Fraunhofer IISB

Fraunhofer Institute for Integrated Systems and Device Technology IISB

Stefan Waldhör – 2025-03-20

Unleashing the Potential of Battery Data: Transforming Measurement Data into Strategic Insights for Battery and Battery System Optimization

Introduction – Fraunhofer IISB

Location: Erlangen (Germany)

Fraunhofer Society

- Applied Research Organization
- Around 32 000 Employees
- 75 Research Institutes
- Annual Budget: 3.4 GEUR

Fraunhofer IISB in Erlangen

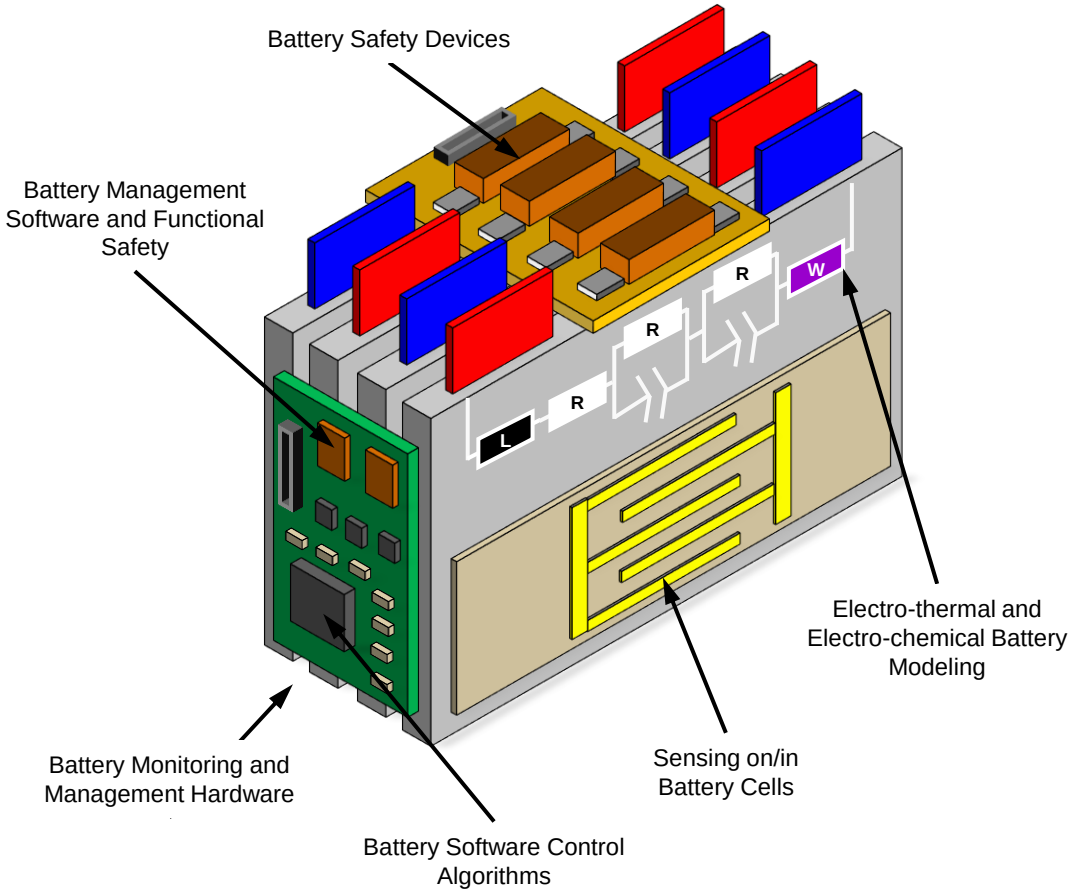
- Director: Prof. Dr. Jörg SCHULZE
- R&D Fields:
  - Semiconductor Technologies (Si & SiC)
    (1000 m² clean room ISO 4/5 Class 100/1000)
  - Power Electronic Systems
- Cooperation with the Friedrich-Alexander-University Erlangen-Nürnberg (FAU) and with the University of Bayreuth (UBT)
- Staff: 460 Employees (380 Scientists/Engineers)
- Annual Budget: ~35 MEUR

Introduction – Fraunhofer IISB

Group Battery Systems: Competences and Services

Research and Development Activities

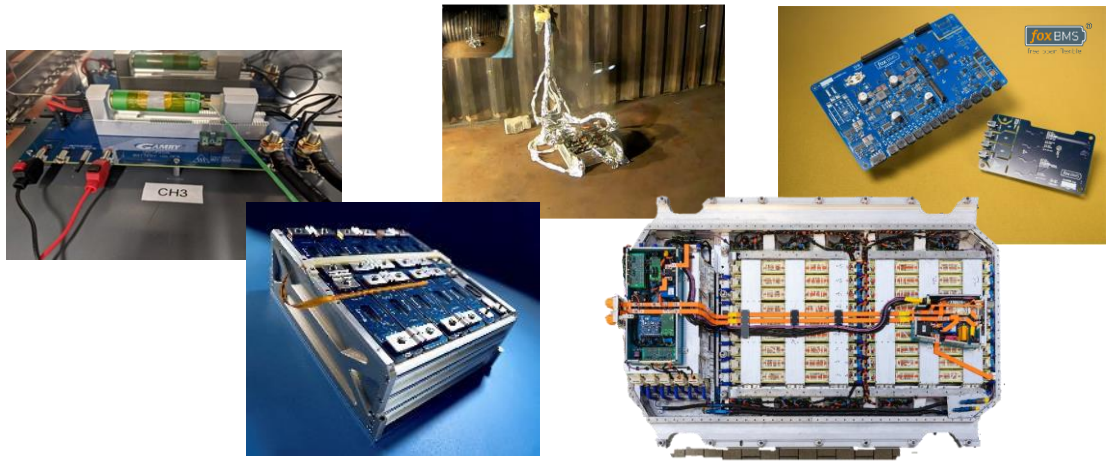
- **Design and Prototyping of custom battery systems** from requirements engineering up to the mechatronic integration
- **Battery Management Systems** (BMS Hardware and Software) with **high availability** concepts (**foxBMS®**)
- **Passive and active safety concepts** for high functional safety integrity levels in multiple domains (ASIL-D / SIL-3 / DAL-C)
- **Battery Junction Boxes** (BJB) and **Power Distribution Units** (PDU)
- **Thermal management** for non-propagation in case of **thermal runaway** and temperature homogenization concepts for **ultra-fast charging** (>3C-rate)
- **Modelling and simulation methods** for battery system design and predictive control of battery-based applications

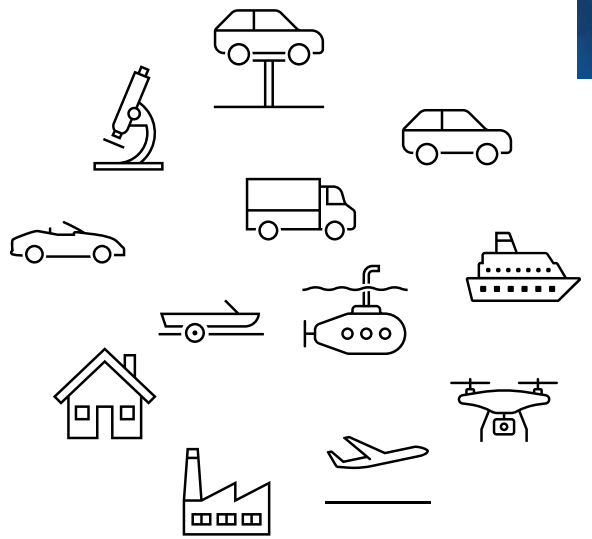


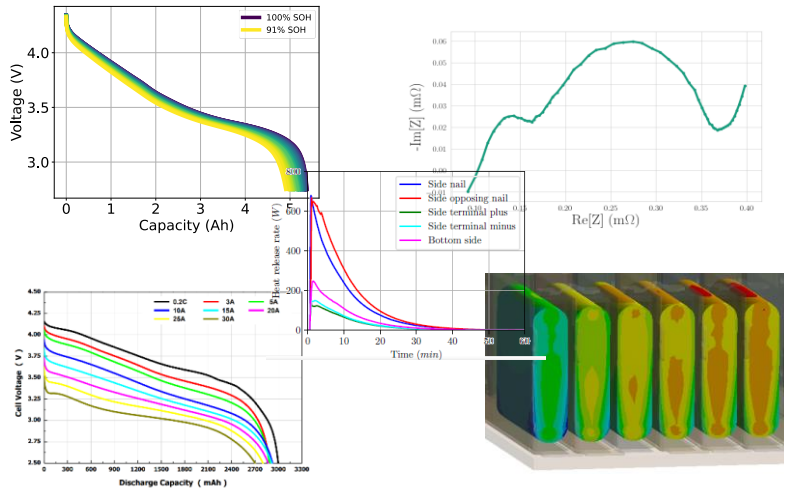
Unleashing the Potential of Battery Data: Transforming Measurement Data into Strategic Insights for Battery and Battery System Optimization

Collecting Battery Data: Where and why?

- Battery data is collected under different conditions aspects and for different purposes
  - **Laboratory**: characterization, modelling during design phase
  - **Application**: Validation, service, lower data rate, product iteration/improvement







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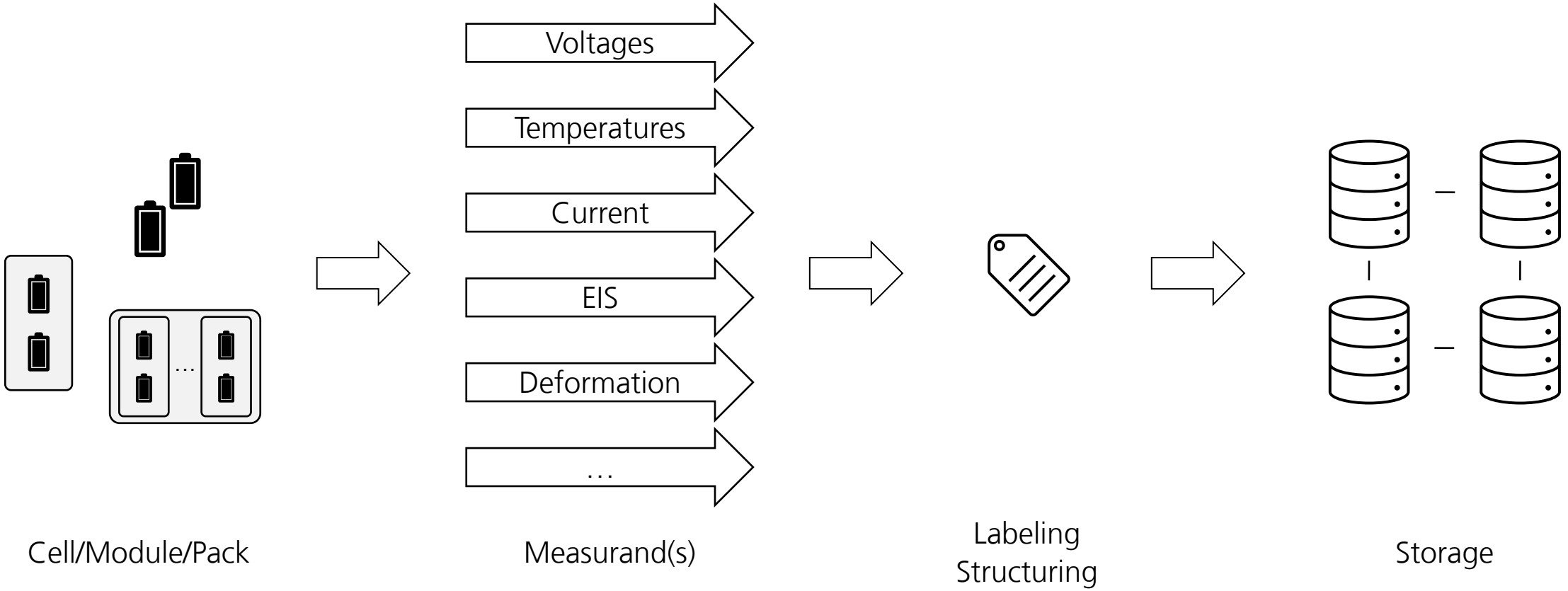
Collecting Battery Data: What?



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Exemplary Battery Usage Data: foxBMS® Battery Data

- The BMS communicates e.g., via CAN with the higher-level control unit
- Transmitted battery data at least contains cell voltages, temperatures and system current
- CAN messages
  - contain a timestamp and a portion of the system data in hexadecimal representation
  - Use a semi-structured format
- Time intervals between different CAN message might be irregular

Timestamp (s)	ID	DLC	Data							
1212239.036196	253	8	00	07	FF	C0	06	00	2F	FF
1212239.035950	252	8	00	07	FF	C0	02	00	10	01
1212239.036442	254	8	00	07	FF	BF	FE	00	0F	FF
1212239.036934	256	8	00	08	01	40	06	00	30	01
1212239.037182	257	8	00	08	00	C0	06	00	2F	FF
1212239.037382	35D	6	01	0D	00	05	FF	55		
1212239.037604	35E	6	02	0C	00	05	FF	01		
1212239.037828	35F	6	03	00	00	05	FF	70		
1212239.038055	528	6	07	01	FF	FF	E8	60		
1212239.038497	526	6	05	0F	FF	FF	FC	5F		
1212239.040365	527	6	06	0B	FF	FF	26	6D		
1212239.040977	223	8	80	1B	FF	80	00	00	17	15
1212239.051044	240	8	00	08	00	40	02	00	10	01
1212239.051290	241	8	00	08	00	C0	02	00	30	01
1212239.051780	242	8	00	08	00	C0	02	00	50	00
1212239.052270	244	8	00	07	FF	BF	FE	00	10	00
1212239.052761	246	8	00	08	00	C0	0A	00	10	02
1212239.053007	247	8	00	08	01	C0	0A	00	50	03
1212239.053253	248	8	00	08	01	40	0A	00	30	02
1212239.053363	130	5	00	F0	FC	FF	FF			

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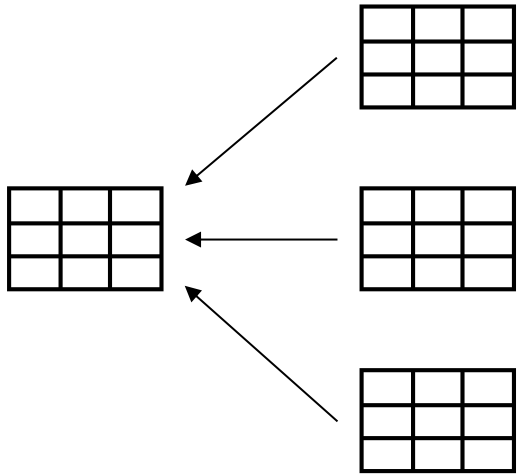
Exemplary Battery Usage Data: foxBMS® Battery Data

- Irrelevant CAN messages are filtered out.
- CAN messages are decoded and converted into JSON format.
- Decoded CAN messages are grouped together with respect to their CAN ID → Grouping creates multiple regular time series
- Synchronize measurement data

Decoded CAN Messages


```
{"Timestamp": 1212239.057110,"860_CurrenSensor_SIG_Current_mA":-2309}
{"Timestamp": 1212239.077085,"860_CurrenSensor_SIG_Current_mA":-2301}
{"Timestamp": 1212239.097439,"860_CurrenSensor_SIG_Current_mA":-2327}
{"Timestamp": 1212239.117353,"860_CurrenSensor_SIG_Current_mA":-2328}
{"Timestamp": 1212239.137263,"860_CurrenSensor_SIG_Current_mA":-2352}
{"Timestamp": 1212239.157239,"860_CurrenSensor_SIG_Current_mA":-2354}
```

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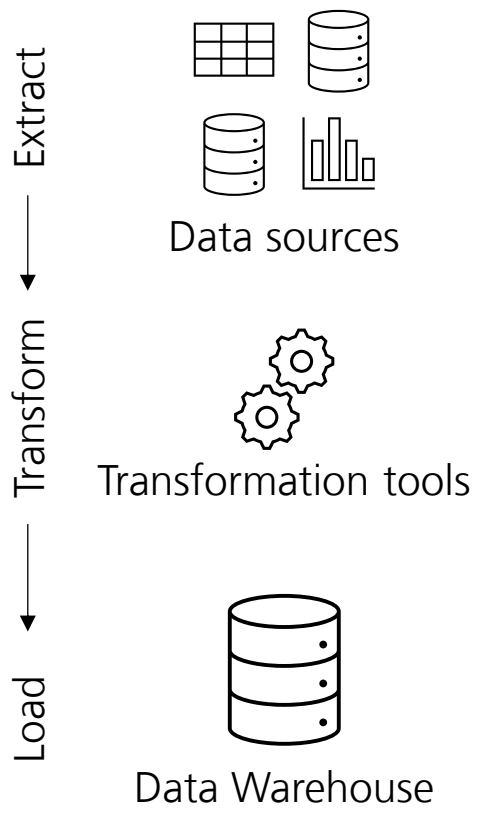
Battery Data: Extract, Transform, Load (ETL)

- ETL is a data engineering concept to automatically **preprocess data from varies sources** and **upload this data** (e.g., to a database or a big data framework for later analysis)
- ETL engine for battery data of different sources will be part of foxBMS 2
  - support data sources providing data from CAN logs, MQTT or structured file formats (e.g., csv, parquet)
  - upload data to various databases, file formats and big data frameworks will be supported



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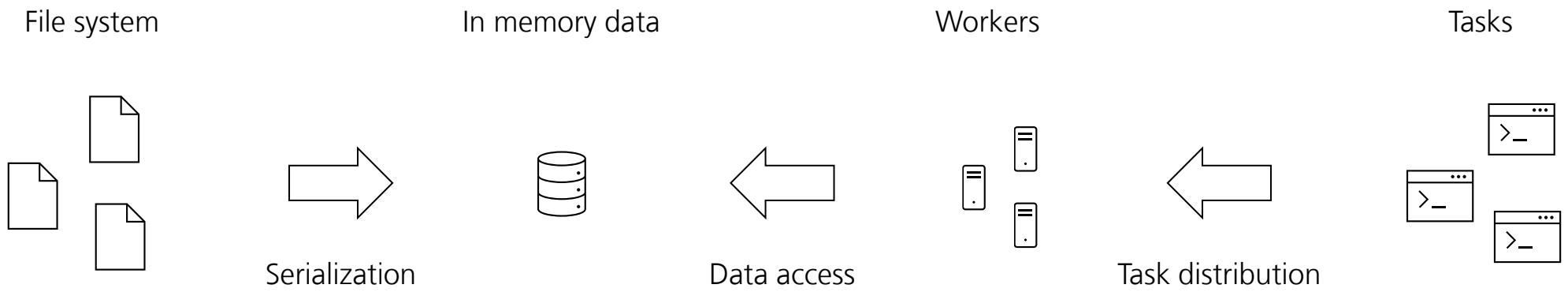
Battery Data: Infrastructure Requirements

- Efficiently store large amount of structured data
- In memory processing should be possible
- Interfaces to different programming, data and visualization frameworks needed



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Battery Data: Infrastructure Requirements

- Battery data analysis: most data queries effect many values of few columns and therefore a **column-oriented data structure** (data locality) is beneficial with respect to performance.
- Tools should
  - offer comprehensive support for **different programming languages**
  - provide support for different **databases and analysis tool** to enable the analysis of a **huge amount of data**

Apache® Hadoop®

- Open-source framework providing a cluster-based file system (HDFS) and a cluster-based batch processing engine (Map Reduce).
- Process and analyze structure, semi-structured and unstructured data
- HDFS inspired the concepts of modern data lakes, a storage for structure, semi-structured and unstructured data
- Map Reduce inspired Apache Spark which tries to accelerate any data processing by prioritizing in memory operations

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Apache® Arrow™

- Open-source language-agnostic software framework for developing data analytics applications that process columnar data
- Support for multiple
  - file formats (e.g., csv, parquet)
  - databases (e.g., InfluxDB®, DuckDB™) via Arrow Flight and,
  - big data frameworks (e.g., Apache® Spark™)

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Apache® Spark™

- Open-source multi-language engine for executing data engineering, data science, and machine learning on single-node machines or clusters.
- Reads files from the underlying HDFS and creates an in-memory data structure
- A master node distributes tasks between the worker nodes

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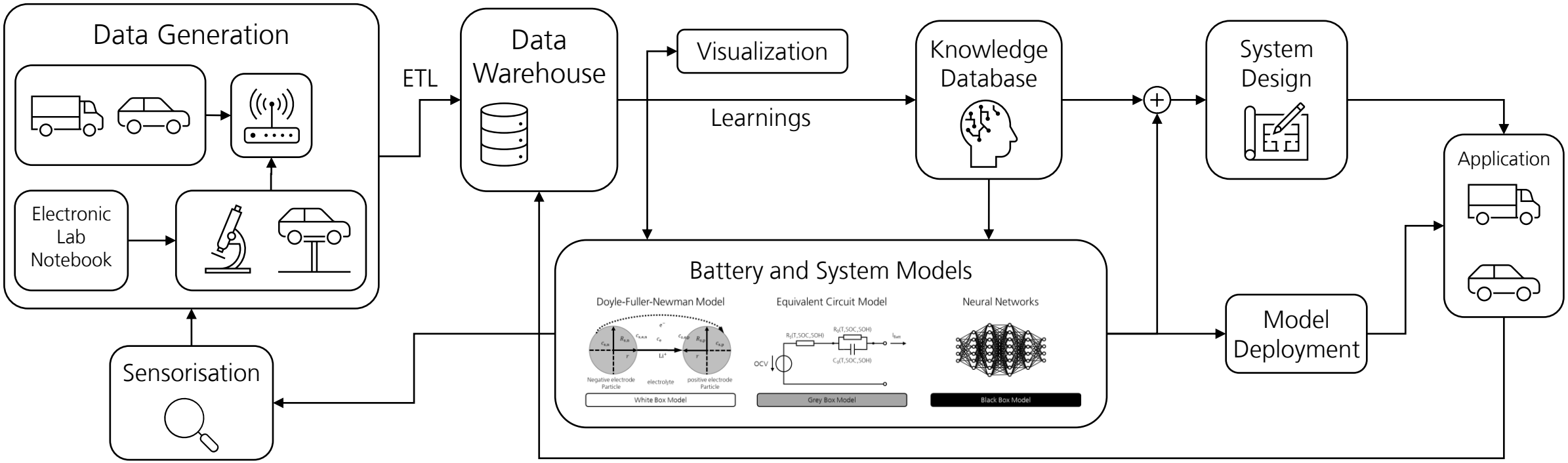
Data and Insights: What do we know now and where to go?



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Thank you for your Attention