Long term strategy for laboratory comparisons

Agnieszka Bialek

Tartu Ülikool · Universitas Tartuensis 1632
ACRI ST
Brockmann Consult GmbH
NPL National Physical Laboratory
PML Plymouth Marine Laboratory
museum Royal Belgian Institute of Natural Sciences

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European Commission
Copernicus Europe's eyes on Earth
EUMETSAT

Outline

- Metrology
- FRM
- 4SOC – laboratory perspective
- Thank you for the review of D-11

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Metrology

The science of measurement and its application

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Organisation of World Metrology

- The Convention of the Metre (*Convention du Mètre*) — 1875
- International System of Units (SI) (*Système International d'Unités)* — 1960
- Mutual Recognition Arrangement (CIPM-MRA) — 1999
- Redefinition of the SI — 2019

Bureau International des Poids et Mesures

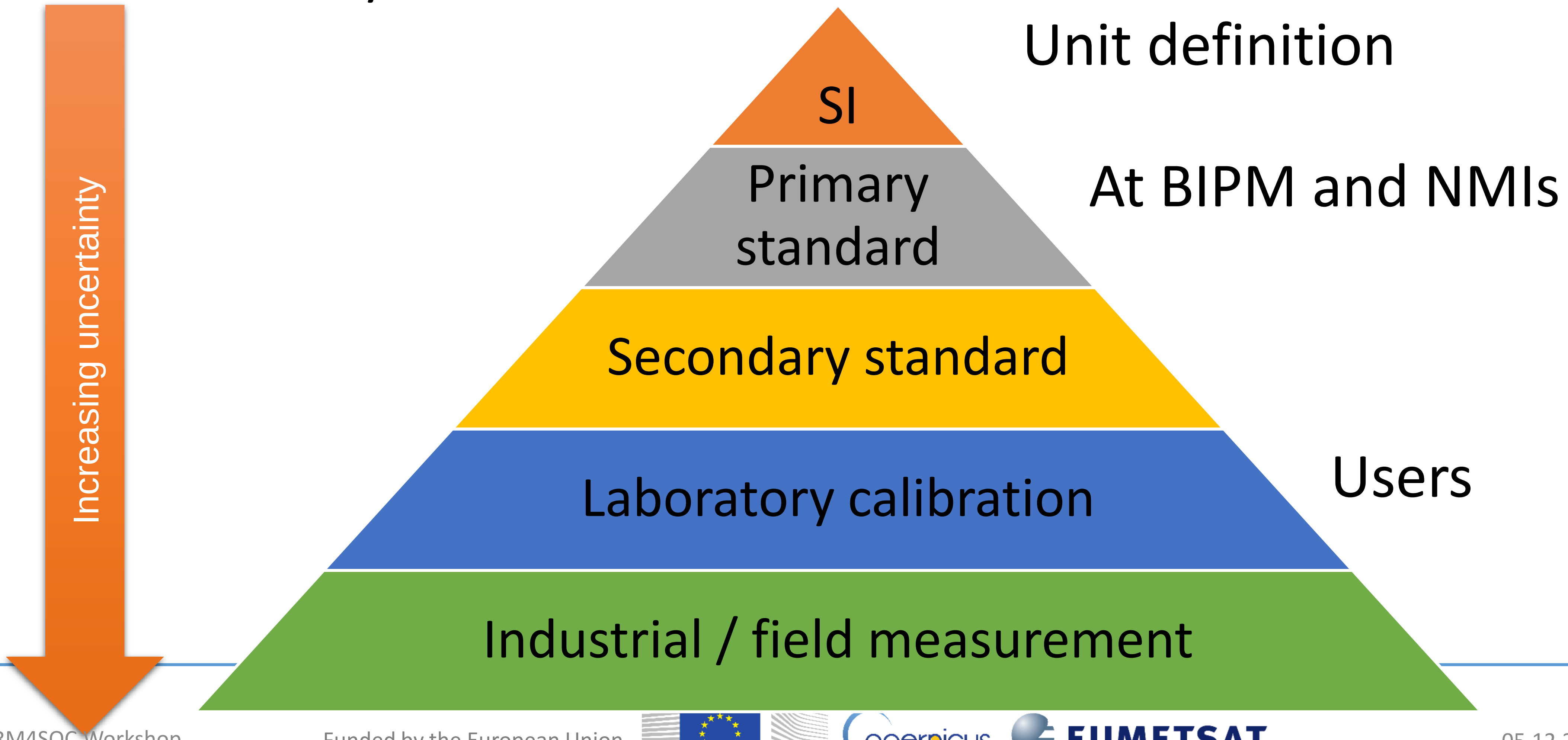
SI: Summary

- Identical worldwide
- Century-long stability
- Absolute accuracy

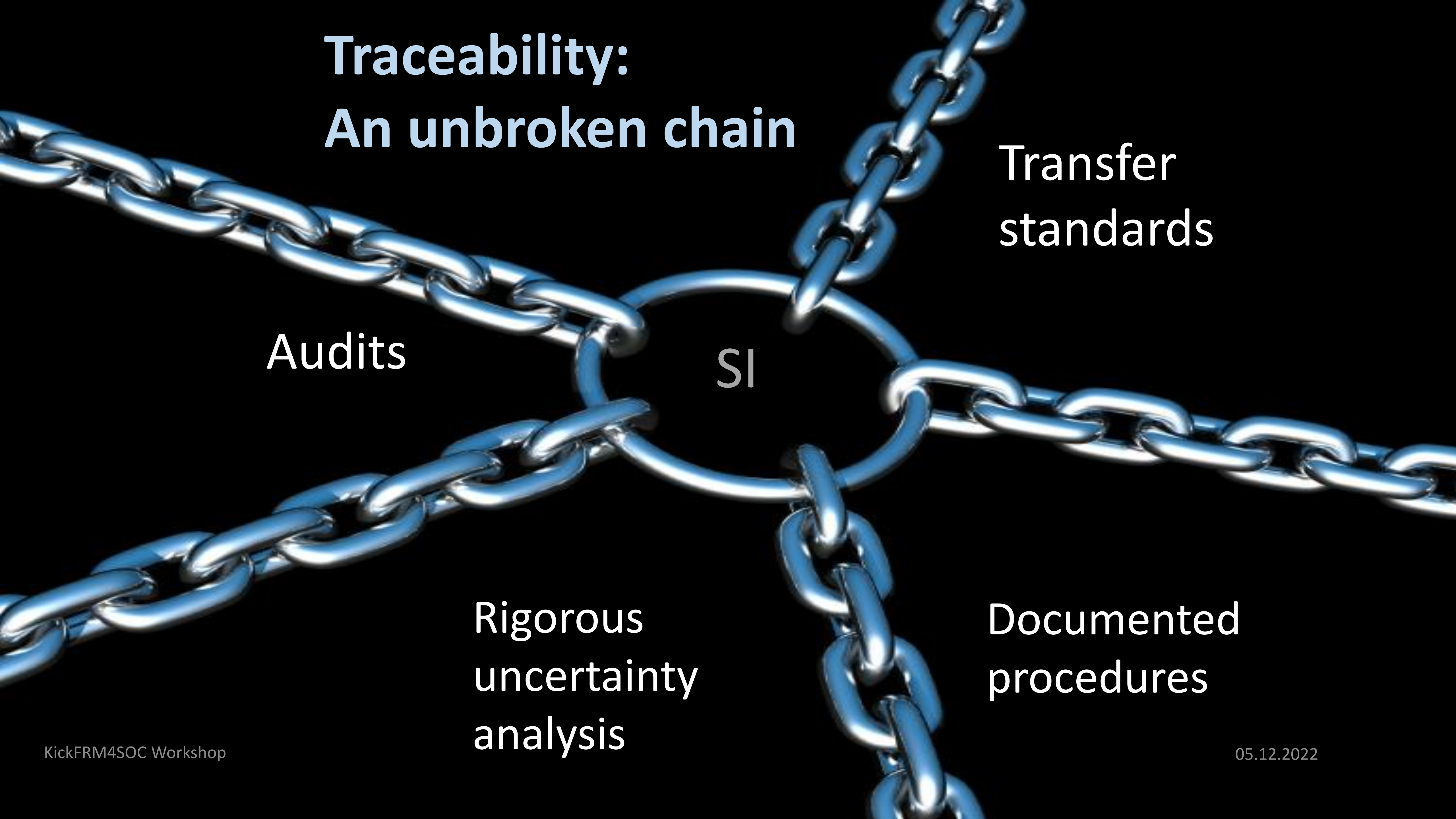
Achieved through:

- Traceability
- Uncertainty Analysis
- Comparison

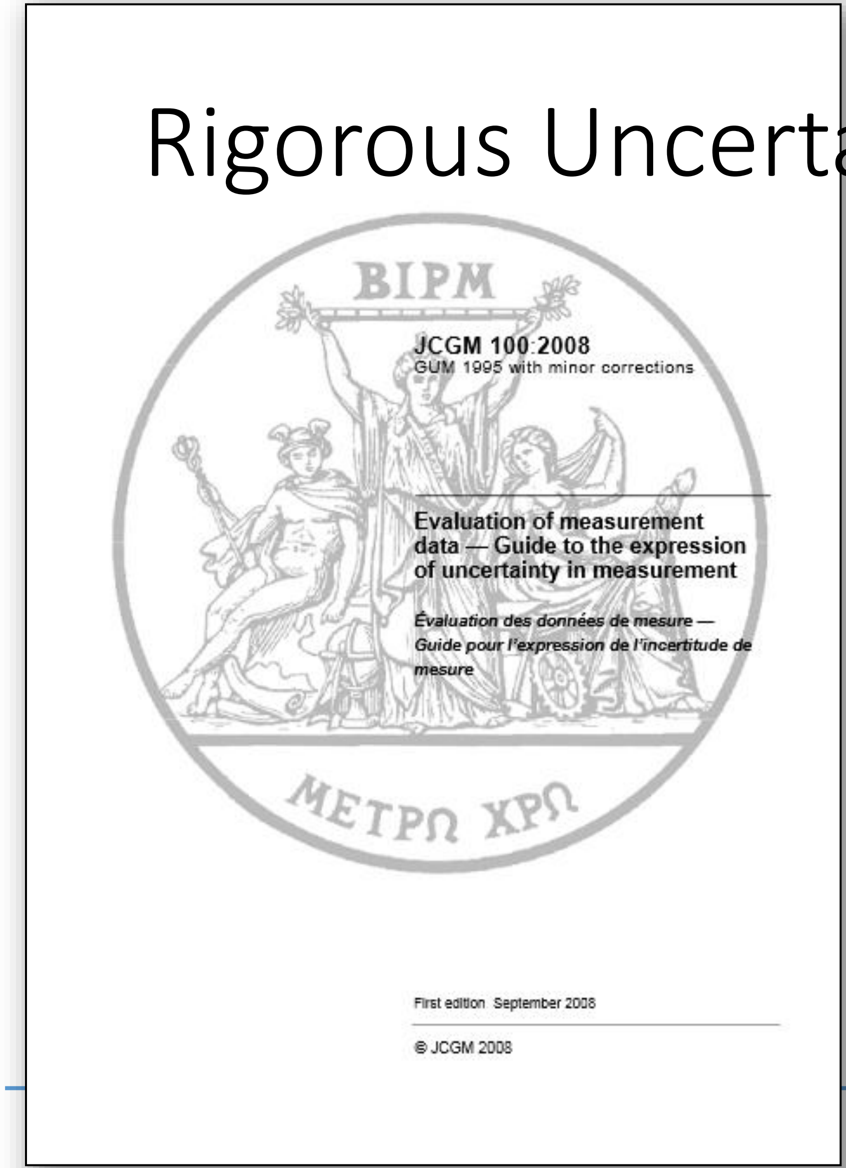
Traceability



Traceability:
An unbroken chain



Rigorous Uncertainty Analysis


BIPM

JCGM 100:2008
GUM 1995 with minor corrections

Evaluation of measurement data — Guide to the expression of uncertainty in measurement

Évaluation des données de mesure — Guide pour l'expression de l'incertitude de mesure

METPΩ XPΩ

First edition September 2008

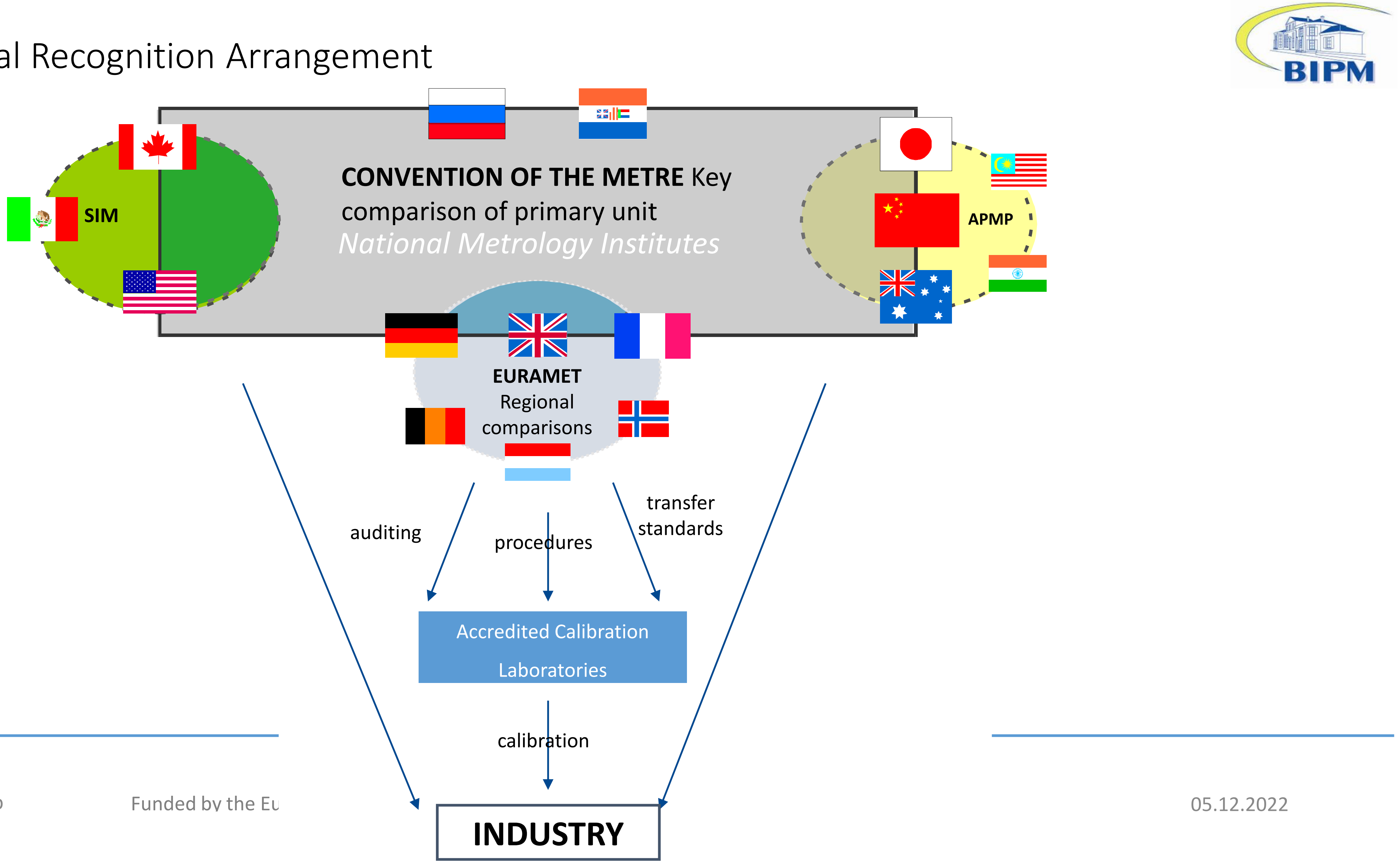
© JCGM 2008

The Guide to the expression of Uncertainty in Measurement (GUM)

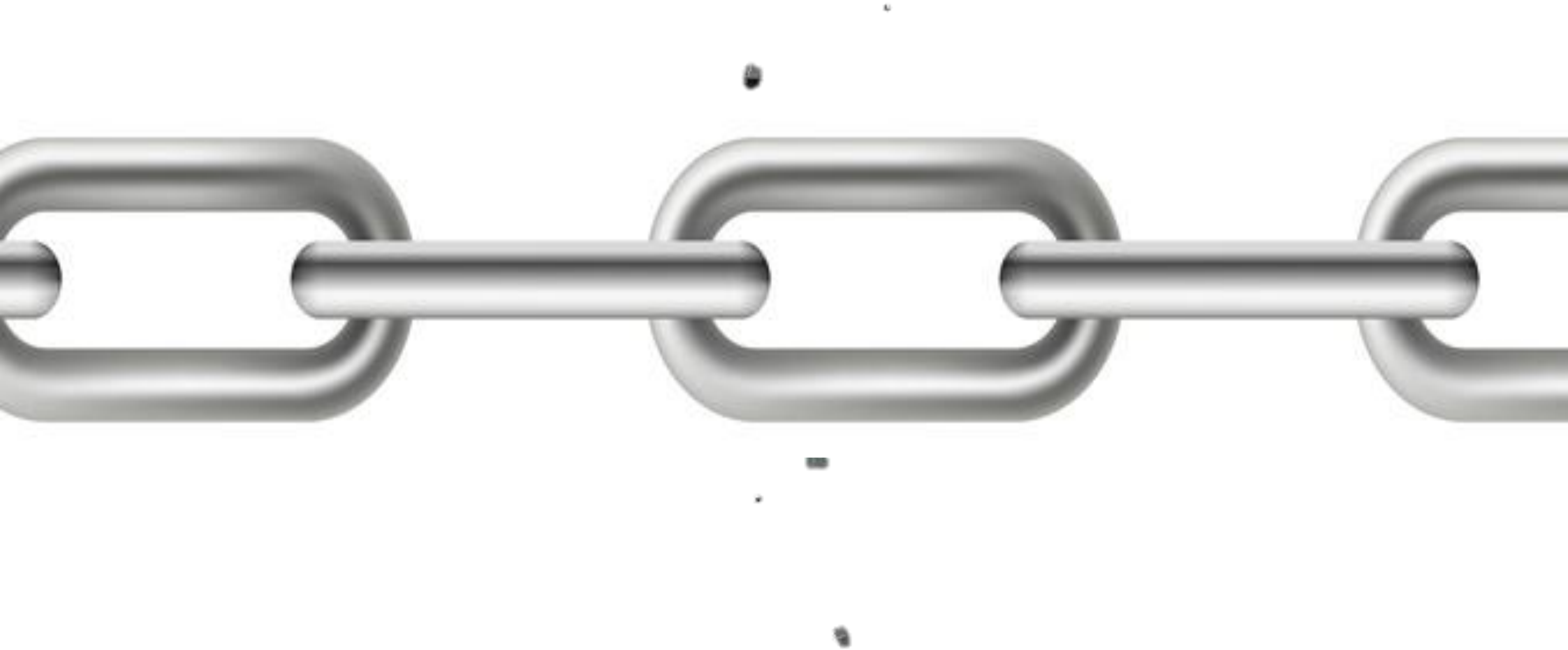
- The foremost authority and guide to the expression and calculation of uncertainty in measurement science
- Written by the BIPM, ISO, etc.
- Covers a wide number of applications
- Also a set of supplements

http://www.bipm.org/en/publications/guides/gum.html

For the Mutual Recognition Arrangement



The traceability chain is broken




No reference in space …
kg
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Our job is to fix it!

FRM

Definition

- FRM have documented SI traceability (e.g. via calibration and/or round robin intercalibration of instruments) using metrology standards;
- FRM measurements are independent from the satellite geophysical retrieval process (noting the exception of L2 product vicarious adjustment that fundamentally depends on FRM ground based measurements);
- Uncertainty budgets for all FRM instruments and derived measurements are available and maintained, measurement results are traceable where appropriate to SI ideally directly through an NMI;
- FRM measurement protocols and community-wide management practices (measurement, processing, archive, documents, etc.) are defined, published openly and adhered to by FRM instrument deployments.
- FRM measurements are openly and freely available for independent scrutiny.

- In red font a proposed updated phrase to align it with VIM SI metrological traceability definition

4SOC

Ensuring measurements validating of Ocean colour are internationally consistent and traceable to SI

Uncertainty analysis with support Ocean platforms and ship transects

FRM4SOC definitions

- **Copernicus FRM-certified OC instrument network (FRMOCnet)** this is a network that will be established and include of FRM-certified instruments and measurements.

- FRM compliant cal/char laboratories
- FRM Certification of OCR instrument models
- FRM certification of single individual OCR instrument
- FRM certified cal/char status
- FRM competence certified operators
- FRM certified measurement protocols
- Network of radiometric measurements with the FRM certification

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FRM compliant laboratories

- quality management system of ISO 17025
- Participation in an international comparison such as FRM4SOC and obtain the results that agree with the comparison reference value with set uncertainties,
- International Laboratory Accreditation Cooperation (ILAC) recognised accreditation,
- NMIs under International Committee for Weights and Measures Mutual Recognition Arrangement (CIPM MRA),
- Establishing or designating a dedicated independent and authorised certification body outside the “ISO” system to make the audits and decisions on conformity

Historical view

Name		Date	Irradiance	Radiance	Comments	Ancillary instrumentation
SIRREX	1	July 1992	Transfer of irradiance scale from a reference lamp to 17 FEL lamps	Integrating spheres (various sizes), lamps + plaques	Based in one lab – aim to transfer a common spectral irradiance and radiance scale from GSFC to participating labs, plaque BRDF issues reported, require improvement of instrumentation to meet the mission goals.	Shunt resistors, voltmeters
	2	June 1993	Transfer of irradiance scale from a reference lamp to 26 FEL and 1 DWX lamps	Integrating spheres (various sizes), lamps + plaques	Based in one lab – aim to transfer the scale. Irradiance results satisfactory, radiance results unsatisfactory	Shunt resistors, voltmeters
	3	Sep 1994	FEL lamps comparison	Integrating spheres (various sizes), lamps + plaques	Based in one lab – irradiance results satisfactory radiance results improved, plaque still require further investigation.	Shunt resistors, voltmeters
	4	May 1995	N/A	N/A	Based at NIST training in a common protocol for calibration of radiometers, Conversion between R (8°/h) to R (0°/45°) geometry for applied,	
	5	July 1996	NIST calibrated participates irradiance radiometers	NIST calibrated participants radiance radiometers	Based at NIST focusing on training and standard measurements protocols implementations	Instruments intercomparison in field
	6	Aug-Sep 1997	2 transfer radiometers measured irradiance at each lab	2 transfer radiometers measured irradiance at each lab	Measurements conducted by NASA personnel traveling to each participating lab.	
	7	March 1999	FEL comparison	lamp + plaques	Based in one lab focused on uncertainty in a single lab, plus rotation and polarisation sensitivity	
	8	Sep-Dec 2001	N/A	N/A	Based in 3 labs, focused on immersion factors and cosine response	
SIMRIC	1	2001	N/A	Lamp plaque, integrating sphere	7 labs measure in-house radiance source with a reference radiometer,	
	2	2002	N/A	Lamp plaque, integrating sphere	10 labs measure in-house radiance source with a reference radiometer,	
FRM4SOC	1	2017-2018	FEL comparison 14 lamps	Radiance comparison as participant laboratory using lamp + plaque	Lamp comparison and training based at NPL; radiance comparison based at each participant own lab. Irradiance results within uncertainty radiance saw two distinctive groups of results.	

Absolute radiometric calibration comparisons

- Measurand - the responsivity calibration factor determined for all transfer radiometers using participant's own spectral irradiance and radiance reference standards,

- Result - differences between each participant's measurement and the mean value of all of them.

- Discrepancy procedure - In the event of discrepancy in the results the pilot will work directly with a participant to investigate source of that difference. It might be possible for the participant to repeat the measurements if the cause of error will be identified before the end of the comparison period. The pilot upon agreement with participants might decide to report the results of the comparison as a weighted mean or median to minimalize the contribution of the outliner results on the final comparison value.

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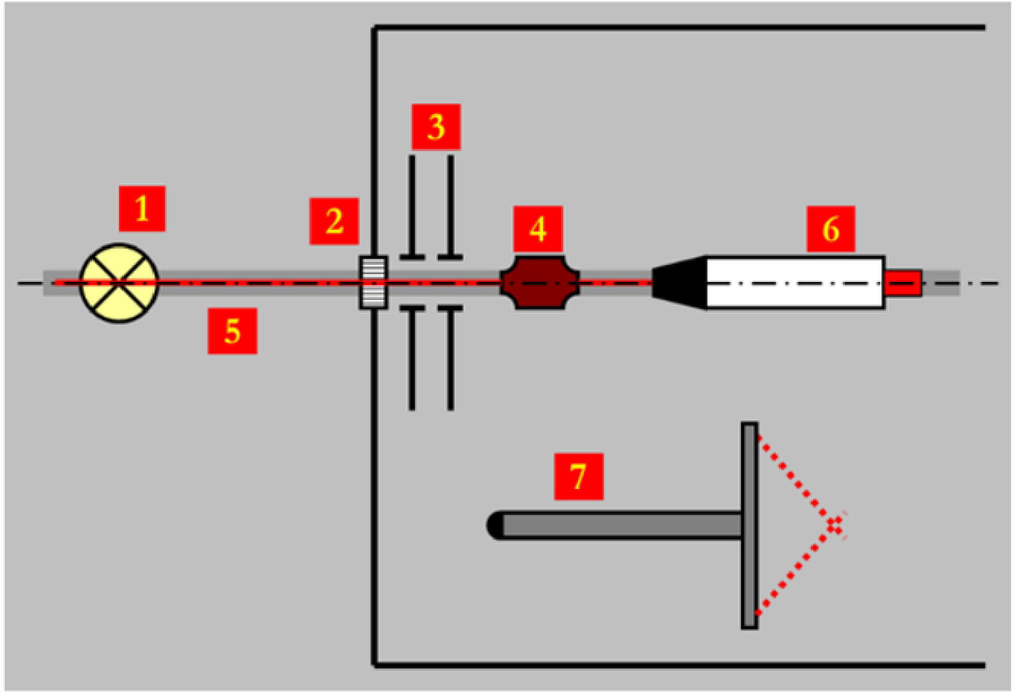
Absolute radiometric calibrations irradiance



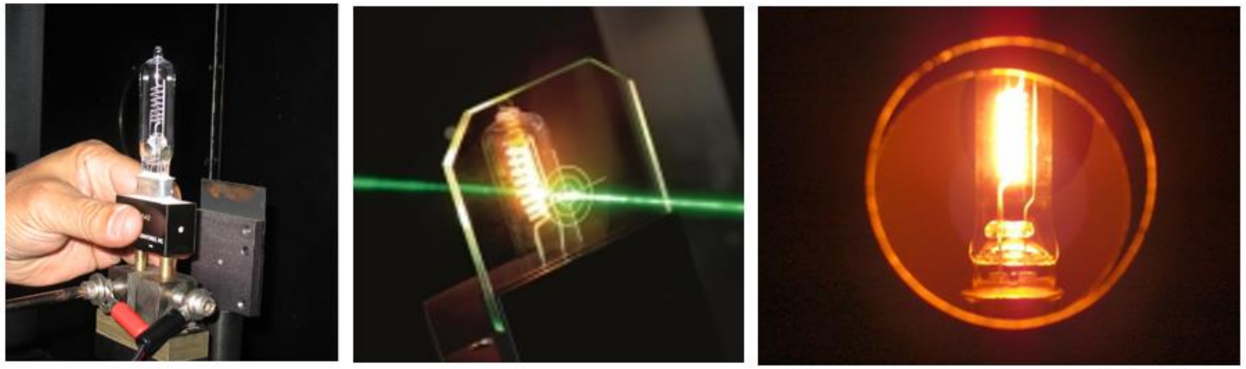


Photo courtesy of Gamma Scientific

Figure 1.Pilot's (UT) irradiance calibration setup. 1 -FEL lamp; 2 – shutter; 3 – baffles; 4- -alignment laser; 5- optical rail; 6 – radiometer; 7 – contactless distance probe.

Check list

- "Required", "Highly recommended" and "Preferable"
- To take part in comparison a participant must meet all required points.
- Lack of items "Highly recommended" increases the measurement uncertainty values.
- The "Preferable" category contains non-essential items that would be good to have to speed up or simplify the measurements, however it is possible to make measurements without them.

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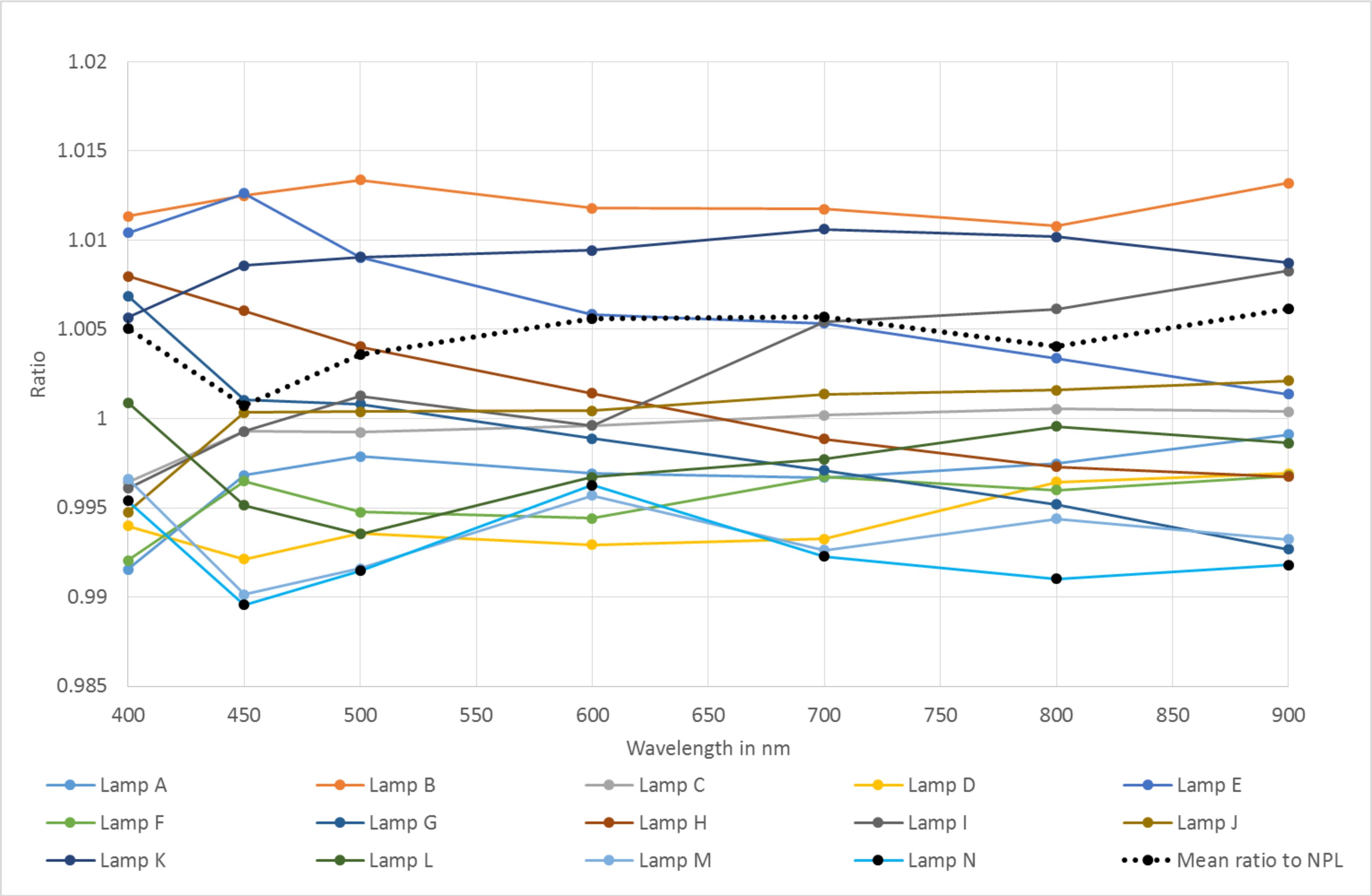
Absolute radiometric calibrations irradiance

1. R – Optical rail or tale to set up the experiment
2. R – At least two radiometrically calibrated FEL lamps with a burning time less than 50 h since last calibration
3. R – Alignment laser to define the optical axis and align the lamps and the radiometers
4. R – Lamp, radiometer and laser posts. P – Six degrees of freedom lamp and laser mount (to facilitate the alignment)
5. R – Alignment procedure that strictly follows the lamp manufacturer instruction and the lamp calibration instruction (e.g. the reference point for distance measurements is different for every manufacturer of FEL lamp, and the distance setting must be done accordingly to the lamp type),
6. R – Power supply, P – Power supply with a function of automatic rump up/down time
7. Hr – Standard resistor and independent voltmeter readings, P – automatic current and voltage readings with the file output, rather than an operator handwritten notes in a lab book.
8. R – Distance measurement devise, Hr – calibrated measurement stick, P – contactless distance probe
9. R – light shields
10. R – Lab temperature readings (section 7 Harmonisation of laboratory guidelines contain the explanation why this is required)

Irradiance comparison FRM4SOC 1



Absolute radiometric calibrations radiance

Reviewer comment –
Not all participant will use lamp/plaques methods.

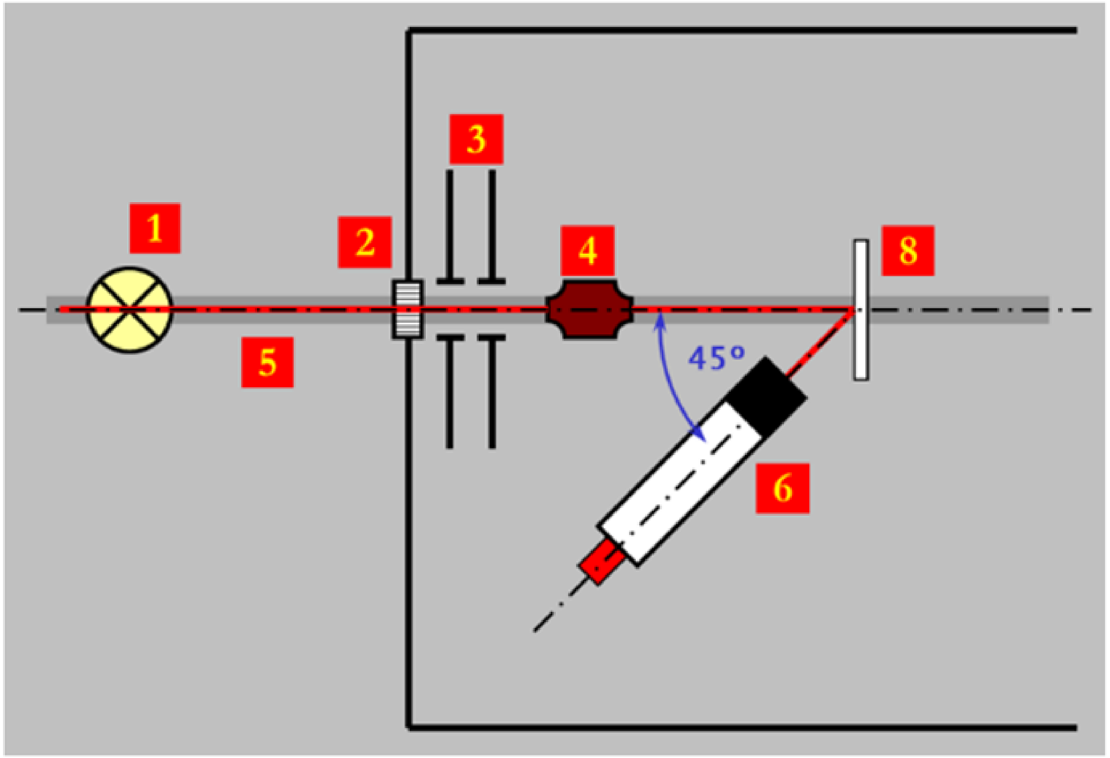


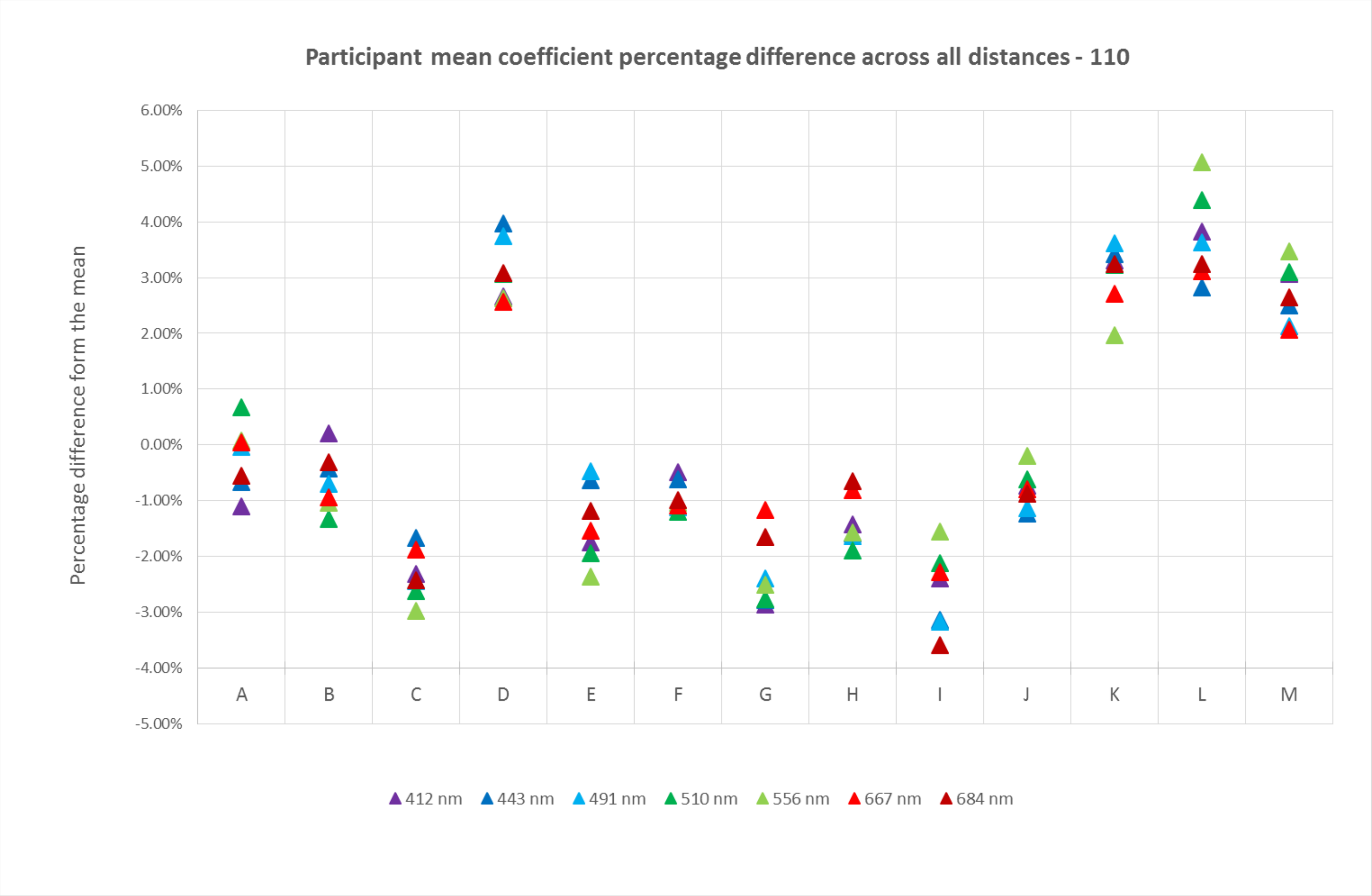
Figure 2. Pilot's (UT) radiance calibration setup. 1 -FEL lamp; 2 – shutter; 3 – baffles; 4- alignment laser; 5- optical rail; 6 – radiometer; 8 – reflectance panel.

Absolute radiometric calibrations radiance

1. R – Any calibrated white pseudo-Lambertian reflectance standard with correction applied to convert the calibration value to 0°:45° geometry for calibration performed at most common and widely available 8°:hemispherical geometry, Hr – Calibrated Reflectance standard with reflectance factor calibration at 0°:45° geometry.
2. P – Mirror with 6 degrees of freedom mount to verify the 45 degrees optical axis
3. R – Lamp filament distance offset. For Gigahertz lamps Hr – lamp filament offset for other lamps types. This is necessary to account for the difference in the plane of the distance setting and actual lamp filament position for measurements performed at any other distance than the default calibration 500 mm.

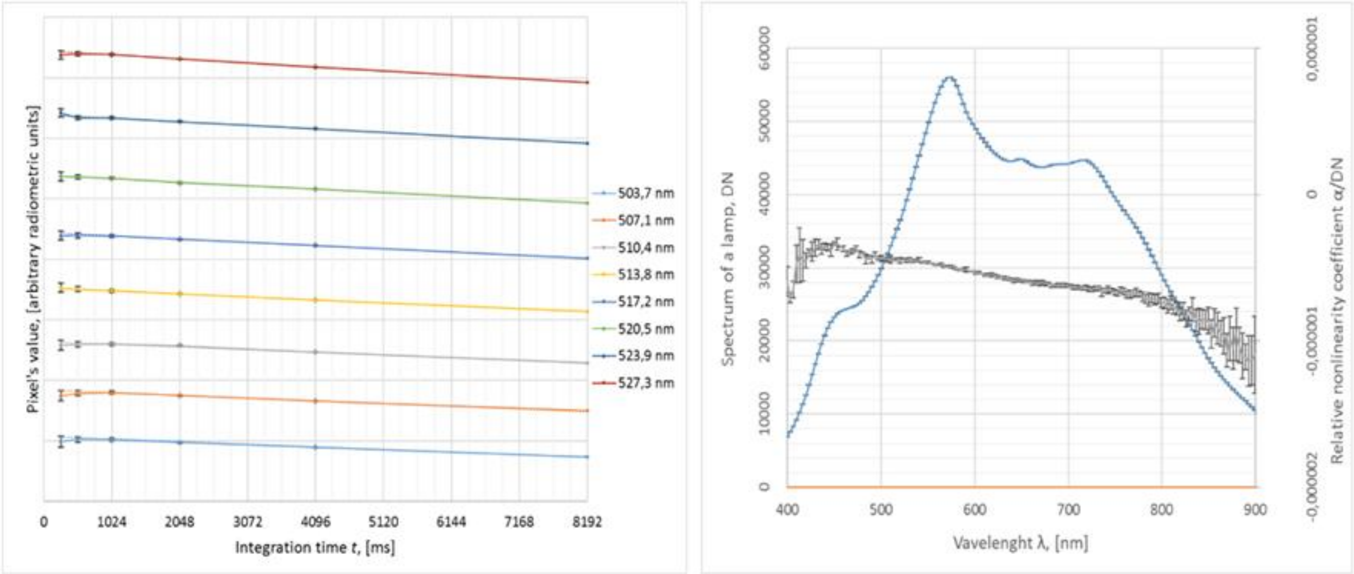
Reviewer comment –
Add references for 8/h and 0/45 reflectance factor conversion.

Challenging radiance FRM4SOC 1



Hyperspectral extra requirements

- **Apply integration time correction**



- **Temperature in the laboratory during the measurements must be below 25°C**

Instruments characterisation

- Difficult to find participant willing to do extra tests (requires a lot of time, expertise and dedicated laboratory equipment, thus cost a lot)

- We will encourage some characterisation tests in the future

Reviewer comment –
Not necessary the capabilities of the laboratory to perform all these characterisations.
Rather, the comparison artifacts should be selected for a single purpose e.g. insensitivies to temperature.

Laboratory comparison strategy

- Publicly announced open to everybody who holds absolute calibration standards and meet minimum requirements
- Executed as round – robin, so tests each participants in house laboratory capabilities
- With hyperspectral transfer radiometers (thus applying additional conditions during measurements)
- There is no a bad result
- Executed every 3-5 years, for a new players open possibility for a bilateral comparisons

D-11

Reviewer's comments

Comment

- I fully agree with the comment about some the wording simplification that implied that for 3 radiometer system the "uncertainty of lamp will cancel out".
- Clearly the effects of errors correlations needs to be included and contribute here to the reduction of the overall radiometric calibration related uncertainty

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Thank you

Agnieszka Bialek

agnieszka.bialek@npl.co.uk

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