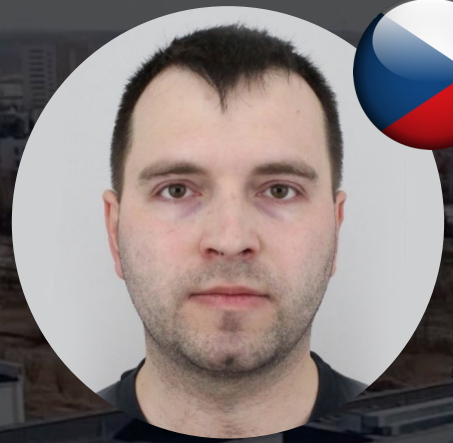
Parnas Fountain, Brno, Czech Republic



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He received a diploma in Plasma Physics from the Masaryk University in Brno, Czechia in 2008 and a PhD. degree in Metrology from Slovak Technical University in Bratislava, Slovakia in 2013. The topic of his thesis work was: Study of Mass Standards in Vacuum. He has been working in Czech Metrology Institute since 2008 as a full time Metrologist. He started working on his diploma thesis on Volume Measurements of Weights in 2006. He became Head of Primary Mass Metrology Department in 2019. He had been a coordinator of the EMPIR project entitled Improvement of the Realisation of the Mass Scale (2020-2023).

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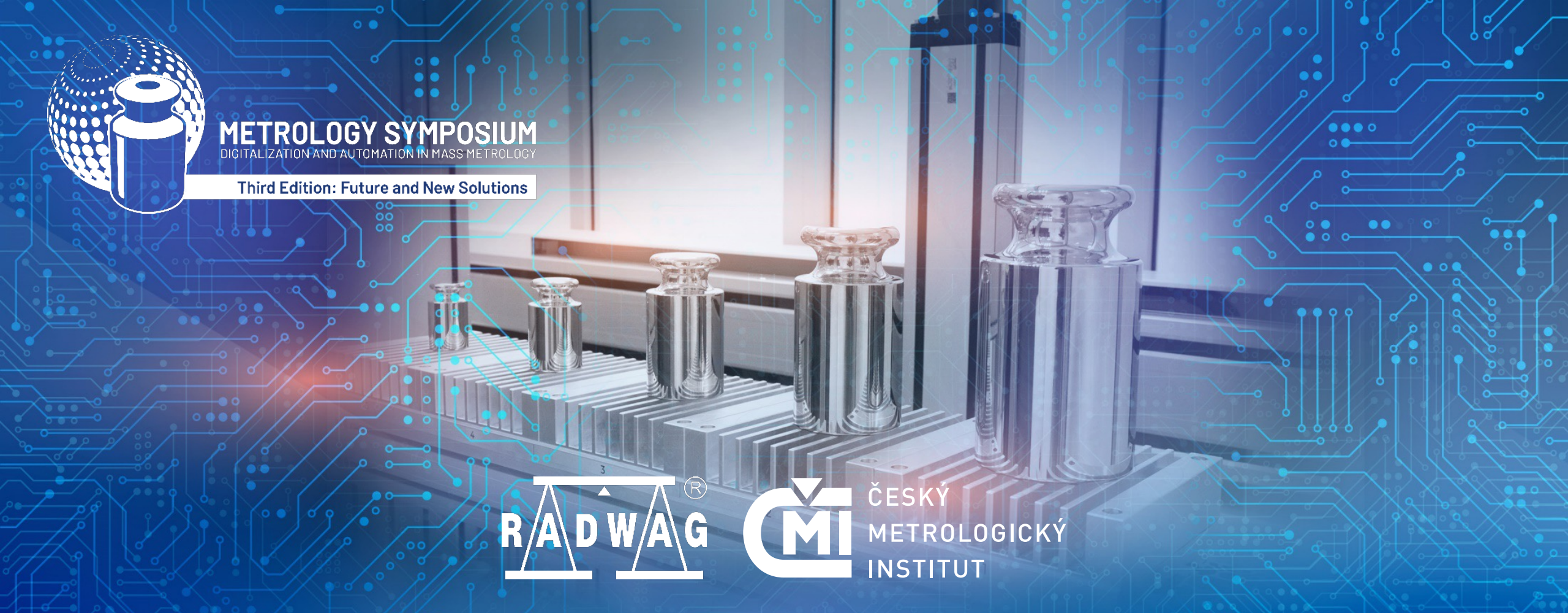

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Calibration guide for dissemination of mass

Calibration guide for dissemination of mass

- EMPIR project 19RPT02 „Improvement of the realisation of the mass scale“
- Started in 2020, finished in 2023
- 11 project partners
  - Lead by CMI

Calibration guide for dissemination of mass

- CMI (Czechia) – project leader
- BEV-PTP (Austria) – leader of WP1
- IMBiH (Bosnia and Herzegovina) – leader of WP2
- INRIM (Italy) – leader of WP3
- BIM (Bulgaria)
- BRML (Romania)
- DMDM (Serbia)
- NSAI (Ireland)
- SMD (Belgium)
- ME-BoM (North Macedonia)
- NSC-IM (Ukraine)

Calibration guide for dissemination of mass

- Analysis of calibration methods for the realisation and dissemination of the mass scale
- Development and implementation of calibration methods to realise, improve and maintain mass scale
- Development of mathematical and statistical tools and software solutions
- Euramet draft guide for the realisation of the mass scale
- Individual strategies for long-term operation

Calibration guide for dissemination of mass

- Elements and influencing quantities of the calibration
- Methods of the measurement and weighing designs
- Mathematical models, reliability of and correlation of the measurement results
- Uncertainty, influencing factors and calculations
- Typical example
  - Dissemination of weight set from 1kg reference
  - Dissemination with more reference weights of different nominal masses

Calibration guide for dissemination of mass

- Starting with equation for direct comparison

$$\Delta m = \delta m \left(1 - \frac{\rho_{a_j}}{\rho_{adj}}\right) + \rho_a(\sum V_B - \sum V_A)$$

- Corrections to temperature

$$V = V_{20}\left(1 + \alpha(T - 20)\right)$$

- Corrections to center of gravity

$$\delta m_G = m_N \left[\frac{\Delta g}{g}(h_A - h_B)\right]$$

Calibration guide for dissemination of mass

- System of equations in matrix notation

$$X_w m = y_w + \epsilon$$

- Evaluation of calibration scheme by least square methods
  - Gauss-Markov approach
  - Lagrange multipliers method
- Mass of the reference weights added as separate lines
- Solution in form like

$$\hat{m} = \left(X_w^T \Psi_y^{-1} X_w\right)^{-1} X_w^T \Psi_y^{-1} y_w$$

Calibration guide for dissemination of mass

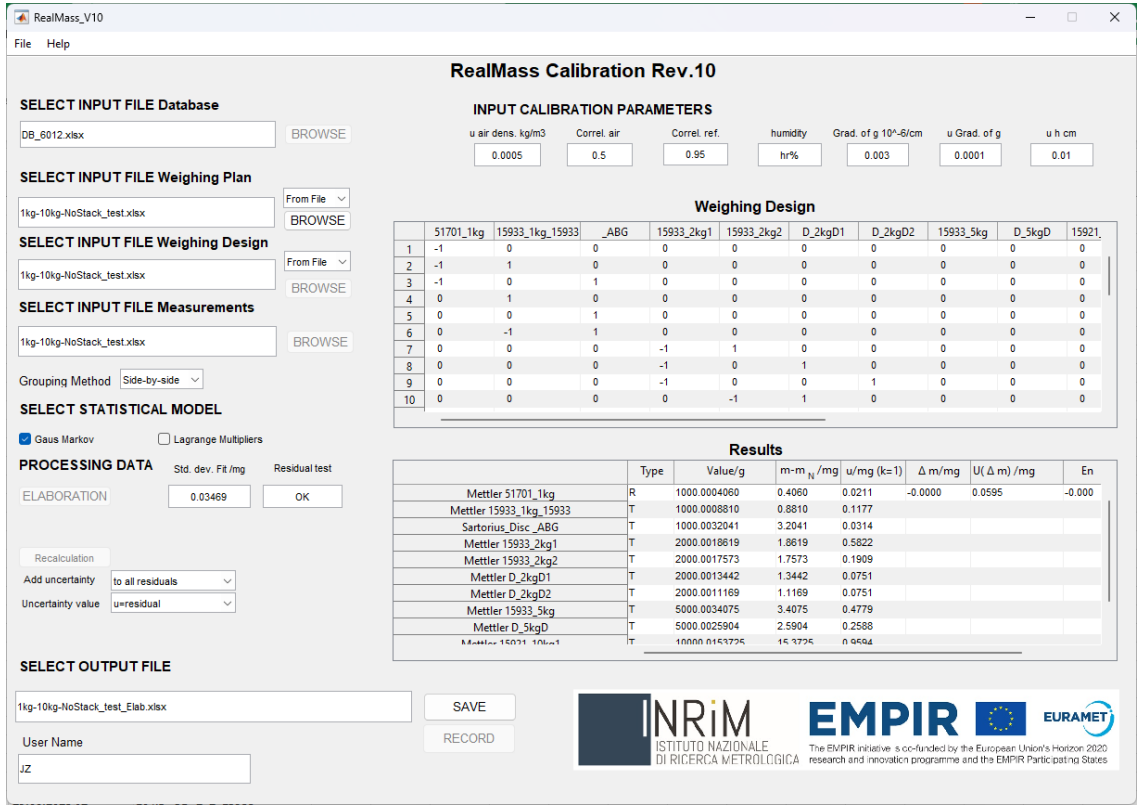
- Uncertainty considerations
  - Standard deviation of the measurements
  - Uncertainty of volume, air density, center of gravity etc.
- Some units can and should be considered correlated
  - Air density – usually measured by the same devices (p, h, T)
  - Mass and volume of the reference

$$u(m,V) = \rho_{a_E} u^2(V)$$

  - When more reference weights used, correlation from the current status of kilogram definition arises

Calibration guide for dissemination of mass

- Software RealMass
  - Developed by INRIM
- Inputs and outputs in Excel
- Correlations, uncertainties, type of stacking etc.



Calibration guide for dissemination of mass

- Following presentations
  - Zoltan Zelenka – Revisiting weighing designs
  - Bianka Mangutova – Stoilkovska – Mass metrology needs in emerging institutes

The EMPIR project 19RPT02, “Improvement of the realisation of the mass scale” (EMPIR Call 2019 –Research Potential), has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.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