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Measurement Trustworthiness: Value Proposition and Steps to Demonstration

December 4, 2024

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Data Quality begins at the source

- Only two observables: voltage and current
- Assessing uncertainty at the source of the measurement
- Definitional uncertainty
- Enabling transparency for uncertainty propagation from wave signals to grid applications, to operator decisions

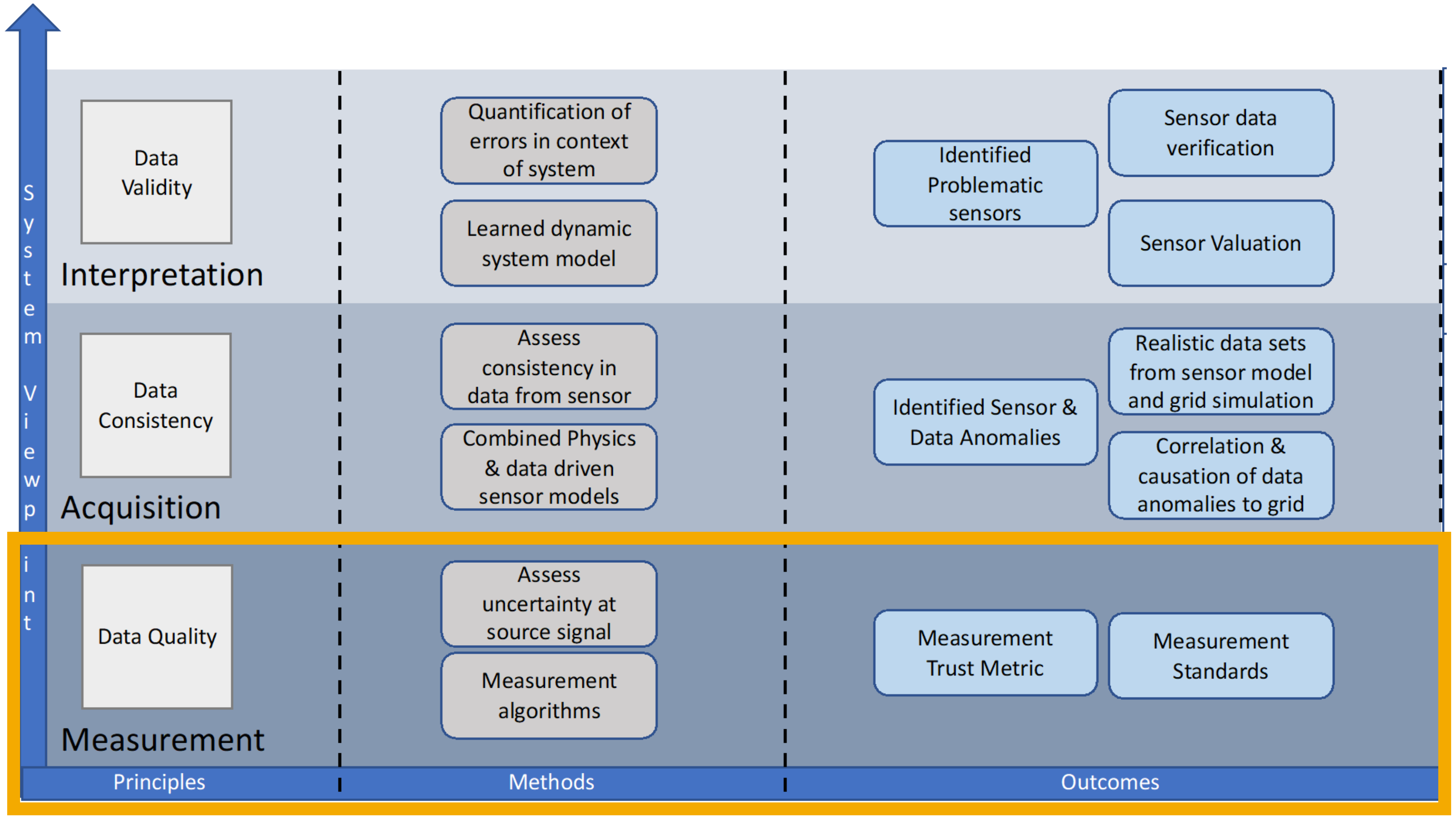

Image courtesy: Jim Ogle, PNNL

The value hypothesis

More relevant information improves decision-making process and outcomes

- Value for grid applications, real time aspect of the trustworthiness
  - Improved frequency measurement-based protection algorithms
  - Improved situational awareness through utilization of trustworthiness metric
  - Improved grid element model development (reduced uncertainty)
- Demonstration value:
  - Value quantification for use case scenarios
  - Feasibility assessment
  - Improved likelihood for technology adoption

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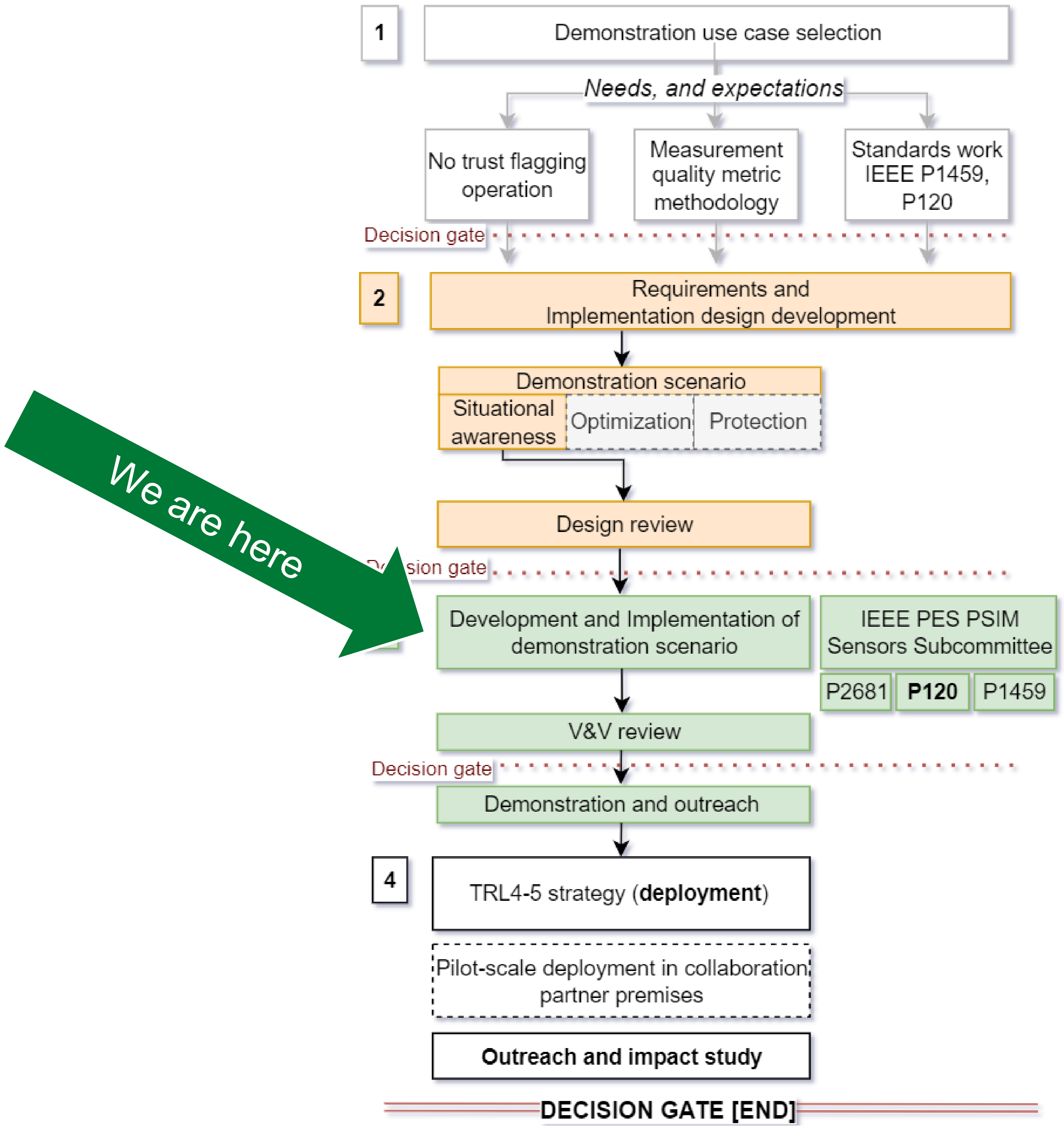
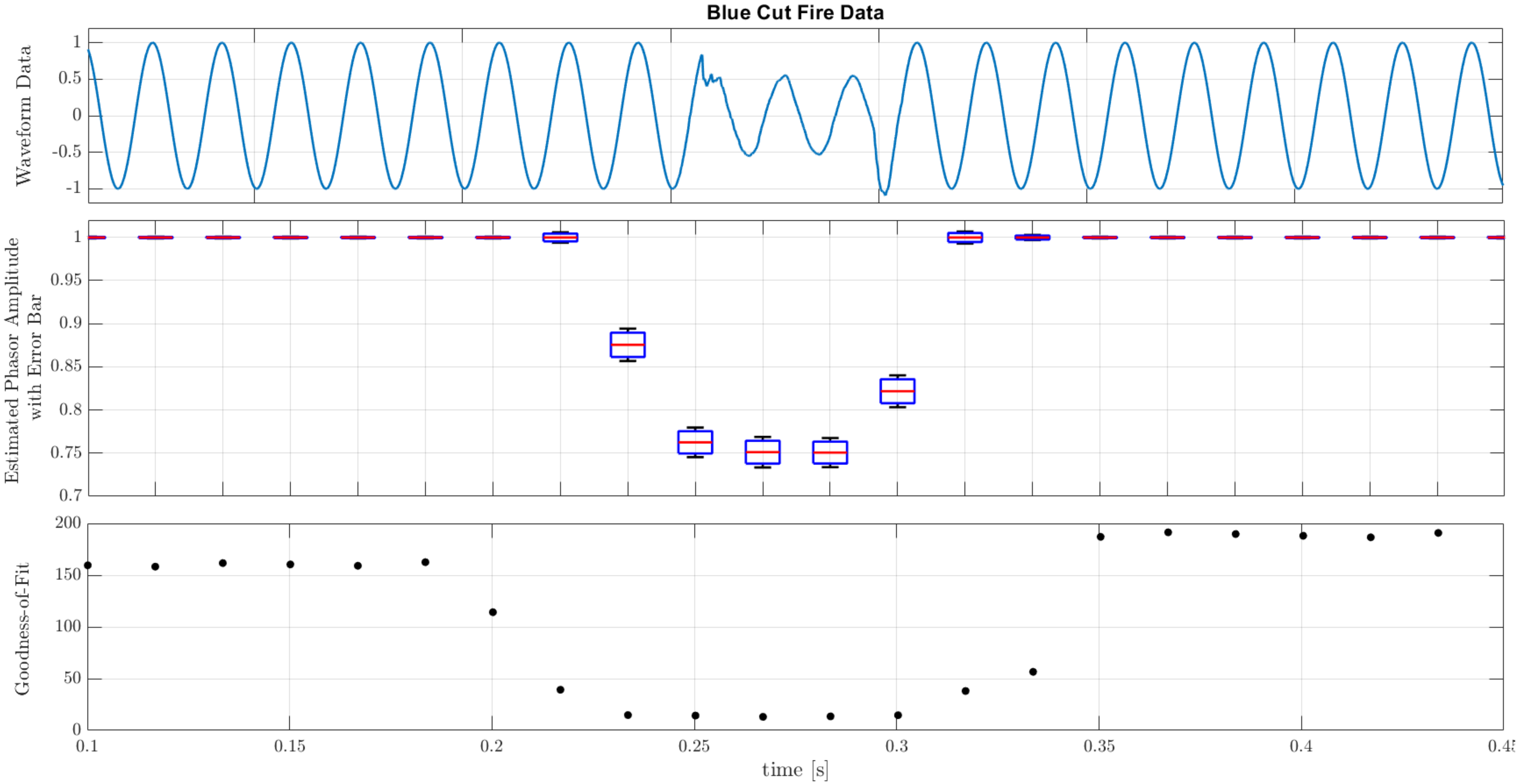
PMU Metrology: Project overview

- Measurement science:
  - Uncertainty quantification
  - Epistemology
  - Philosophical aspects of measurement
- Standardization:
  - IEEE 120
  - IEEE P1459
- Significant focus shift since 2022 towards implementation and demonstration

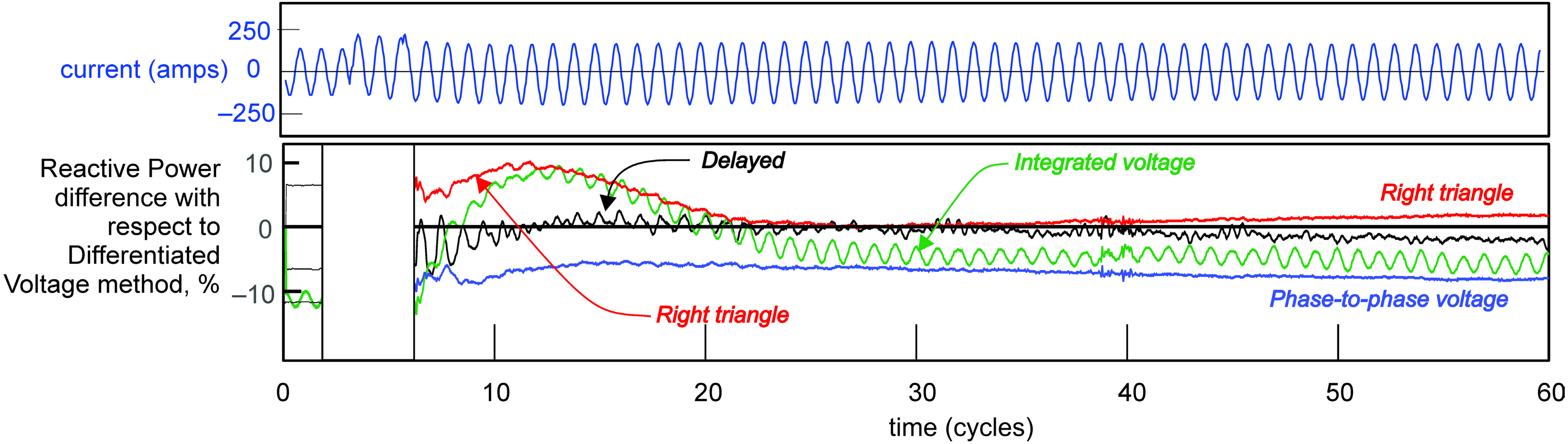


Measurement trustworthiness



[1] *https://www.bipm.org/en/committees/jc/jcgm/publications*

Power quantity measurement uncertainty



- At least 7 different measurements
- All “correct”, all provide different answers in unbalanced, non-sinusoidal systems
    - In the picture: 5 reactive power measurands, single-cycle, sliding-window measurements,

H. Kirkham and A. Riepnieks, "A Future Standard for Reactive Power Measurement," *2020 IEEE Power & Energy Society General Meeting (PESGM)*, 2020, pp. 1-4

Power quantity measurement standard for the future

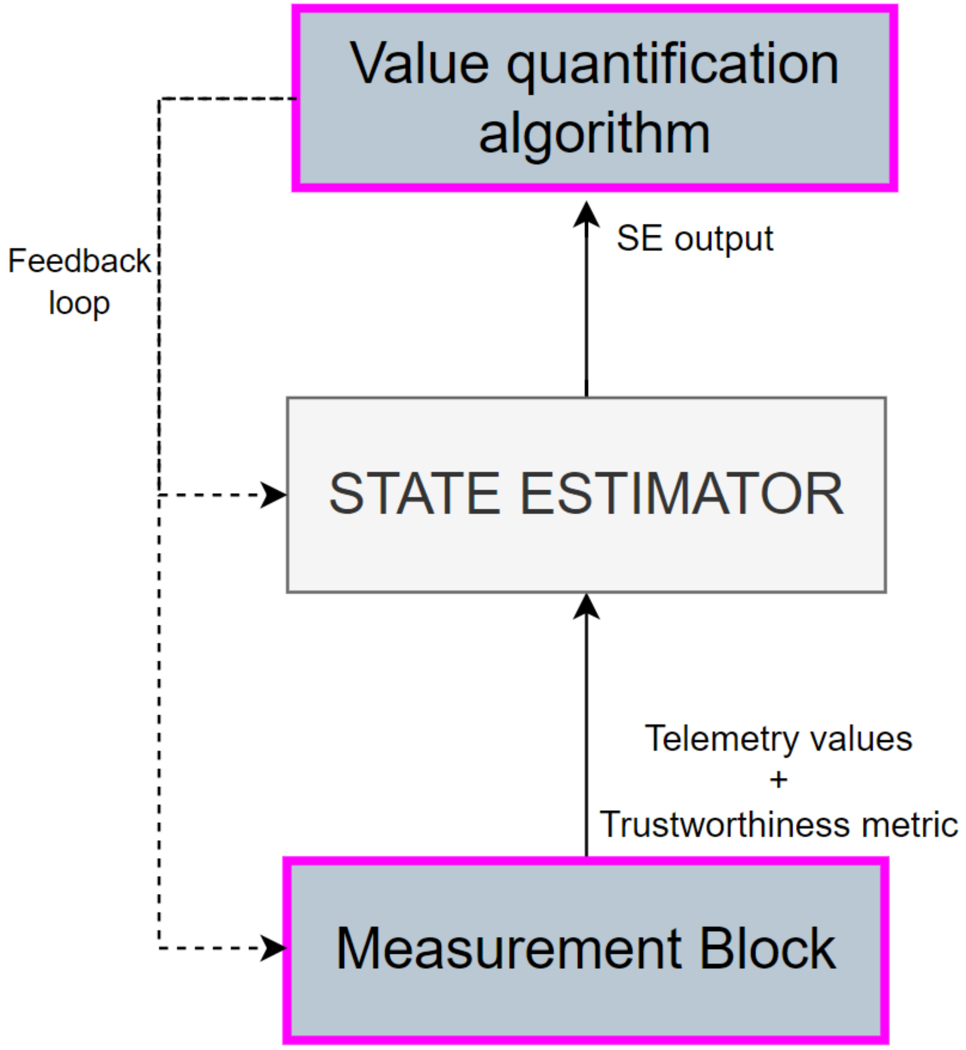
IEEE Standard 1459 "Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions" *(in ballot 2024)*

- Defines measurement process requirements
- Provides workable solutions
- Indicates the necessary consensus requirements for measurement interoperability and consistency:
  - ✓ Signal limitations
  - ✓ Filtering
  - ✓ Measurement algorithms
  - ✓ Necessary metadata

Situational awareness use case demo

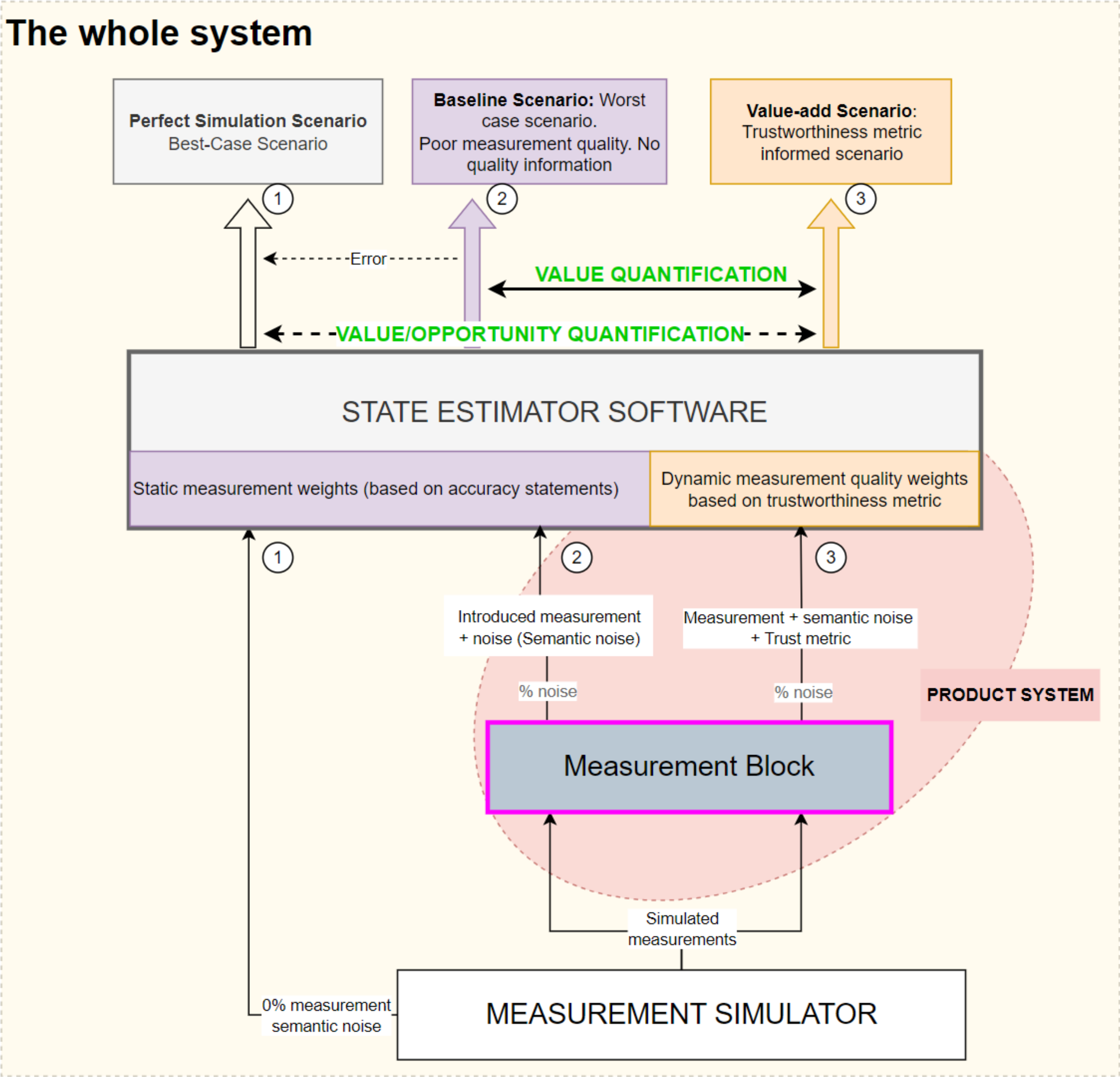
- Trustworthiness value quantification
- Demonstrable operation modes with and w/o trust information
- Relatable grid application (potentially high TRL)

- State Estimation selected for demo scenario



Architectural demo considerations

- Implementation in Python (transitioning from MATLAB)
- Dynamic weight selection based on received real-time measurements
- Three operational scenarios providing quantification opportunities
  - Best-case scenario (no uncertainty)
  - Worst case scenario (uncertainty without trustworthiness metric)
  - Test scenario (uncertainty with trustworthiness metric)



Some remarks

- Power system becoming increasingly dynamic, less well-behaved, and with higher demand for control
- Fast and high-quality (including consistent and trustworthy) measurements are essential for building human operated or automated grid actions
- Human operators – generally pushed for time
  - Measurement quality should be assessed at the source and used to inform decision making real-time

- *Measurement* ***trustworthiness metrics***
  - *Inform automated grid*
  - *Inform grid operators*

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Thank you