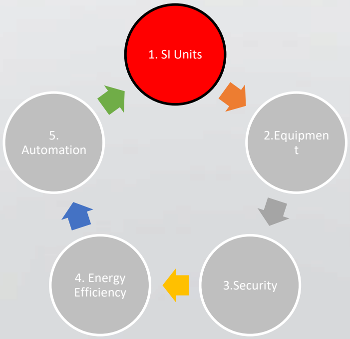




Traceability Chain of Kg







New Kg Realization and Dissemination

TÜBİTAK
UME

Planck Constan

IPK is not used

Primary level methods for kg defintion

Primary level mass Standards

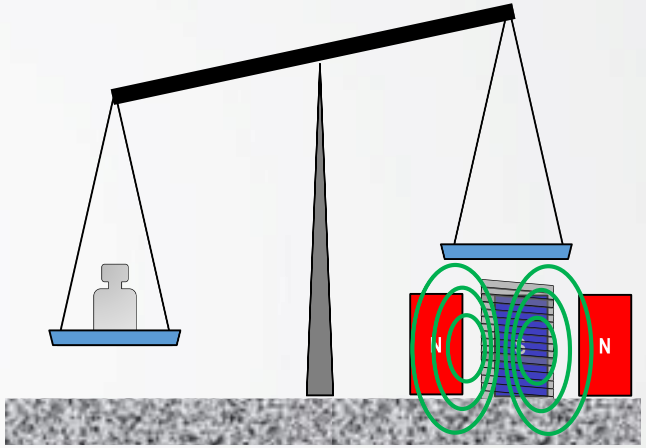
Mass performed at every scale

Dissemination of Kilogramın

Secondary Level Mass Standards

Kibble (Watt) Balance Experiment

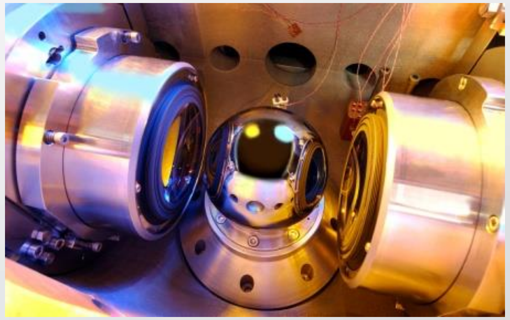
Mechanical Power = Electrical Power

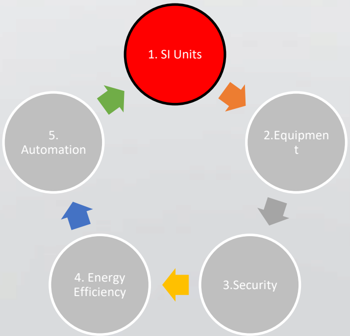


Brian Kibble
1938-2016

XRCD Experiment (Avagadro project)

Mass = Atom quantities x Atom mass

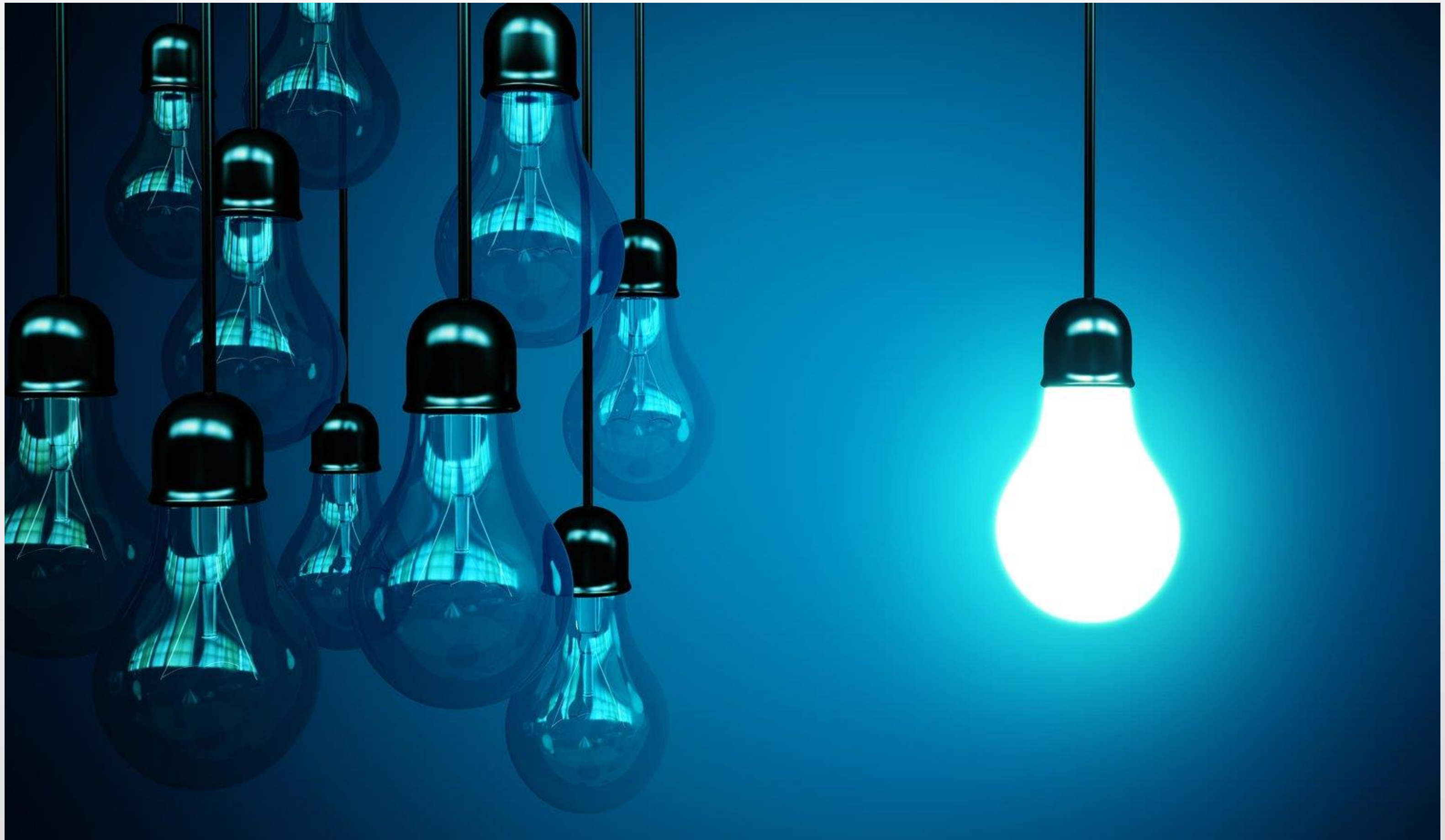


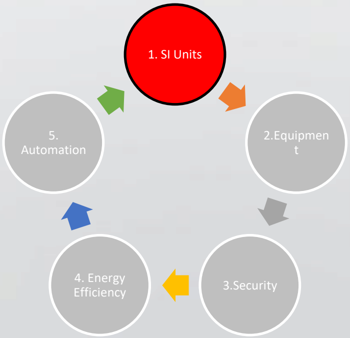


CURRENT

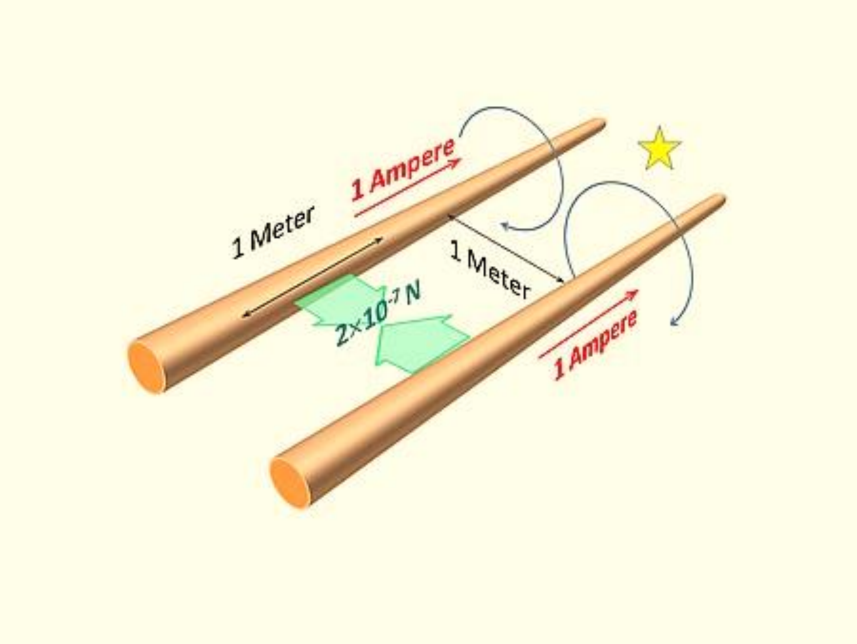
TÜBİTAK UME

AMPER

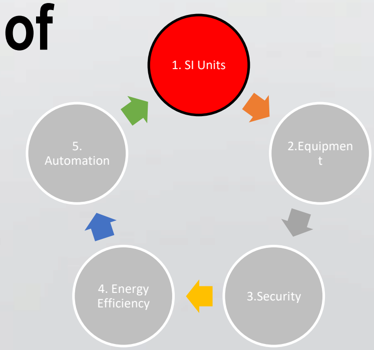




Old Definition of Amper



Ampere is defined as the electric current intensity that does not change over time, which, when a constant current is passed through two parallel linear conductors of negligible circular cross-section, which are one meter apart in vacuum and at an infinite distance from each other, creates a force of $2x10^{-7}$ Newtons per meter between these conductors.



New Definition of Amper

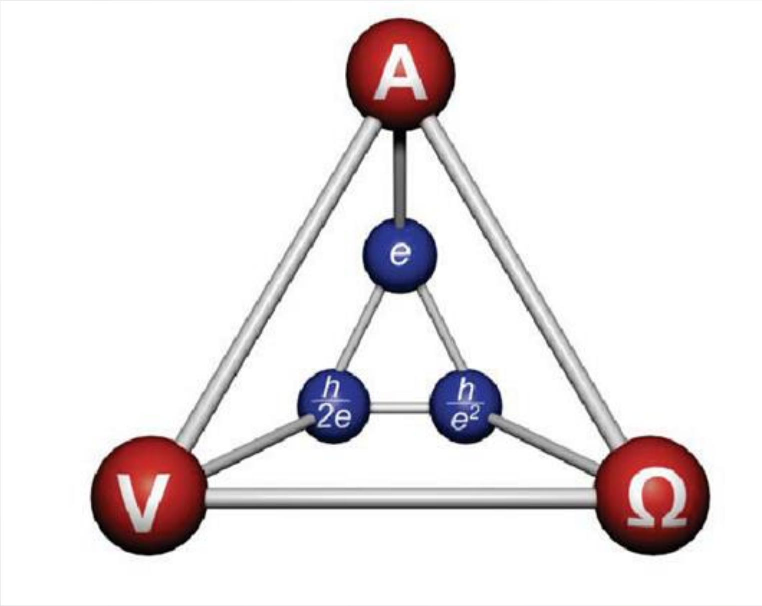
- At the 26th International General Conference on Weights and Measures (CGPM) held on November 13-16, 2018,

the value of the unit electron charge was accepted as the following fixed value.

Unit electron Charge (e) : 1.602 176 634 × 10^{-19} C

Where, the value of C is equal to the value of Amper.second

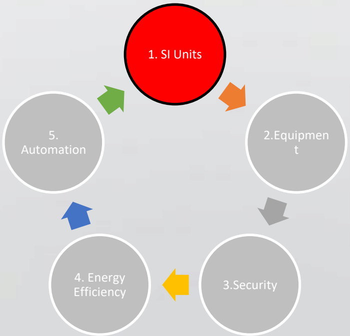
- The unit electron charge was accepted as one of the universal constants instead of a value obtained from other constants.



THERMODYNAMIC TEMPERATURE

TÜBİTAK UME

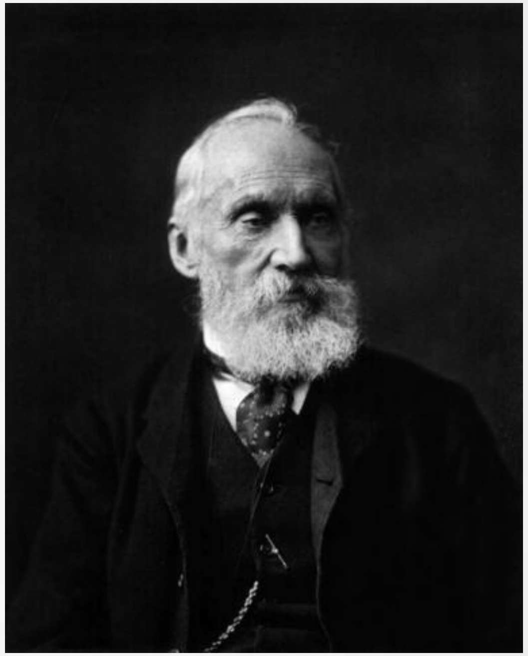
KELVIN



Old Definition of Kelvin

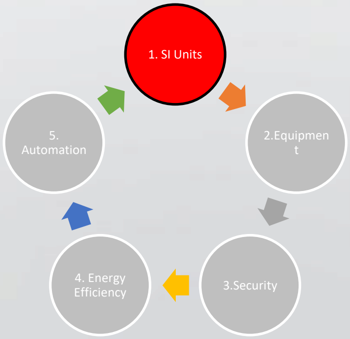
The unit of Thermodynamic Temperature, Kelvin, is defined as 1/273.16 of the Thermodynamic Temperature of the Triple Point of Water.

13rd CGPM meeting (1967/68, 4. decision; CR, 104)



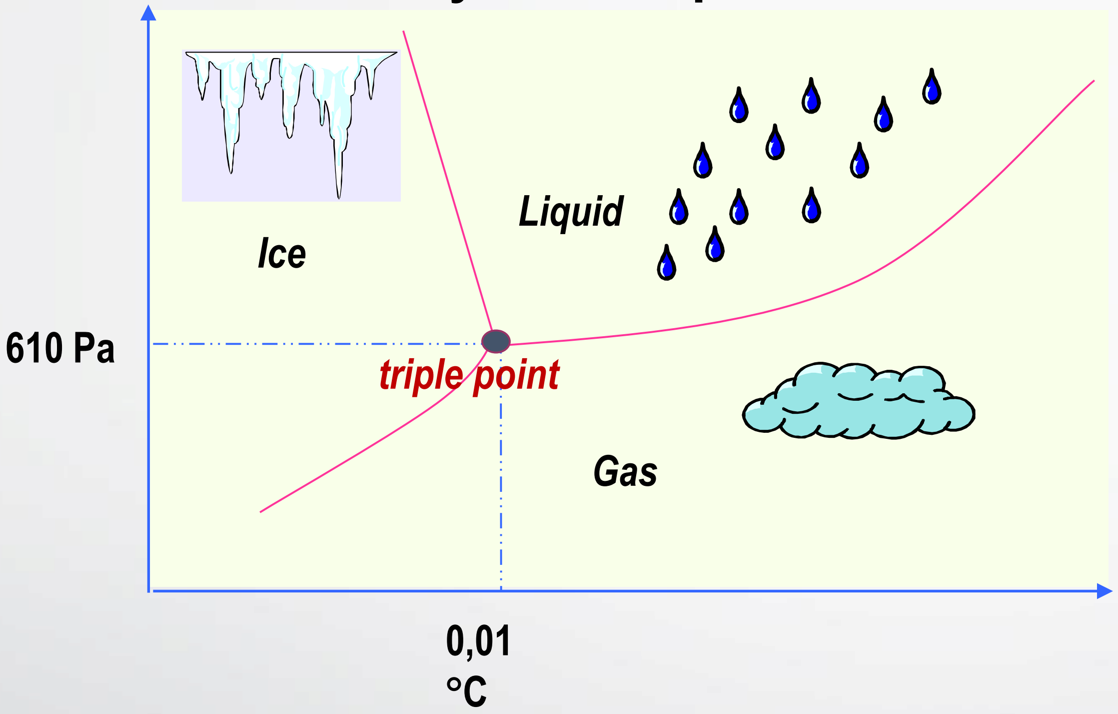
Lord Kelvin

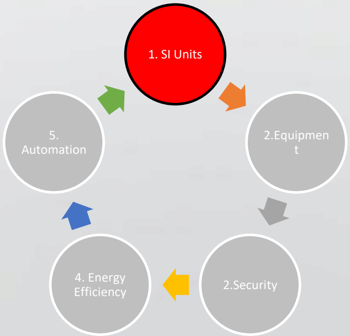
1824 - 1907



Triple Point of Water

The triple point (SUN) temperature of water is the temperature at which the three phases (solid, liquid and gas) coexist in thermodynamic equilibrium.





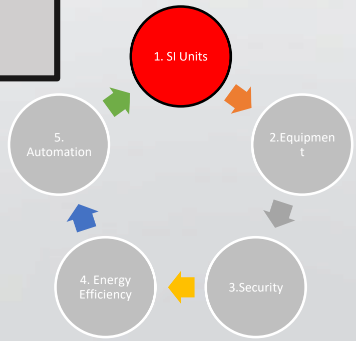
New Definition of Kelvin

SI unit of thermodynamic temperature Kelvin (K) Value is defined by using Boltzmann constant (k)

$k = 1.380\ 649 \times 10^{-23}\ J/K$

The thermodynamic temperature unit is defined over the Energy SI unit ($kg.m^2.s^{-2}.K^{-1}$).

Determining the temperature in Kelvin, the average molecular energy can be expressed as $\left[{h\Delta\nu_{Cs}}/{k}\right]$



Traceability Chain of Kelvin

Kelvin
Boltzmann Constant

⇓

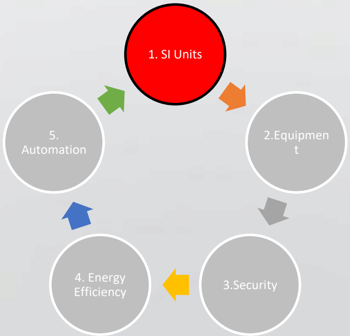
International Temperature Scale -1990
(Relative Primary Temperature Measurement Method)

⇓

Transfer Standards

⇓

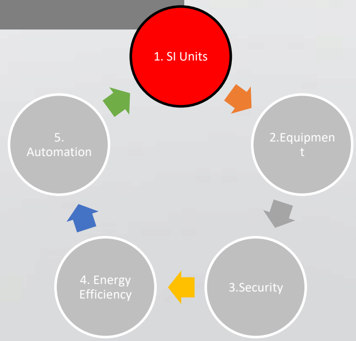
Working Standards



TÜBİTAK
UME

MATERIAL QUANTITY

MOL



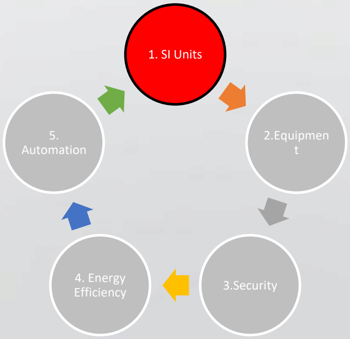
Old Definition of Mol

Mol, (Eng. mole) is the SI unit for the amount of substance.

The number of components corresponding to the atomic number of 0.012 kg of the element carbon-12 (^{12}C) of any substance is called mole.

This number is defined as Avagadro's number (N_A) and is equal to 6.022 140 76 × 10^{23} .

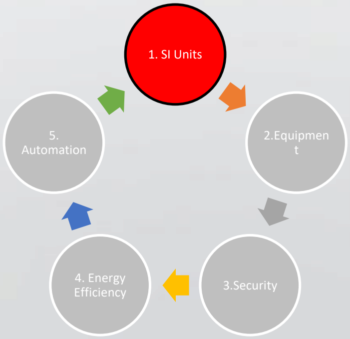
In this definition, the mole content is linked to the amount in the ^{12}C isotope of the stable element C.



New Definition of Mol

A substance containing components (atoms, molecules, etc.) up to Avogadro's number (N_A = 6.022 140 76 × 10^{23} mol^{-1}) is called 1 mole.

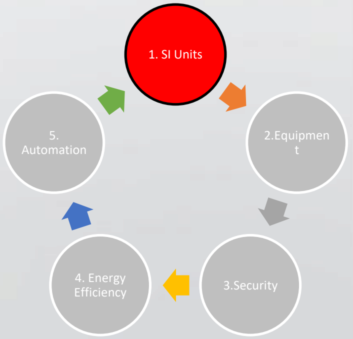
The definition was independent of the amount (unit mass kg) of the ^{12}C isotope and defined as a constant (N_A).



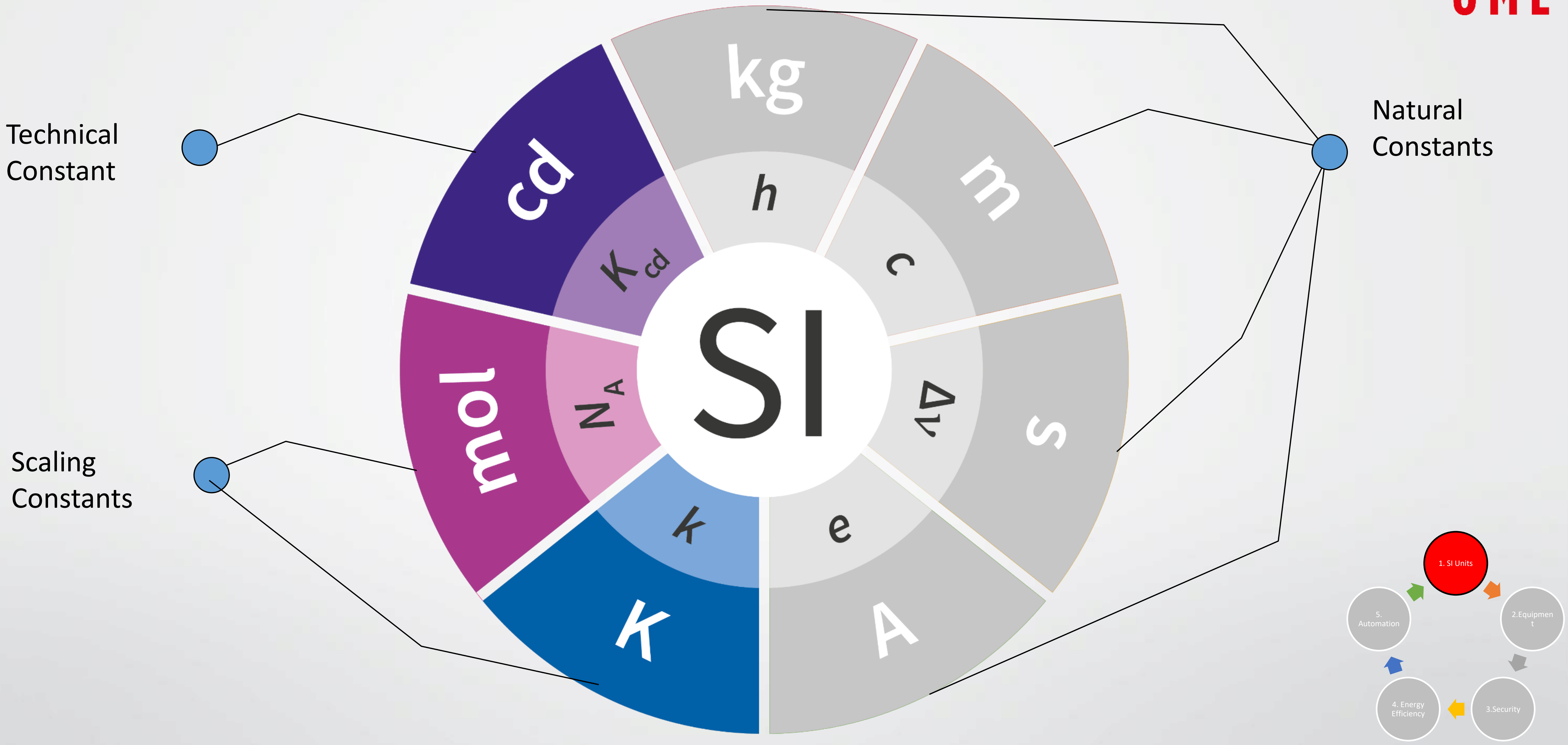
TÜBİTAK
UME

TIME LENGTH LUMINOUS INTENSITY

SECOND, METER, CANDELA

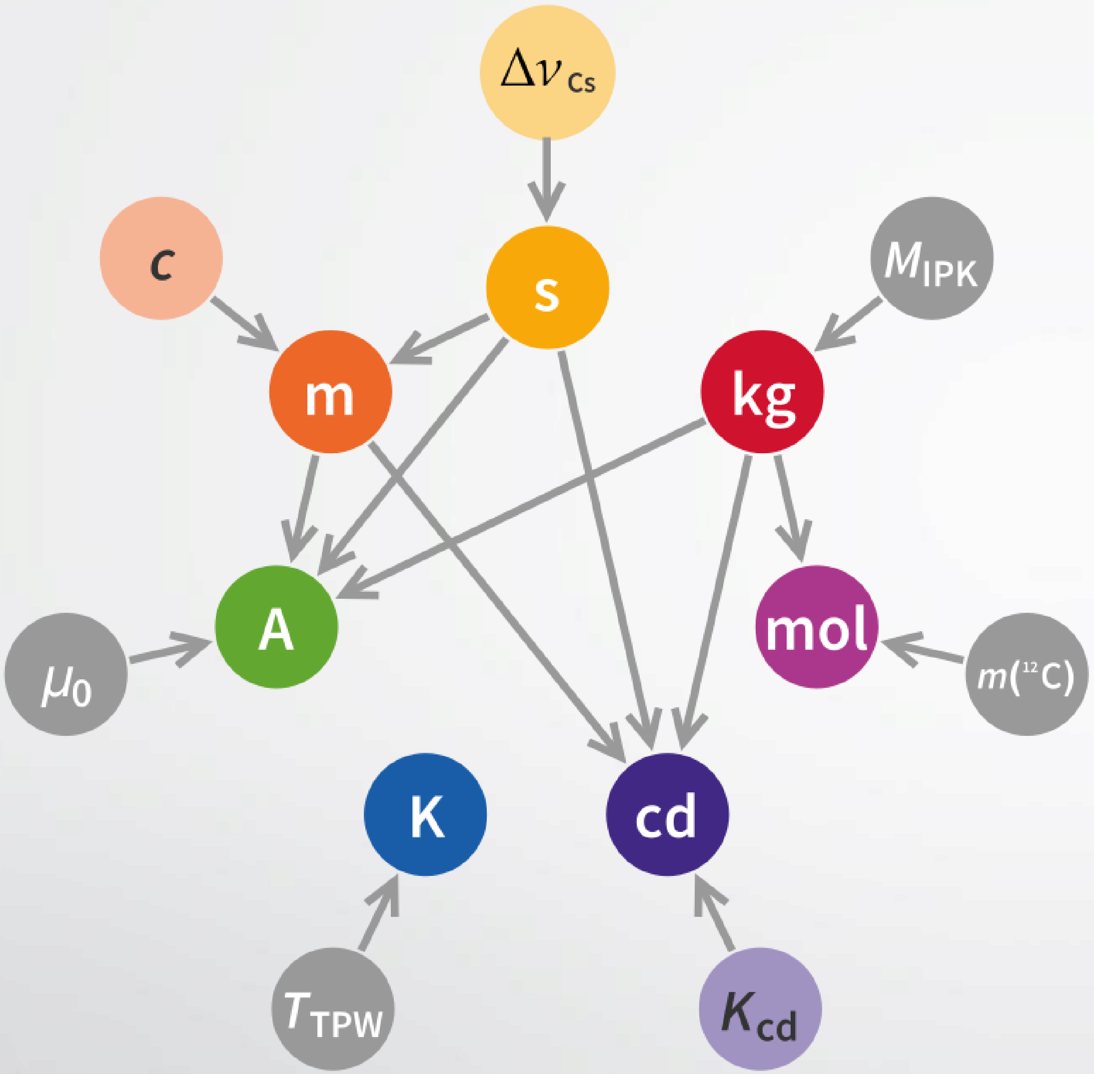


1. SI Units Definition

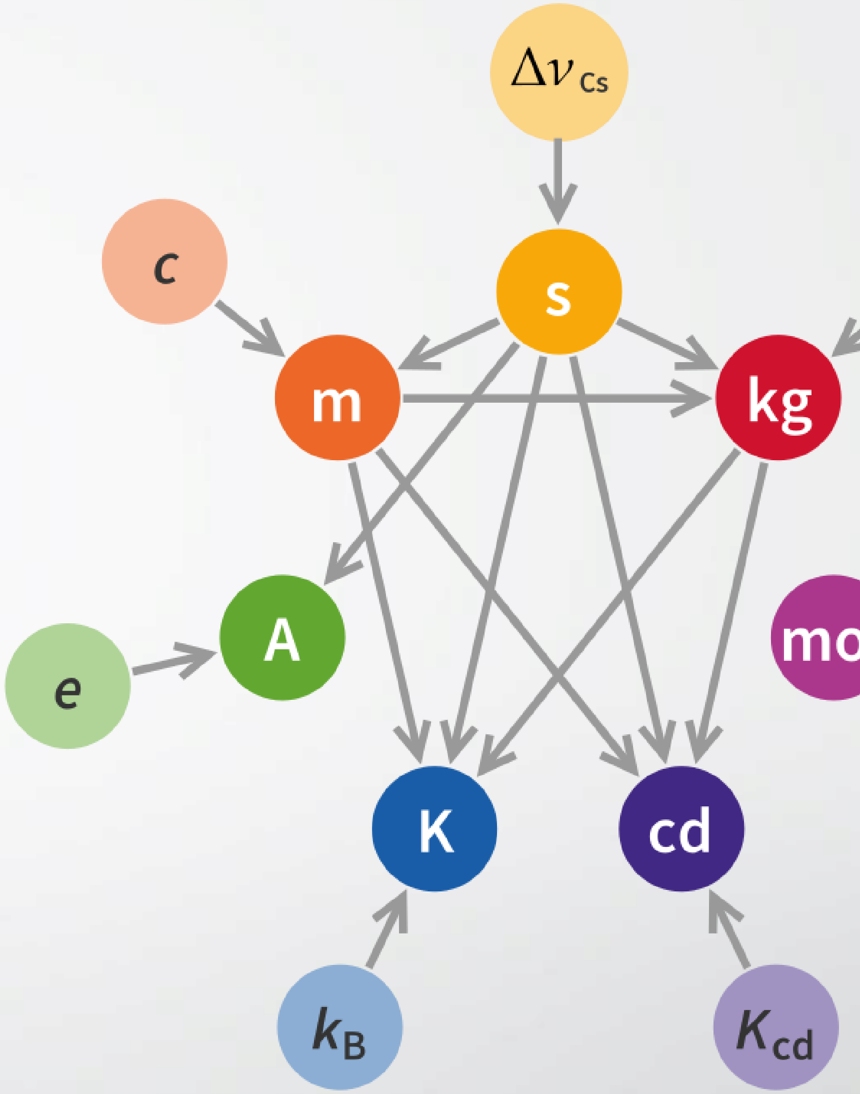


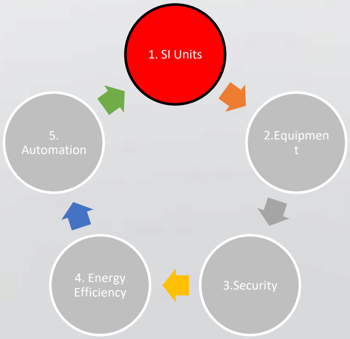
1. SI Units Definition

Old SI



New SI

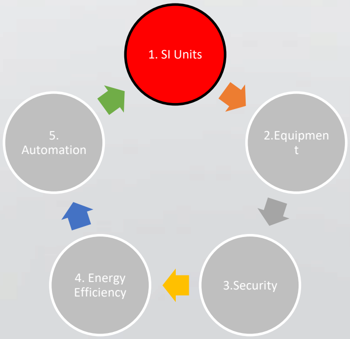




1. SI Units Definition

What was the purpose of defining the new SI unit?

- To ensure stability in kilograms and hence reliability in the long term
- Significantly increase the accuracy of electrical and radiometric temperature measurements with new definitions of Ampere and Kelvin
- Conversion factor (Stefan-Boltzmann constant) between measured luminance and thermodynamic temperature to be precise using new definitions of Kelvin and Kilogram and to make a better temperature metrology as technology improves

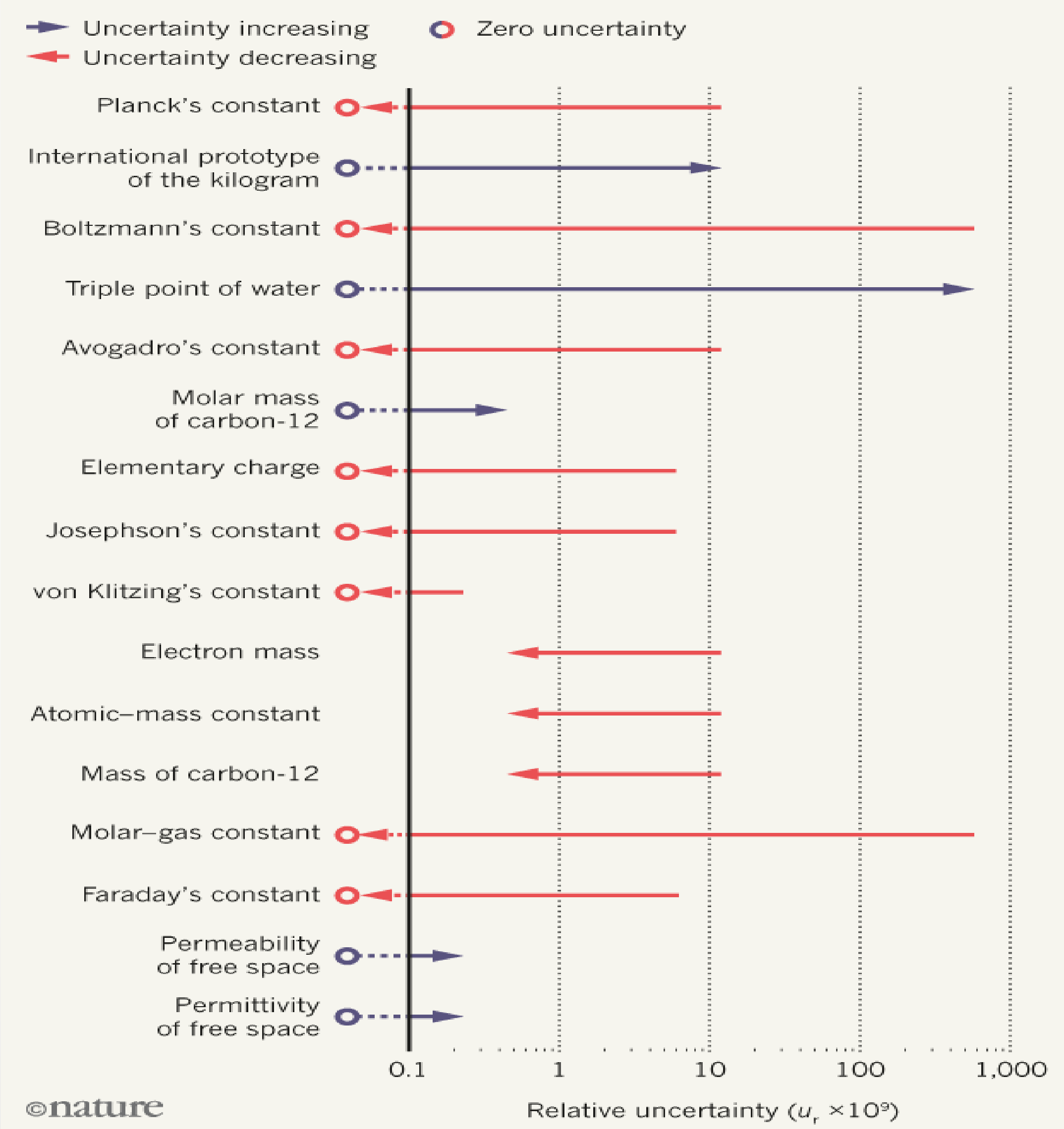


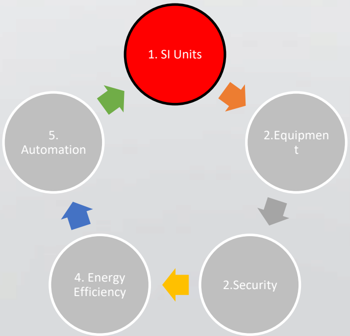
1. SI Units Definition

TÜBİTAK UME

How will the new SI measurement unit definition impact the industry?

Forecast of changes in uncertainty values in the future

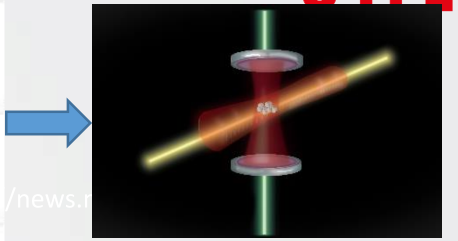




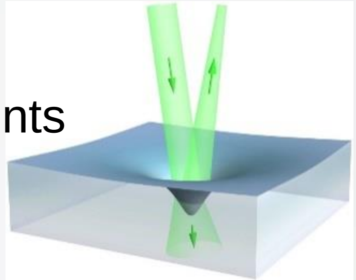
1. SI Units Definition

In the Near Future

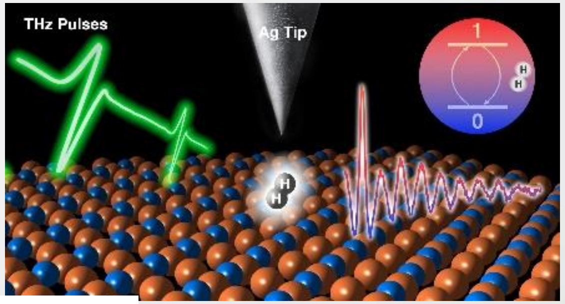
- The unit of time, the second, is expected to change by 2030



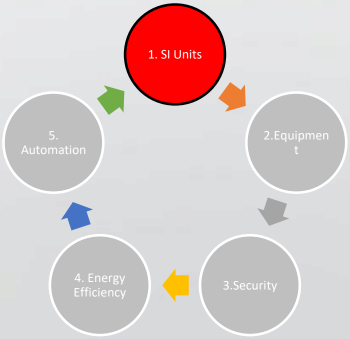
- Photon pressure or interferometric methods will be used for measurements of small values (nano, pico) of mass-derived quantities



- There will be changes in the measurement philosophy with Quantum Sensors



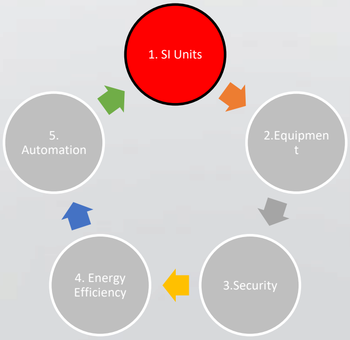
- Dynamic measurements will increase to improve product quality



1. SI Units Definition

In the Near Future

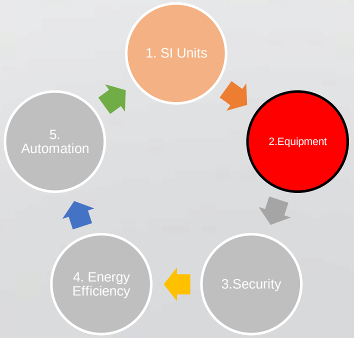
New CMCs



2. Equipment

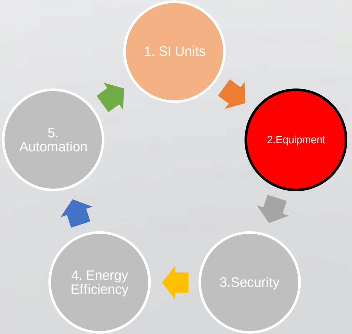
Changes in Measurement Methods as a result of Developments in Measurement Devices

- Creating Digital Twins of Measurement Devices
- Providing the calibration and test as Remote
- Evolution of the measurement devices with Autonom Systems
- Calibration period determination by Scientific Methods



2. Equipment

- **Creating Digital Twins of Measurement Devices**

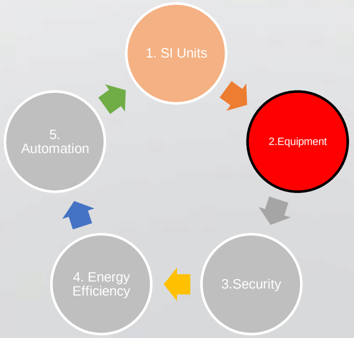


2. Equipment

- **Creating Digital Twins of Measurement Devices**

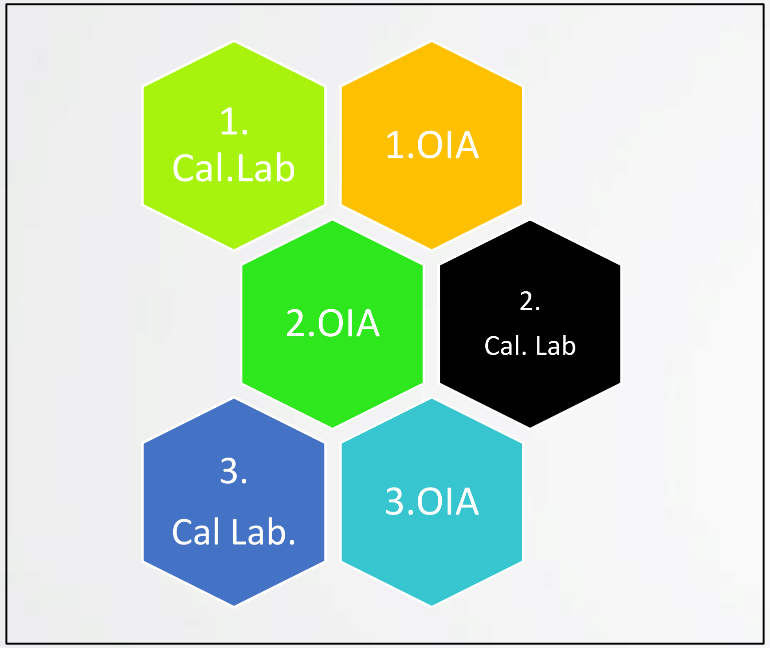
- *Creating of the twins*
- *Measurement and testing before realization*
- *Getting experience with twins*

EPM (*European Partnership on Metrology*) project call as digital transformation in 2022 (https://www.euramet.org/research-innovation/metrology-partnership)



2. Equipment

- **Remote Calibration and Remote Test**



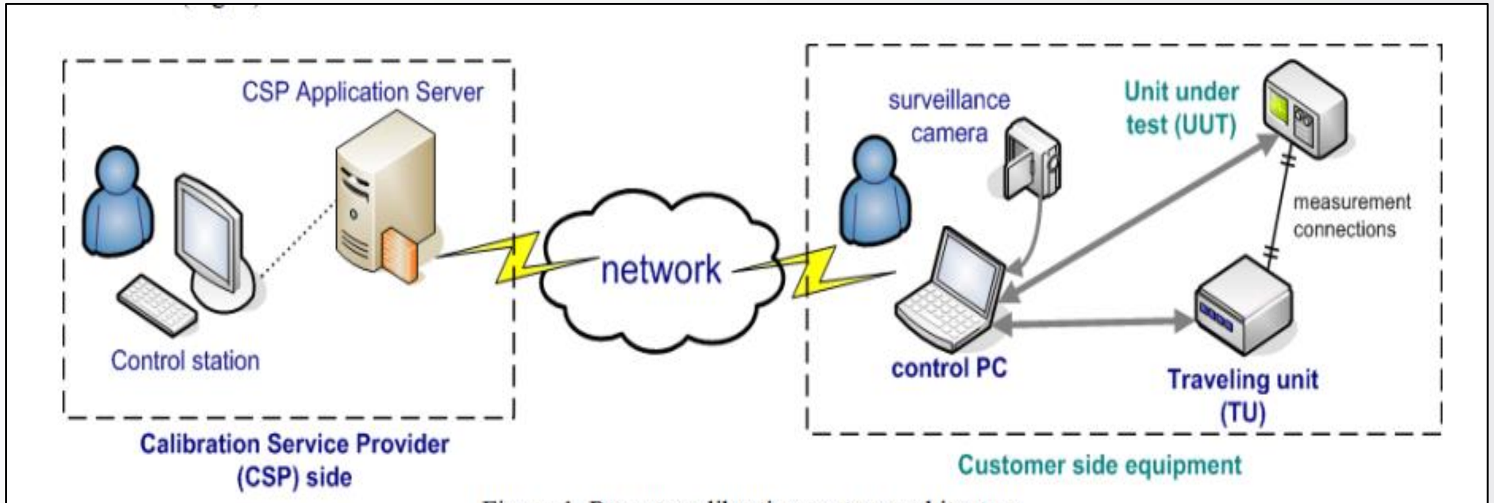
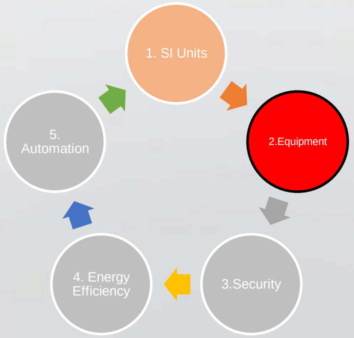


Figure 1. Remote calibration system architecture

Jurcevic, Marko & Hegedus, Hrvoje & Malarić, Roman & Zeba, Hrvoje. (2008). Generic Environment for internet-enabled calibration services.

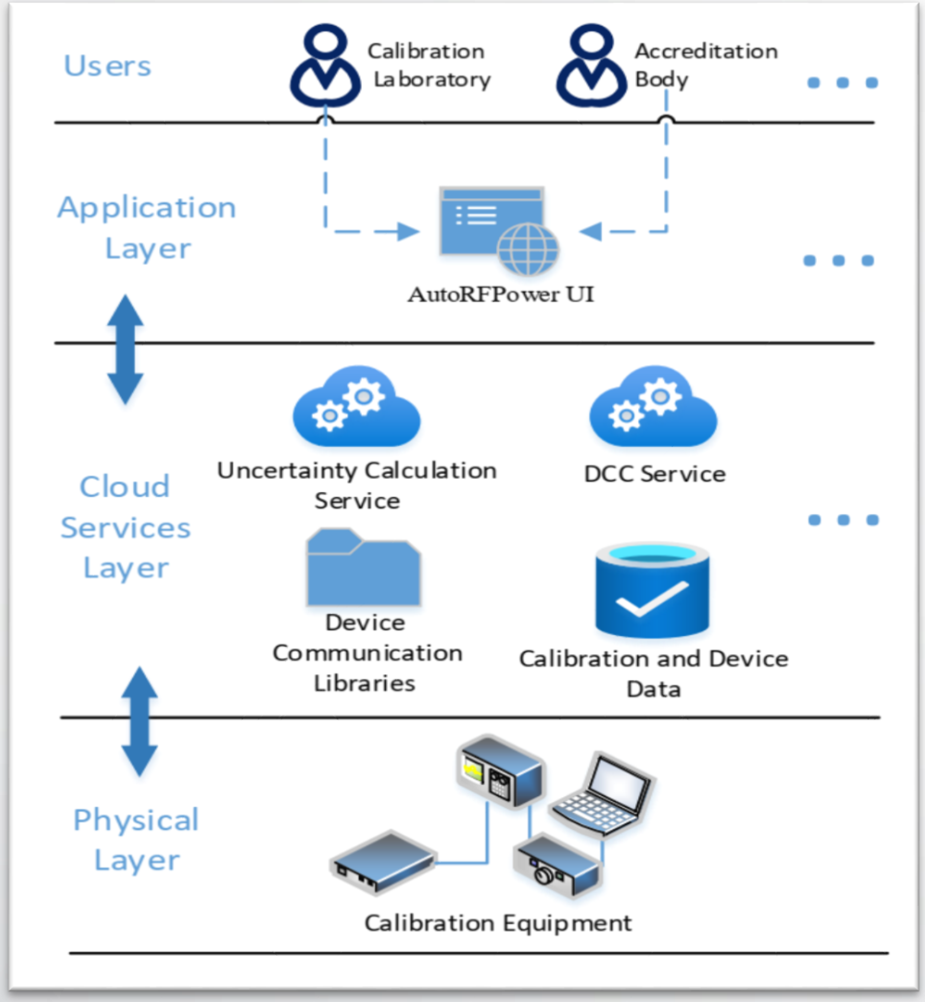
The calibration and testing of these devices in cloud

A full-fledged calibration and test laboratory in every organized industrial zone



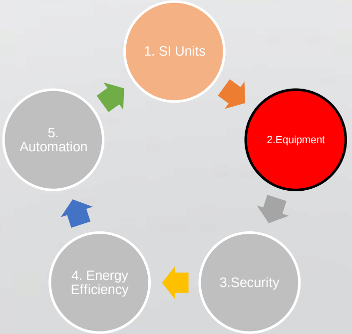
2. Equipment

- **Remote Calibration and Test**



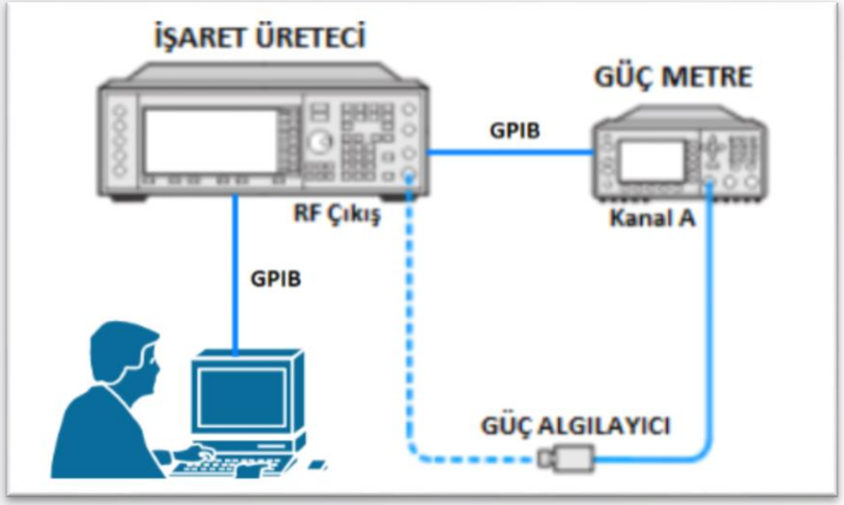
https://robodk.com/blog/virtual-reality-offline-programming

By creating digital twins of the measuring devices, it will be possible to make measurement experiments in a virtual environment and to gain experience for the personnel.

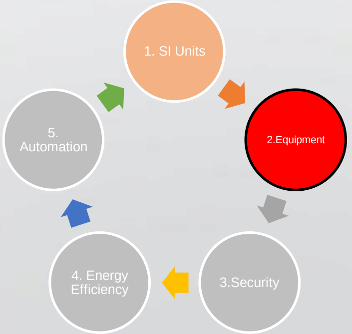


2. Equipment

- **Evolution of the measurement devices with Autonom Systems**

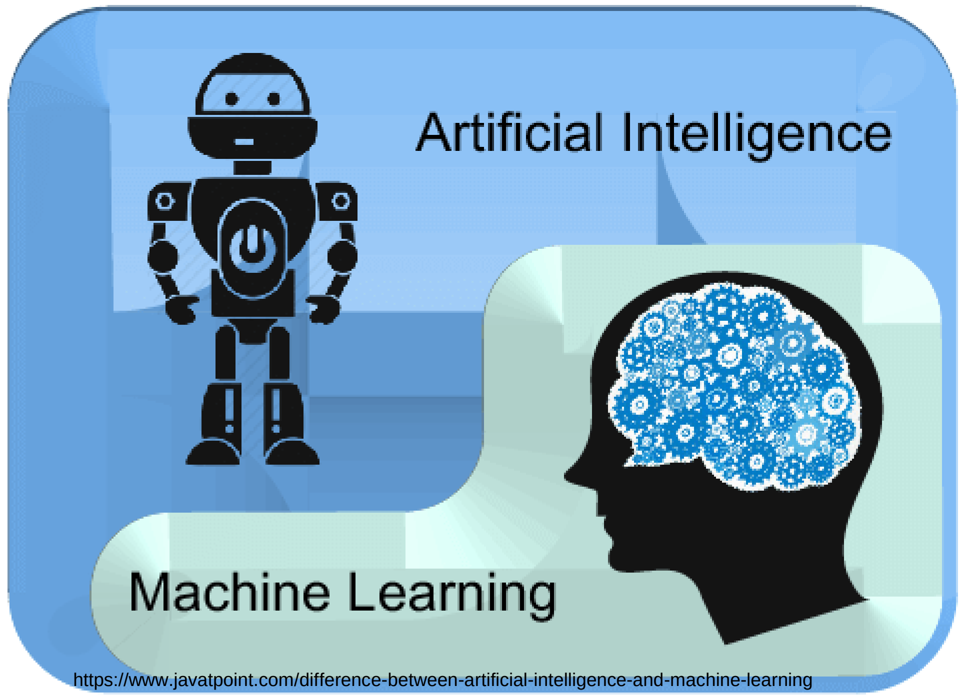


Measurement systems will evolve towards a semi-autonomous system with robotics and software.



2. Equipment

- **Calibration period determination by Scientific Methods**



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IMEKO International Measurement Confederation

Technical Committee TC6 Digitalization

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TC6
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- Members
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TC6 - Digitalization

The aim of TC6 is to develop, organise and disseminate fundamental concepts of measurement science that relate to digitalisation and digital transformation in science, industry, and society. The TC promotes the accumulation and curation of knowledge in various forms, relating to the digitalisation of measurement methodologies and measurement outcomes. Its purpose is to provide a robust body of knowledge to support digital transformation when measurement is involved.
Digitalisation's multidisciplinary nature is expected to overlap with other IMEKO groups' interests. TC6 thus encourages collaborations and joint activities with other TCs.

TC6 Officers
Chairperson: Dr Sascha Eichstädt, Sascha.Eichstaedt@ptb.de
Vice-Chairperson: Dr Hugo Gasca-Aragon, hgasca@cenam.mx
Scientific Secretary: Zoltan Zelenka, z.v.zelenka@gmail.com

TC6 is announcing:

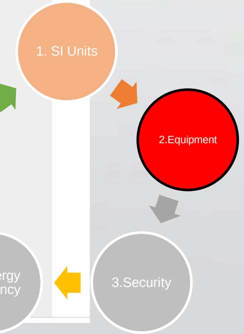
IMEKO Save the Date! 19. – 21. September 2022
IMEKO TC6 International Conference on Metrology and Digital Transformation (M4D)
Hybrid with physical attendance in Berlin, Germany

TC6 M4Dconf2022: First International Conference on Metrology and Digital Transformation

Organizing MO: PTB
Chair of Organizing Committee: Sascha Eichstädt (PTB)
Chair of International Programme Committee: Daniel Hutzschenreuter (PTB)
Conference website: https://m4dconf2022.ptb.de
Conference on IMEKO Indigo platform: https://conferences.imeko.org/event/2/

On 19. - 21. September 2022, the IMEKO TC6 "Digitalization" organizes the first international conference on metrology and digital transformation - the M4Dconf 2022. The conference will be organized as a hybrid event - with a limited number of places for physical attendance in Berlin.

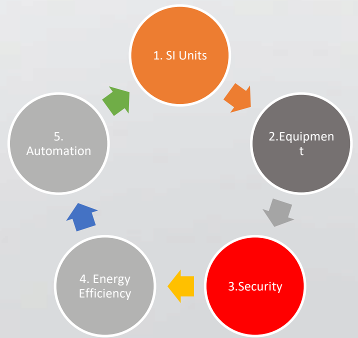
Scope



3. Security

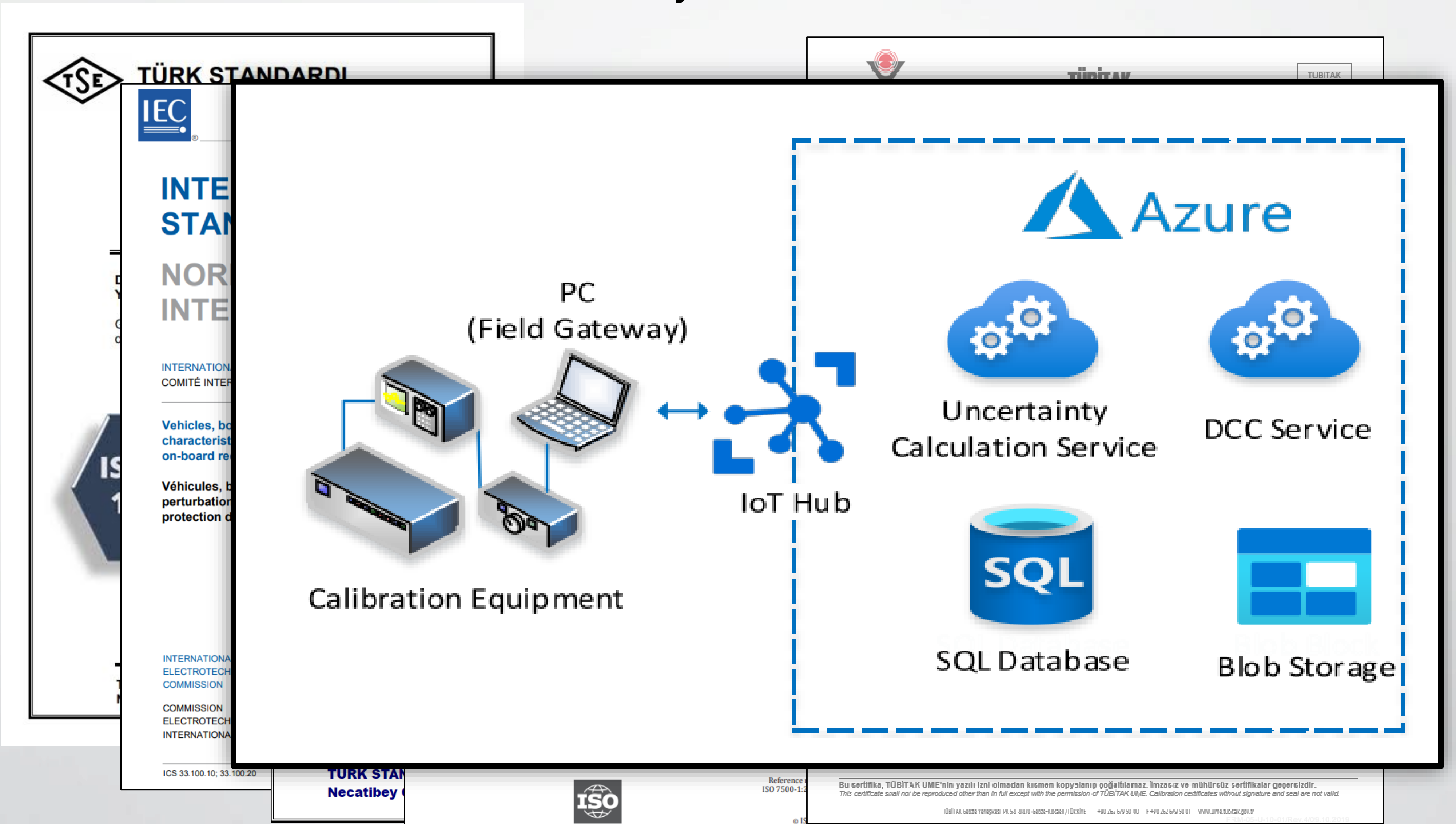
Changes in processes regarding the safety of measurement results

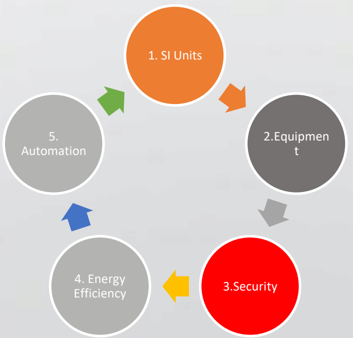
- **Certificate and Data Security**
- **Digital Calibration Certificate in Cloud**
- **Uncertainty Calculation in Cloud**



3. Security

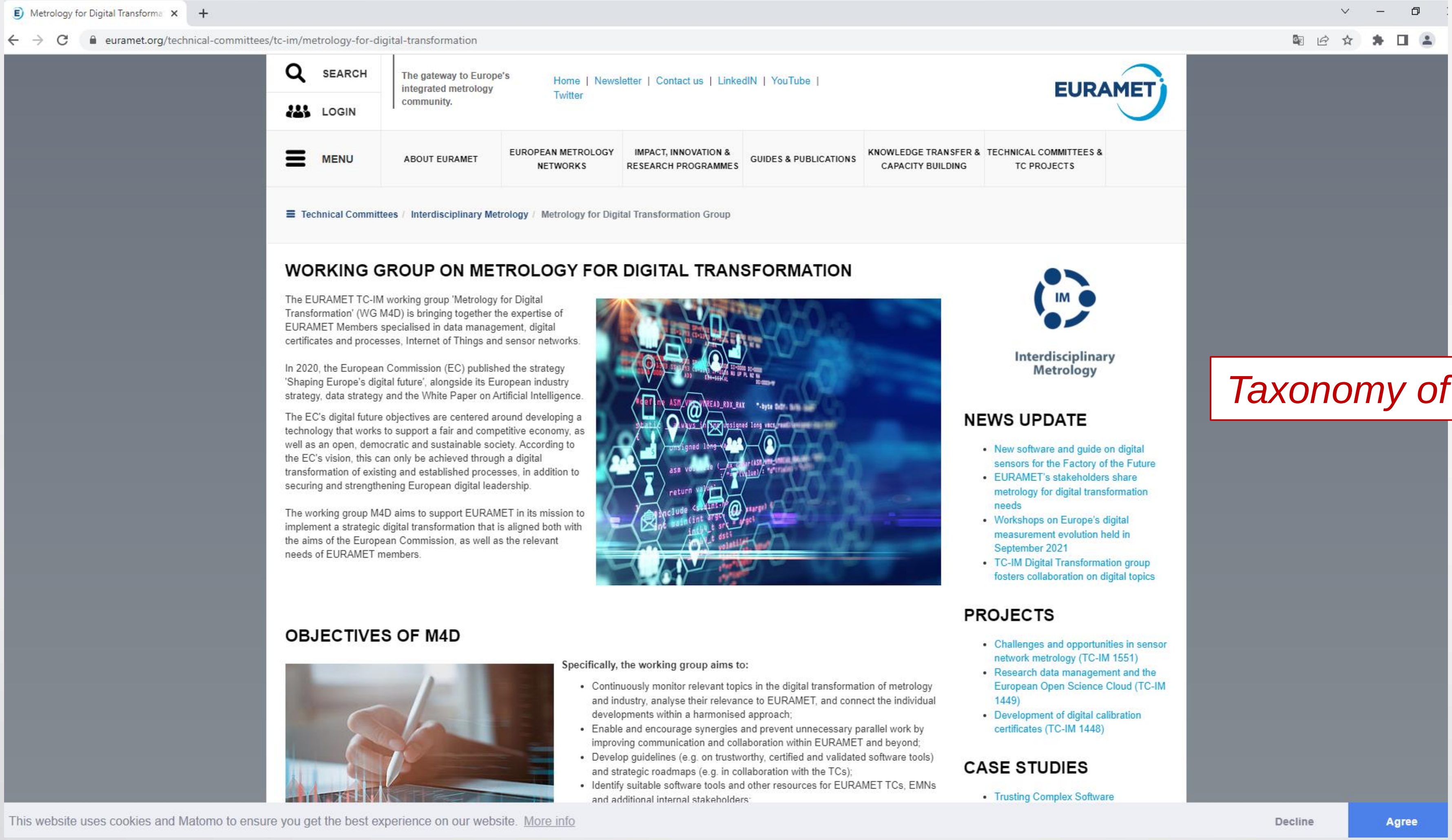
- **Certificate and Data Security**





3. Security

- **Digital Calibration Certificate in Cloud**


Metrology for Digital Transforma

euramet.org/technical-committees/tc-im/metrology-for-digital-transformation

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Technical Committees / Interdisciplinary Metrology / Metrology for Digital Transformation Group

WORKING GROUP ON METROLOGY FOR DIGITAL TRANSFORMATION

The EURAMET TC-IM working group 'Metrology for Digital Transformation' (WG M4D) is bringing together the expertise of EURAMET Members specialised in data management, digital certificates and processes, Internet of Things and sensor networks.

In 2020, the European Commission (EC) published the strategy 'Shaping Europe's digital future', alongside its European industry strategy, data strategy and the White Paper on Artificial Intelligence.

The EC's digital future objectives are centered around developing a technology that works to support a fair and competitive economy, as well as an open, democratic and sustainable society. According to the EC's vision, this can only be achieved through a digital transformation of existing and established processes, in addition to securing and strengthening European digital leadership.

The working group M4D aims to support EURAMET in its mission to implement a strategic digital transformation that is aligned both with the aims of the European Commission, as well as the relevant needs of EURAMET members.

OBJECTIVES OF M4D

Specifically, the working group aims to:

- Continuously monitor relevant topics in the digital transformation of metrology and industry, analyse their relevance to EURAMET, and connect the individual developments within a harmonised approach;
- Enable and encourage synergies and prevent unnecessary parallel work by improving communication and collaboration within EURAMET and beyond;
- Develop guidelines (e.g. on trustworthy, certified and validated software tools) and strategic roadmaps (e.g. in collaboration with the TCs);
- Identify suitable software tools and other resources for EURAMET TCs, EMNs and additional internal stakeholders;

IM Interdisciplinary Metrology

NEWS UPDATE

- New software and guide on digital sensors for the Factory of the Future
- EURAMET's stakeholders share metrology for digital transformation needs
- Workshops on Europe's digital measurement evolution held in September 2021
- TC-IM Digital Transformation group fosters collaboration on digital topics

PROJECTS

- Challenges and opportunities in sensor network metrology (TC-IM 1551)
- Research data management and the European Open Science Cloud (TC-IM 1449)
- Development of digital calibration certificates (TC-IM 1448)

CASE STUDIES

- Trusting Complex Software

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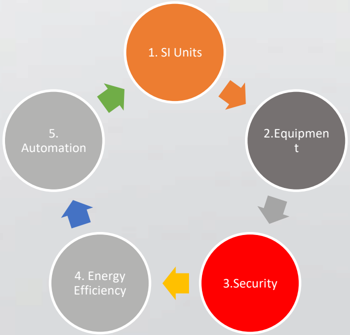
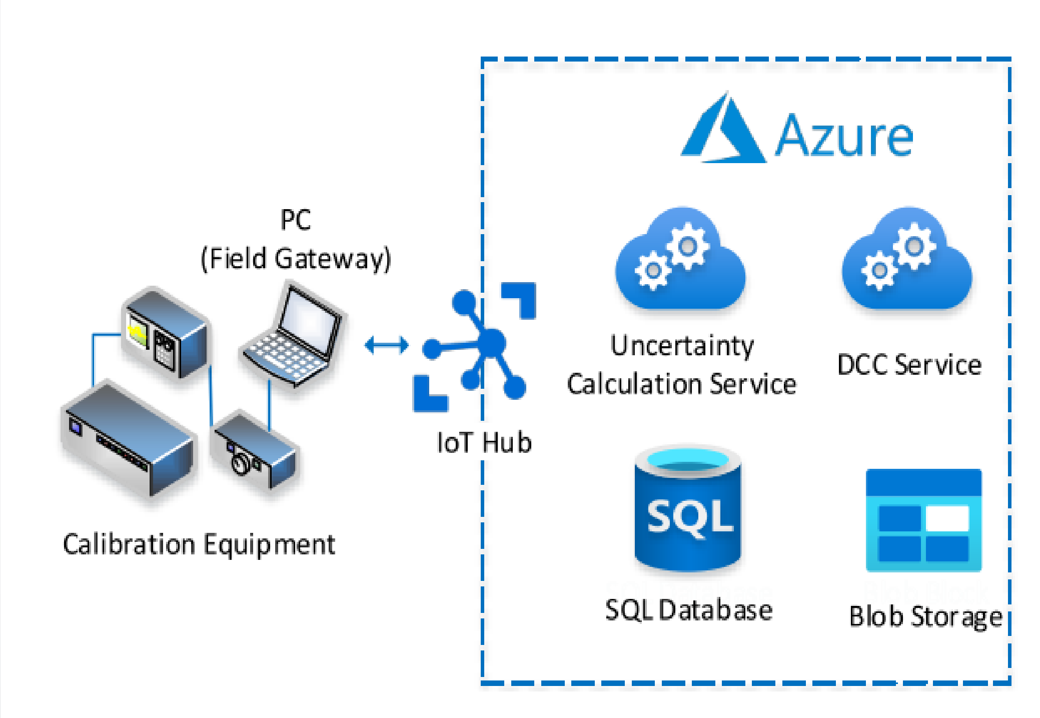
Taxonomy of measurement results !!!

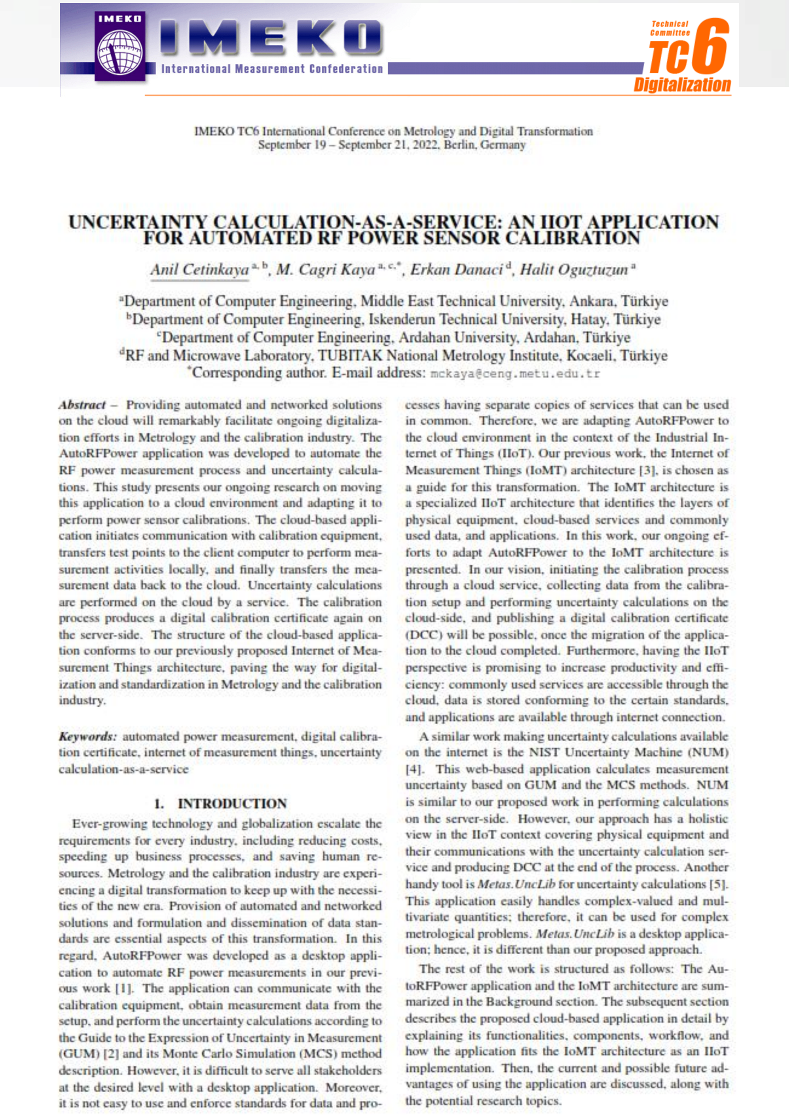
https://www.euramet.org/technical-committees/tc-im/metrology-for-digital-transformation



3. Security

- **Uncertainty Calculation in Cloud**





IMEKO
International Measurement Confederation
Technical Committee TC6 Digitalization

IMEKO TC6 International Conference on Metrology and Digital Transformation
September 19 – September 21, 2022, Berlin, Germany

UNCERTAINTY CALCULATION-AS-A-SERVICE: AN IIOT APPLICATION FOR AUTOMATED RF POWER SENSOR CALIBRATION

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[b] Department of Computer Engineering, Iskenderun Technical University, Hatay, Türkiye
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[d] RF and Microwave Laboratory, TUBITAK National Metrology Institute, Kocaeli, Türkiye
[*] Corresponding author. E-mail address: mckaya@ceng.metu.edu.tr

Abstract – Providing automated and networked solutions on the cloud will remarkably facilitate ongoing digitalization efforts in Metrology and the calibration industry. The AutoRFPower application was developed to automate the RF power measurement process and uncertainty calculations. This study presents our ongoing research on moving this application to a cloud environment and adapting it to perform power sensor calibrations. The cloud-based application initiates communication with calibration equipment, transfers test points to the client computer to perform measurement activities locally, and finally transfers the measurement data back to the cloud. Uncertainty calculations are performed on the cloud by a service. The calibration process produces a digital calibration certificate again on the server-side. The structure of the cloud-based application conforms to our previously proposed Internet of Measurement Things architecture, paving the way for digitalization and standardization in Metrology and the calibration industry.

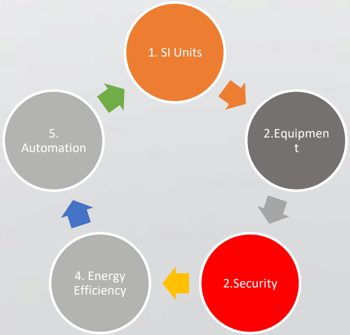
Keywords: automated power measurement, digital calibration certificate, internet of measurement things, uncertainty calculation-as-a-service

1. INTRODUCTION

Ever-growing technology and globalization escalate the requirements for every industry, including reducing costs, speeding up business processes, and saving human resources. Metrology and the calibration industry are experiencing a digital transformation to keep up with the necessities of the new era. Provision of automated and networked solutions and formulation and dissemination of data standards are essential aspects of this transformation. In this regard, AutoRFPower was developed as a desktop application to automate RF power measurements in our previous work [1]. The application can communicate with the calibration equipment, obtain measurement data from the setup, and perform the uncertainty calculations according to the Guide to the Expression of Uncertainty in Measurement (GUM) [2] and its Monte Carlo Simulation (MCS) method description. However, it is difficult to serve all stakeholders at the desired level with a desktop application. Moreover, it is not easy to use and enforce standards for data and processes having separate copies of services that can be used in common. Therefore, we are adapting AutoRFPower to the cloud environment in the context of the Industrial Internet of Things (IIoT). Our previous work, the Internet of Measurement Things (IoMT) architecture [3], is chosen as a guide for this transformation. The IoMT architecture is a specialized IIoT architecture that identifies the layers of physical equipment, cloud-based services and commonly used data, and applications. In this work, our ongoing efforts to adapt AutoRFPower to the IoMT architecture is presented. In our vision, initiating the calibration process through a cloud service, collecting data from the calibration setup and performing uncertainty calculations on the cloud-side, and publishing a digital calibration certificate (DCC) will be possible, once the migration of the application to the cloud completed. Furthermore, having the IIoT perspective is promising to increase productivity and efficiency: commonly used services are accessible through the cloud, data is stored conforming to the certain standards, and applications are available through internet connection.

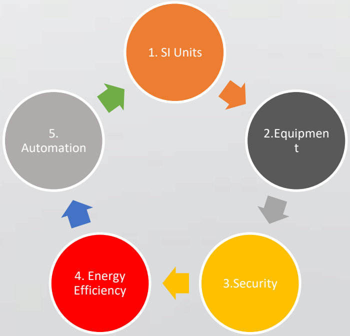
A similar work making uncertainty calculations available on the internet is the NIST Uncertainty Machine (NUM) [4]. This web-based application calculates measurement uncertainty based on GUM and the MCS methods. NUM is similar to our proposed work in performing calculations on the server-side. However, our approach has a holistic view in the IIoT context covering physical equipment and their communications with the uncertainty calculation service and producing DCC at the end of the process. Another handy tool is *Metas.UncLib* for uncertainty calculations [5]. This application easily handles complex-valued and multivariate quantities; therefore, it can be used for complex metrological problems. *Metas.UncLib* is a desktop application; hence, it is different than our proposed approach.

The rest of the work is structured as follows: The AutoRFPower application and the IoMT architecture are summarized in the Background section. The subsequent section describes the proposed cloud-based application in detail by explaining its functionalities, components, workflow, and how the application fits the IoMT architecture as an IIoT implementation. Then, the current and possible future advantages of using the application are discussed, along with the potential research topics.



4. Energy

Changes in terms of energy efficiency of laboratory (Energy)



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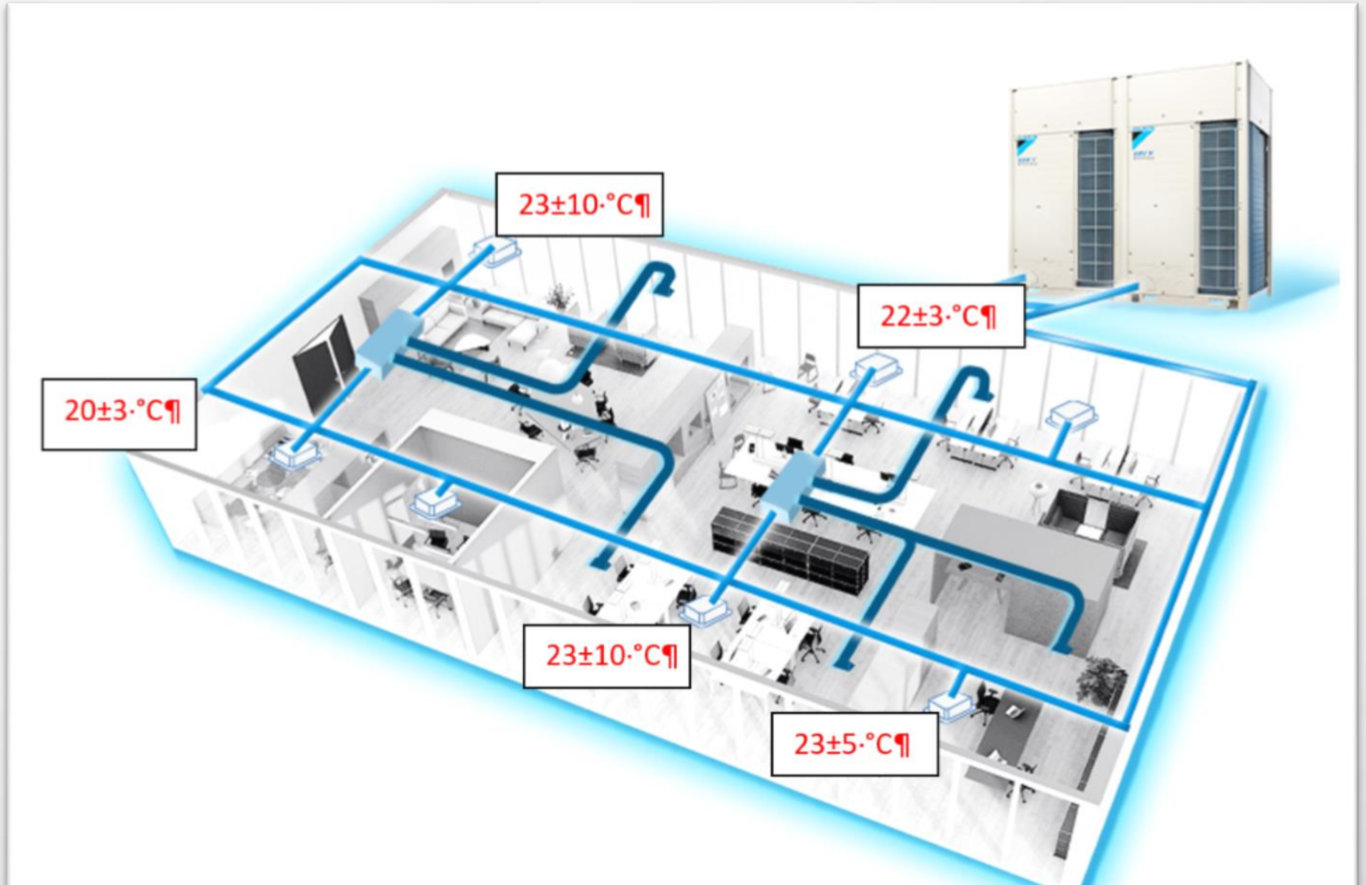

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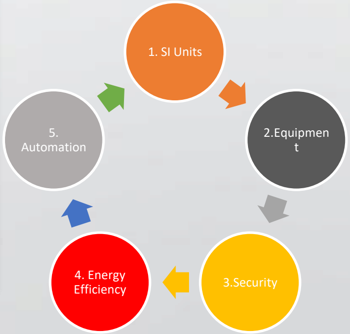

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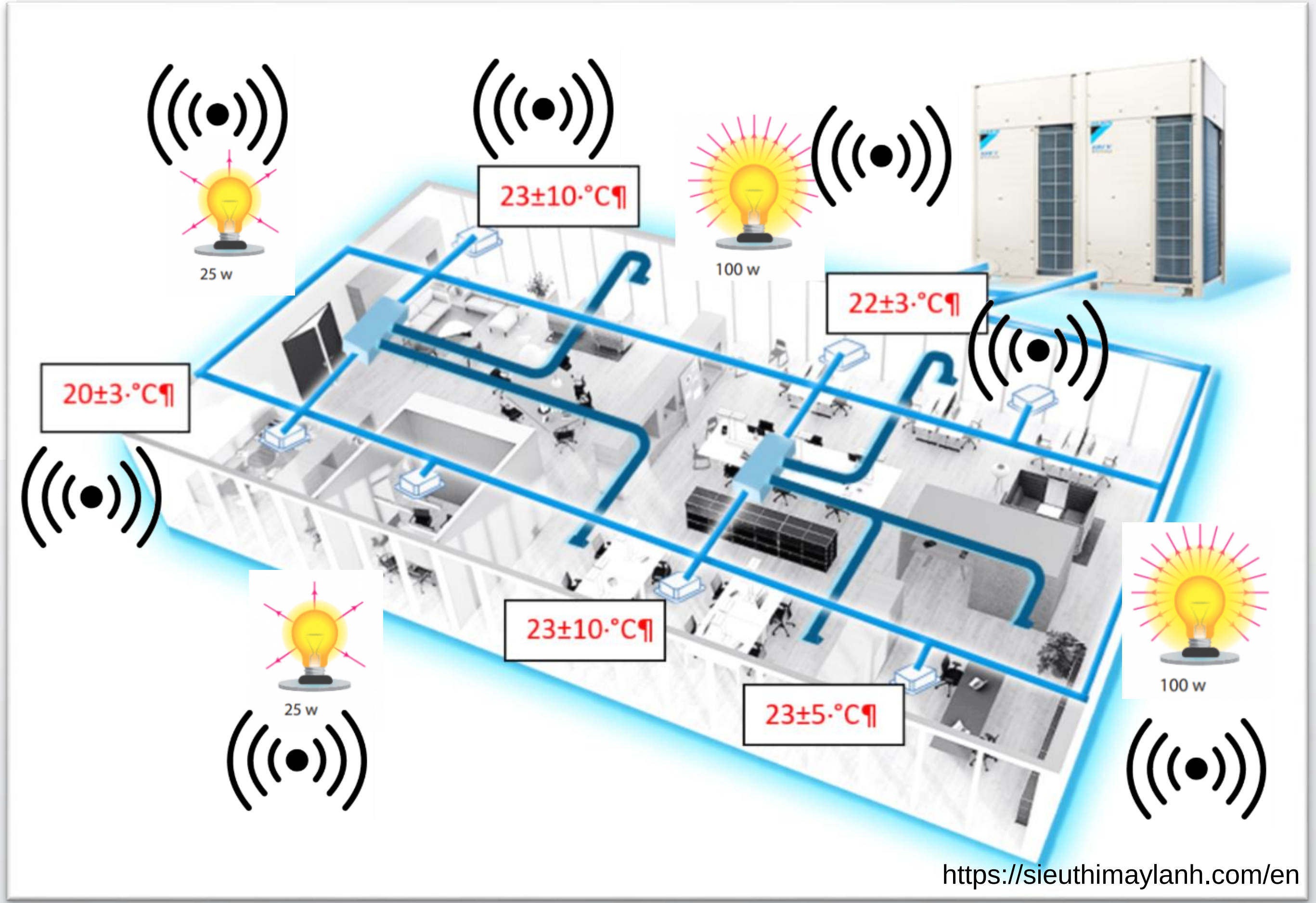
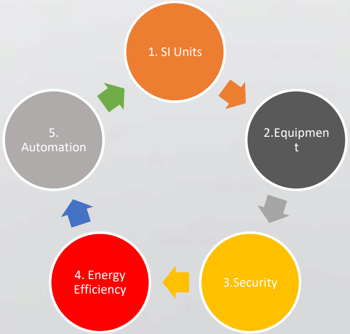




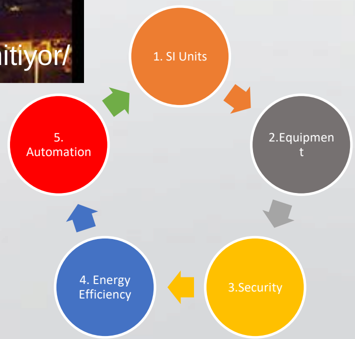
5. Automation

Changes in terms of automation of laboratories (Automation)

Digital Age and New Consepts

- Smart City
- Smart Building
- Smart Grids
- Artificial Inteligent
- Automation

https://netas.com.tr/netas-akilli-cozumlerini-smart-city-expo-world-congress-2017de-tanitiyor/



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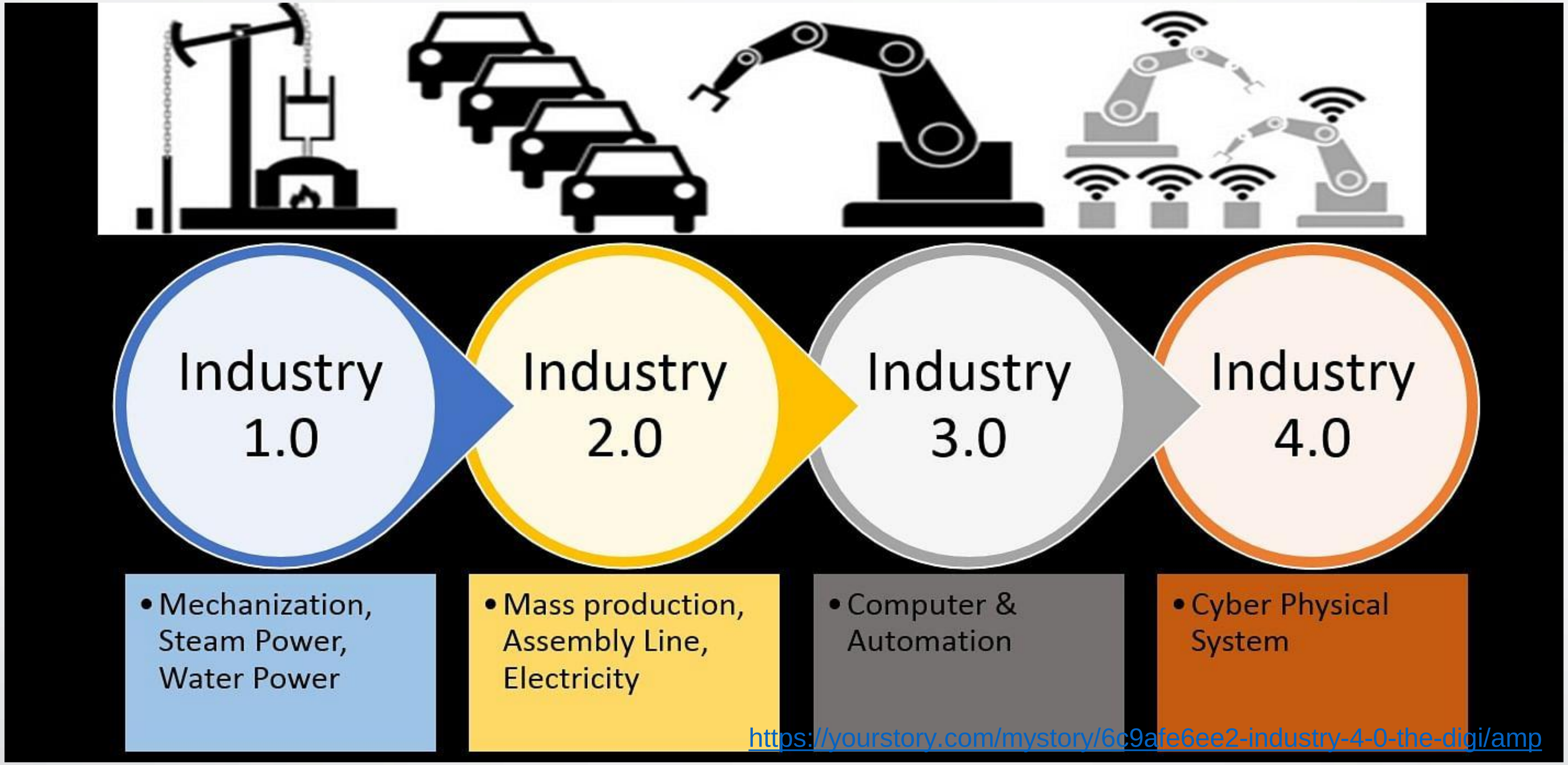

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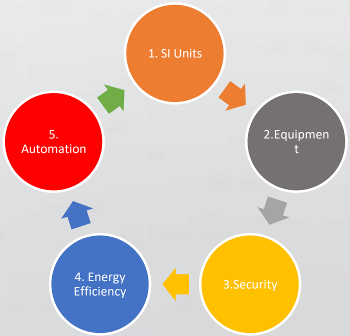

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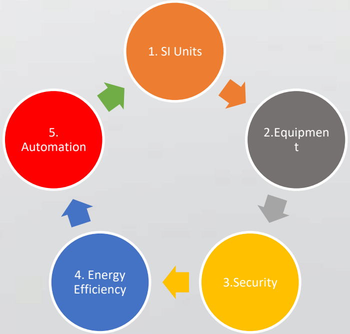

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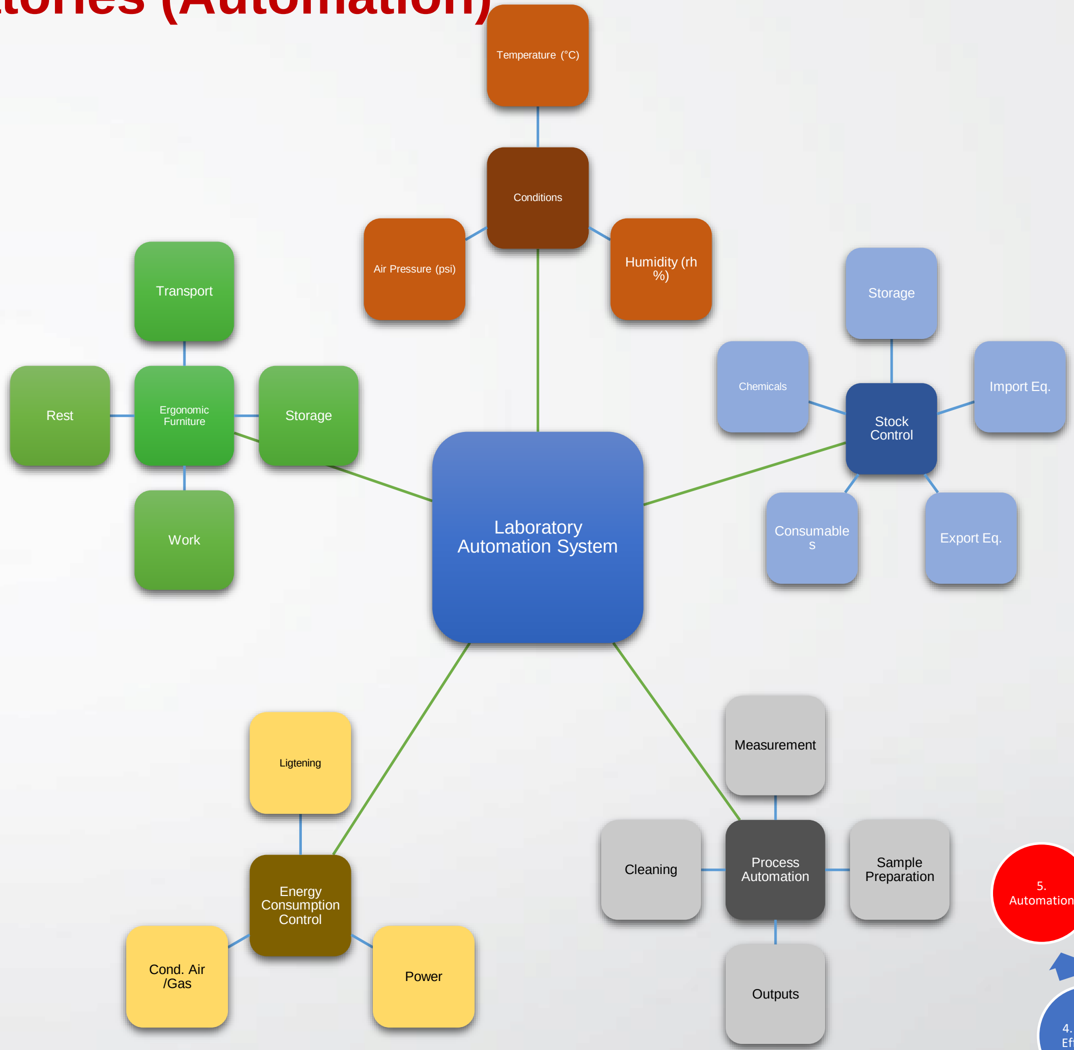
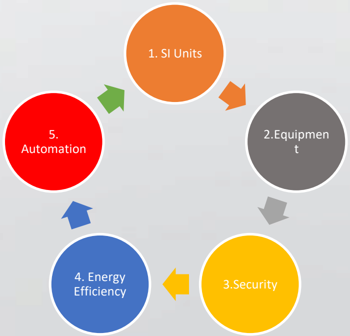




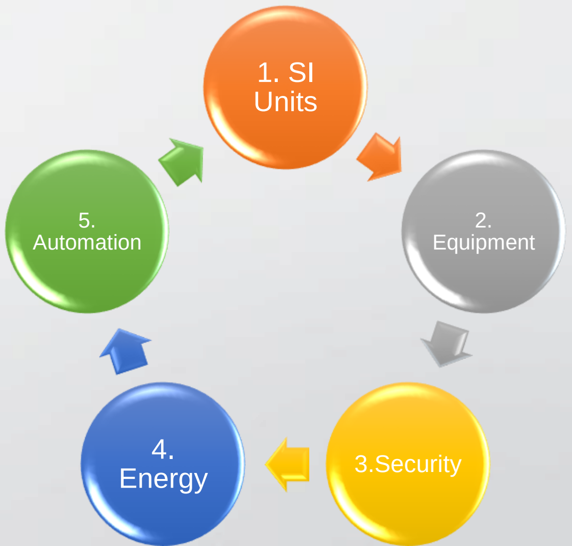
Laboratory automation in future

- ❑ Lab condition automation
- ❑ Stock control automation
- ❑ Process automation
- ❑ Energy consumtion automation
- ❑ Ergonomic furniture

Conclusion

Lab of the future, Future of the Lab (LoF, FoL);

- SI Units will be redefinited, If necessary (SI Units Redefinition)
- Measuring devices will be evolved and measurement methods will be changed (Equipment)
- Measurement results will be migrated to cloud computing (Cloud Security)
- Less energy-consuming and autonomous laboratories will be transitioned (Energy)



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ume@tubitak.gov.tr