

SLICES-DE Research Infrastructure

Reproducibility, Energy Efficiency, and Research Data Management

SLICES-DE Research Infrastructure

Our Motivation:

How can we make ICT research more effective?

- ▶ Research prototypes are often developed as isolated islands
- ▶ Experiment workflows are rarely transferred between research groups
- **Create a shared research infrastructure (RI)** used by academia and industry

How to create an RI for the ICT community?

- ▶ Flexible RI covering many research fields
- ▶ Provide valuable services (reproducibility, data management)
- **Create a European RI** collaborating with national initiatives (e.g., SLICES-DE)

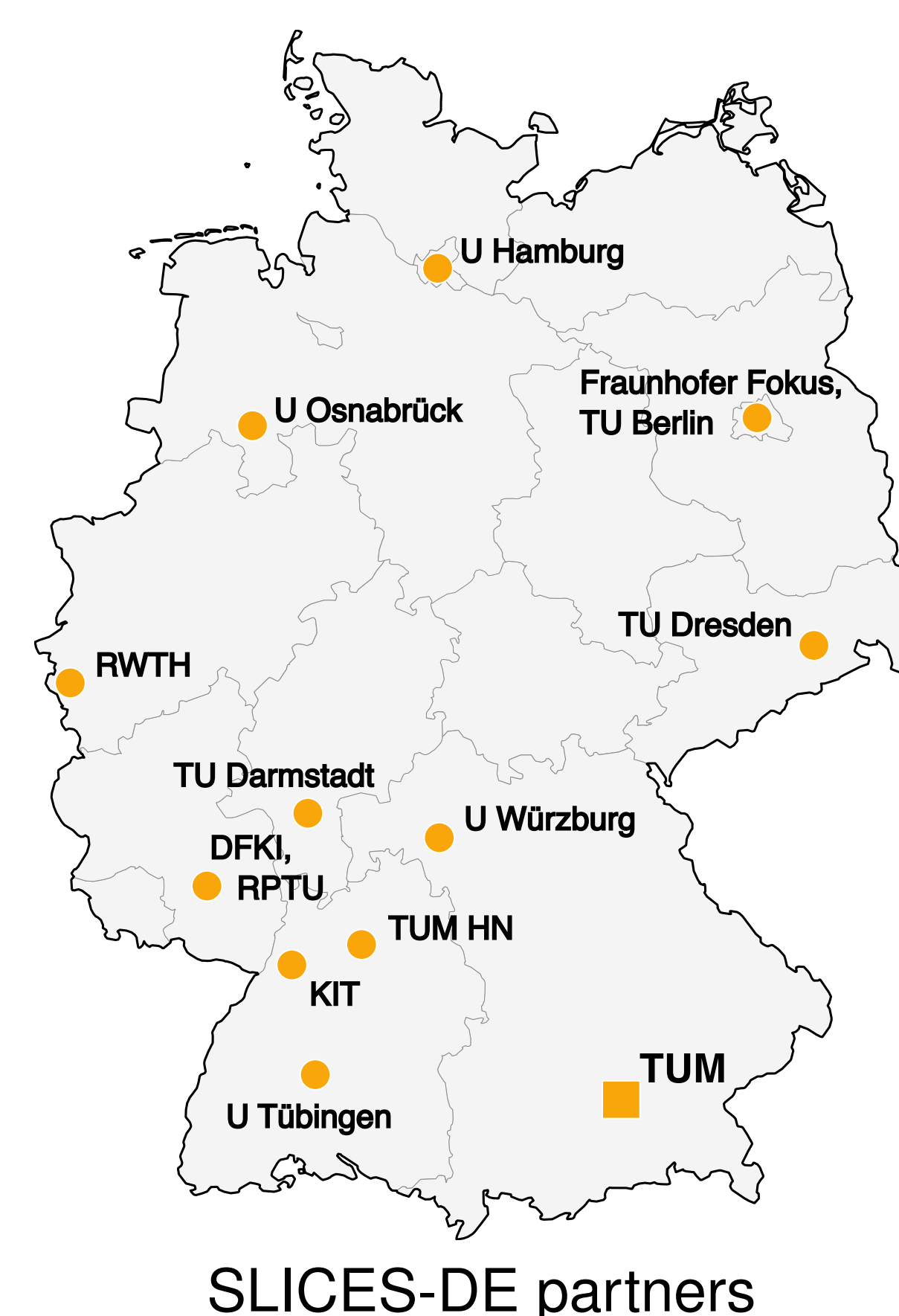
SLICES research infrastructure

SLICES-RI (Europe)

- ▶ Participation from 16 European countries
- ▶ Long-term funding (>10 years) through ESFRI framework of the European Union
- ▶ Joint platform with a shared experiment API [1] and research data management

SLICES-DE (Germany)

- ▶ Participation from 12 German partners
- ▶ TUM is the designated lead organization
- ▶ SLICES-DE is part of the German RI roadmap (prospective funding by BMFTR)



SLICES-DE partners

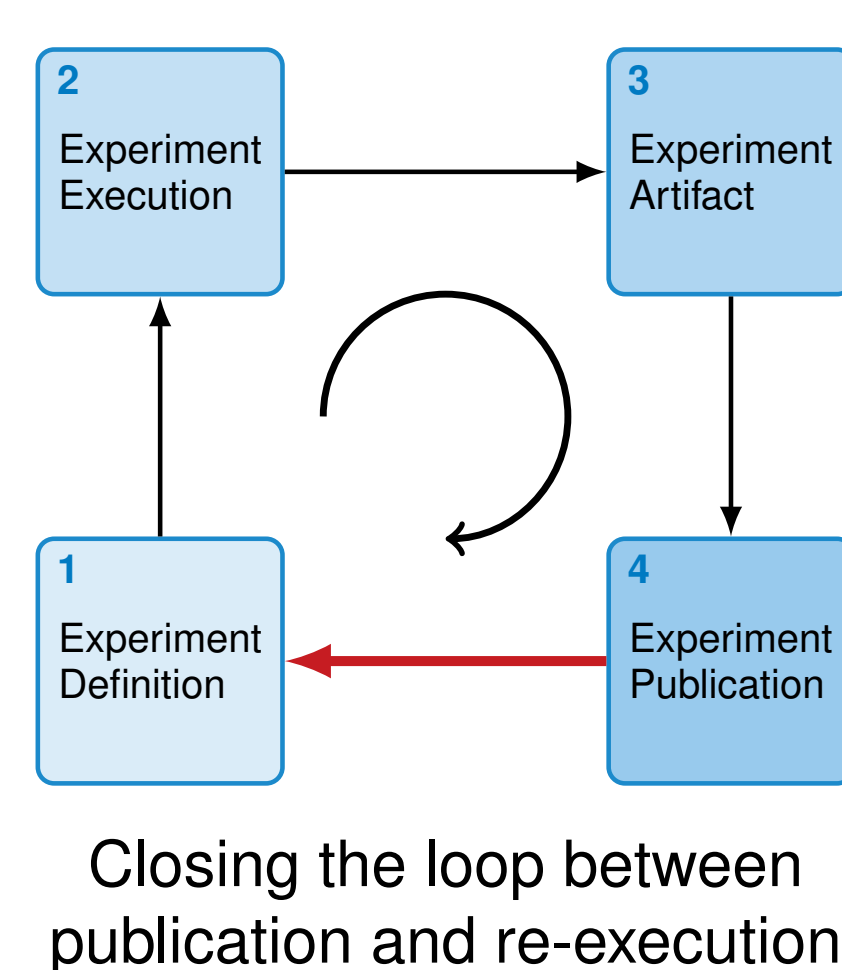
Motivation for Reproducibility in Testbeds

Reproducibility is a cornerstone of the scientific process

- ▶ In many testbed experiments, reproduction is the missing link in the experimental loop → remains a tedious and manual process
- ▶ Lack of standardized packaging and documentation hinders reproducibility of experiment results → missing experiment metadata

Closing the Reproducibility Gap [3]

- ▶ Introduce structured, machine-readable format to provide experiment context and metadata
- ▶ Provide necessary metadata about used hardware, topology and scripts
- ▶ Enable a closed feedback loop from experiment definition to publication



Closing the loop between publication and re-execution

RO-Crate Metadata Packaging

RO-Crate is a lightweight format for **FAIR research data** using JSON-LD

Automatic packaging [2] of

- ▶ Configuration files and input scripts
- ▶ Output logs and files (such as `.stdout` and `.stderr`)
- ▶ Node-specific parameters and experiment variables
- ▶ Environment metadata (such as OS image, authors, etc.)



<https://ro-crate.org/>

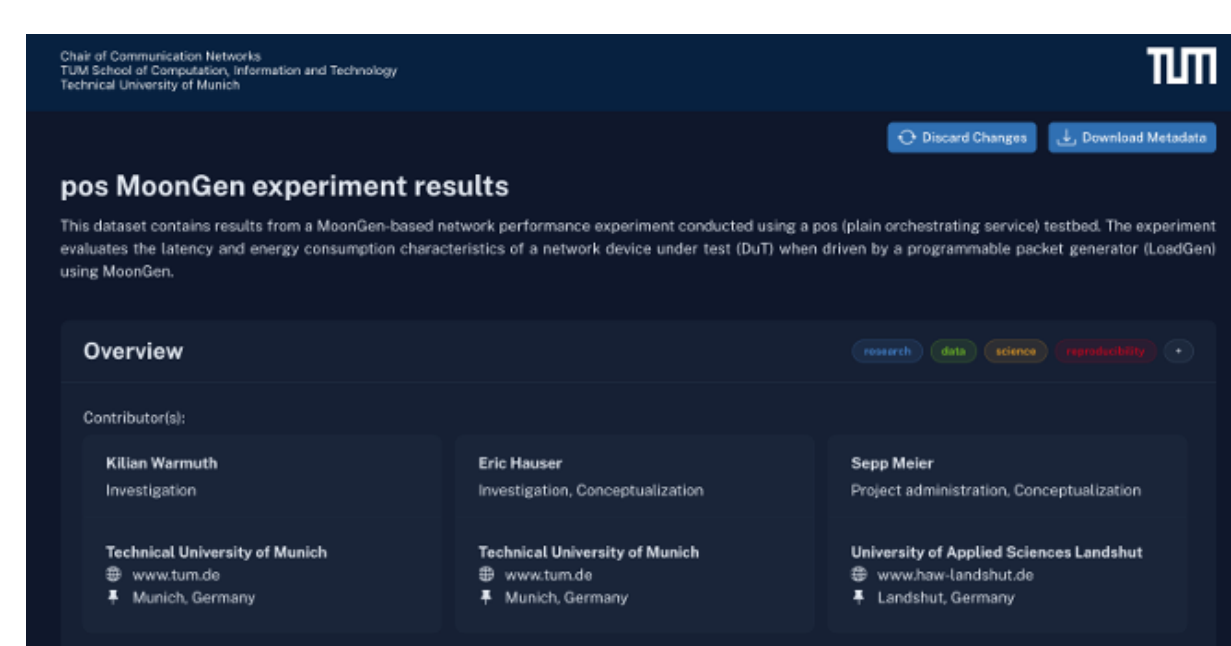
Benefits

- ▶ Improves reproducibility and sharing in the research community
- ▶ Achieving cross-testbed compatibility and portability

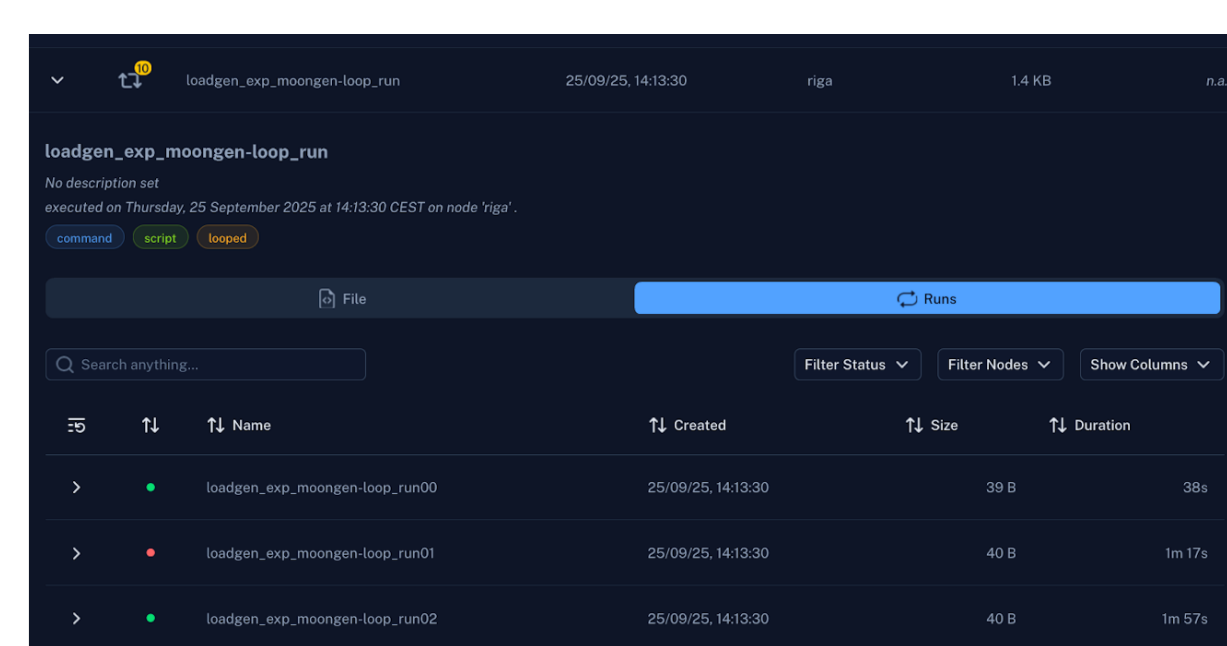
RO-Crate Visualization

RO-Crate recommends to provide a custom HTML visualization

- ▶ Human-friendly overview shipped *inside* each crate
- ▶ Visualization of metadata such as authors and affiliations, license, and keywords
- ▶ Chronological listing of executed scripts with details and filters
- **Reduces complexity** for users and simplifies exploration and sharing of results



General overview of an experiment crate

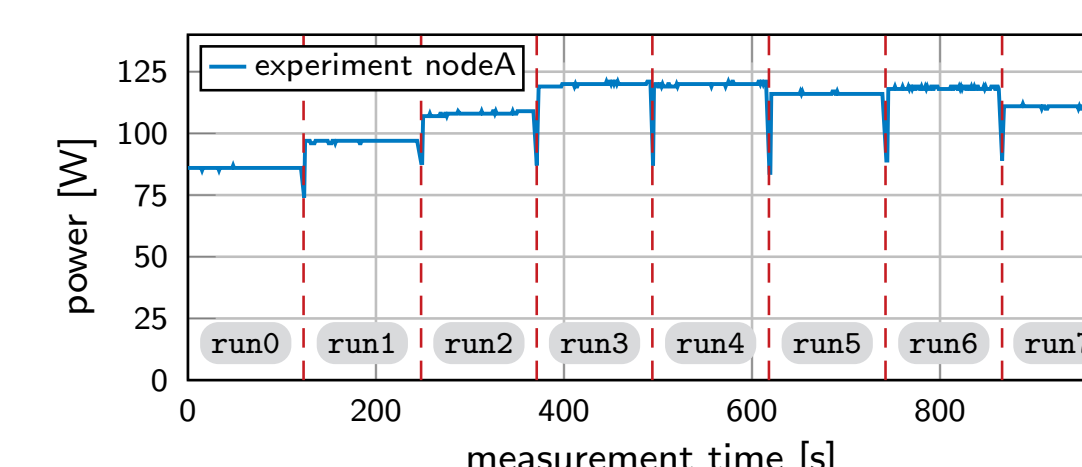


Detail view of executed script results

Energy Monitoring, Analysis, and Modeling

Energy-aware experimentation

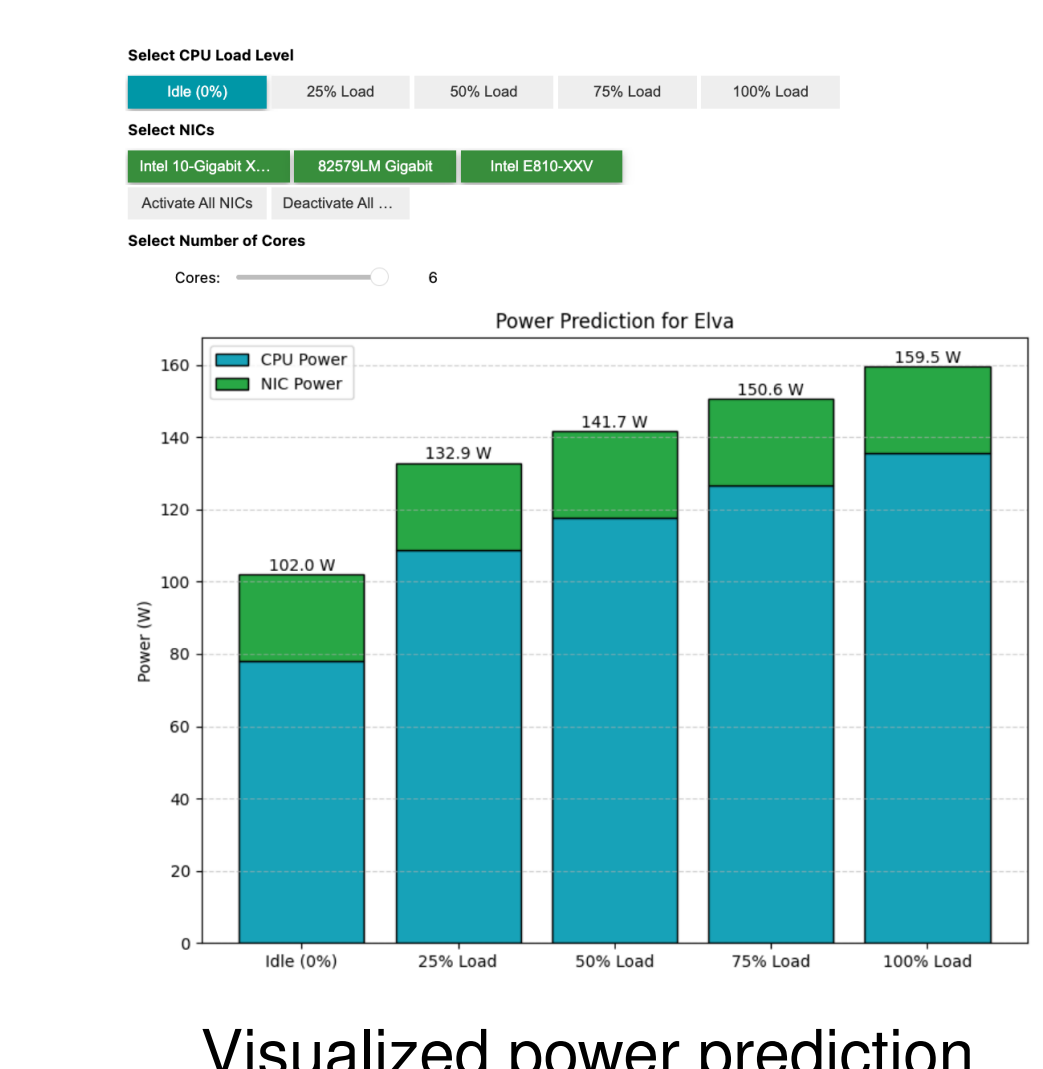
- ▶ Continuous monitoring of power consumption across testbeds
- ▶ Enables more conscious and efficient use of research infrastructures



Energy consumption monitoring

Predictive modeling

- ▶ Regression models estimate energy demand before execution
- ▶ Helps researchers compare configurations and reduce carbon footprint
- Enables **sustainable research**



Visualized power prediction

- [1] S. Gallenmüller, D. Scholz, H. Stubbe, and G. Carle. The pos Framework: A Methodology and Toolchain for Reproducible Network Experiments. In *CoNEXT '21, Virtual Event, Munich, Germany, December 7–10*. ACM, 2021.
- [2] E. Hauser, S. Gallenmüller, and G. Carle. RO-Crate for Testbeds: Automated Packaging of Experimental Results. In *IFIP Networking 2024, Thessaloniki, Greece, June 3–6*. IEEE, 2024.
- [3] E. Hauser, K. Warmuth, M. Kempf, S. Lachnit, and G. Carle. MARTE: Malleable and Automated Reproduction for Testbed-driven Experiments. In *ACM Conference on Reproducibility and Replicability (ACM REP '25)*, Vancouver, BC, Canada, July 2025.