Engineering Institute of Technology.

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Phase 2: Research Practice (Designing and Executing Research)

DEng Program: Designing Rigorous Engineering Research - Methods, Models, and Validation

2 April 2026

Presented by Emeritus Professor Akhtar Kalam

EIT EMERITUS PROFESSOR

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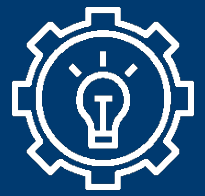

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EIT is one of the only institutes in the world specializing in Engineering. We deliver professional certificates, diplomas, advanced diplomas, undergraduate and graduate certificates, bachelor's and master's degrees, and a Doctorate of Engineering.

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Introduction – Presenter

Professor Akhtar Kalam

Emeritus Professor at Victoria University and EIT.
Academic Director and Chair of the Academic Board - Texila College Australia.
Director of Al-Kalam Educational Solutions.
Editor-in-Chief of AJEEE
Distinguished Professor/Adjunct Faculty in Australia, India, Malaysia and Oman.
He has published over 610 publications in his area of expertise and has written over 29 books.
Supervised 50 postgraduate research students to graduation, including 39 Ph.Ds.' and 11 MEngs. Currently, 15 postgraduate research students (Eight Ph.D., one MEng student at VU, and six DEng students at EIT) are being supervised.
Public, University, and Motivational Lecturer.
Consultant for the electricity supply industries in Australia and overseas.
Assisted in change management plans for Universities and the higher education sector.

Education

The University of Bath, Bath, UK, D.Eng., Electrical Engineering
The University of Oklahoma, Norman, USA, MS, Electrical Engineering
Aligarh Muslim University, Aligarh, India, BSc. Eng., Electrical Engineering
St Xavier's College, Calcutta, India, Applied Science

Professional Society Activities

Australian Institute of Energy – Fellow
Engineers Australia – Fellow
The Institution of Engineers and Technology, UK – FellowThe Institution of Electrical and Electronic Engineers, USA –Life Senior Member.

"My vision is to provide exciting higher education science and engineering courses, research, consultancy and collaborate in development work of the industry and communities within Australia and beyond."

Agenda

1	Research design in engineering
2	Methodology frameworks
3	Modelling and experimentation
4	Validation strategies
5	Case studies
6	Final Thoughts
7	Q & A

Research design in engineering

Objectives of Doctoral Engineering Research

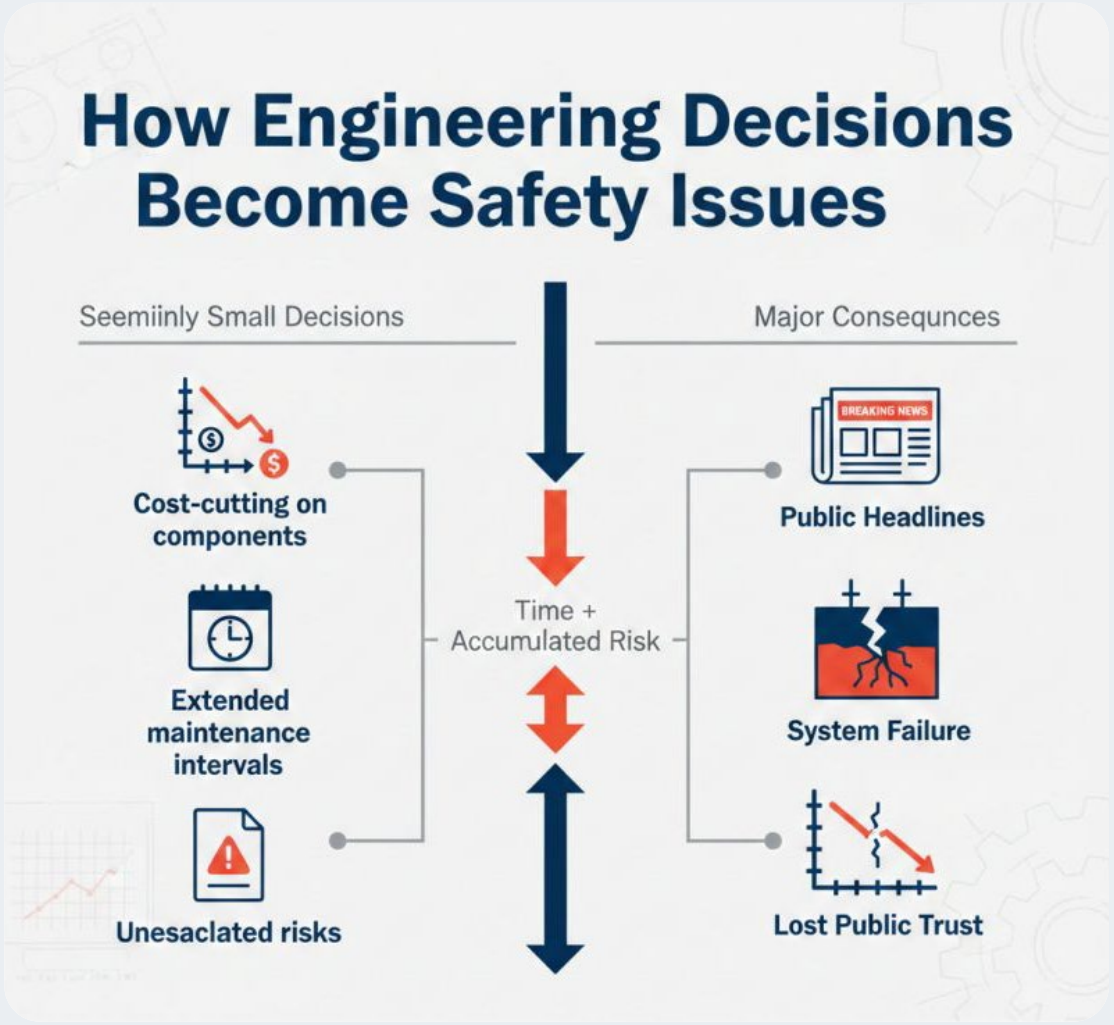
- Move beyond problem-solving to knowledge generation.
- Develop new methods, theories, or models,

  rather than just applying existing ones.

- Ensure research is both rigorous (methodologically sound) and relevant (practical/industrial impact).

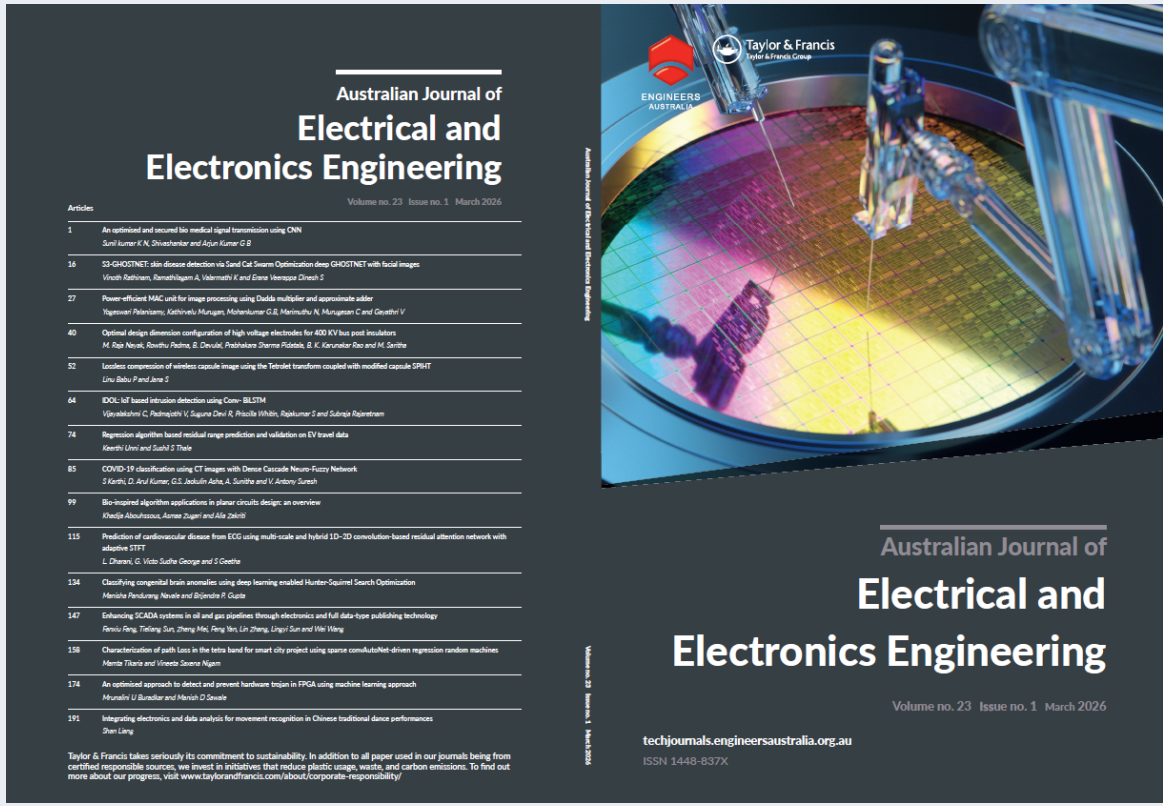
Why Rigorous Research Matters?

- Engineering decisions affect safety and infrastructure
- Results must be reliable and reproducible
- Doctoral research must produce new knowledge

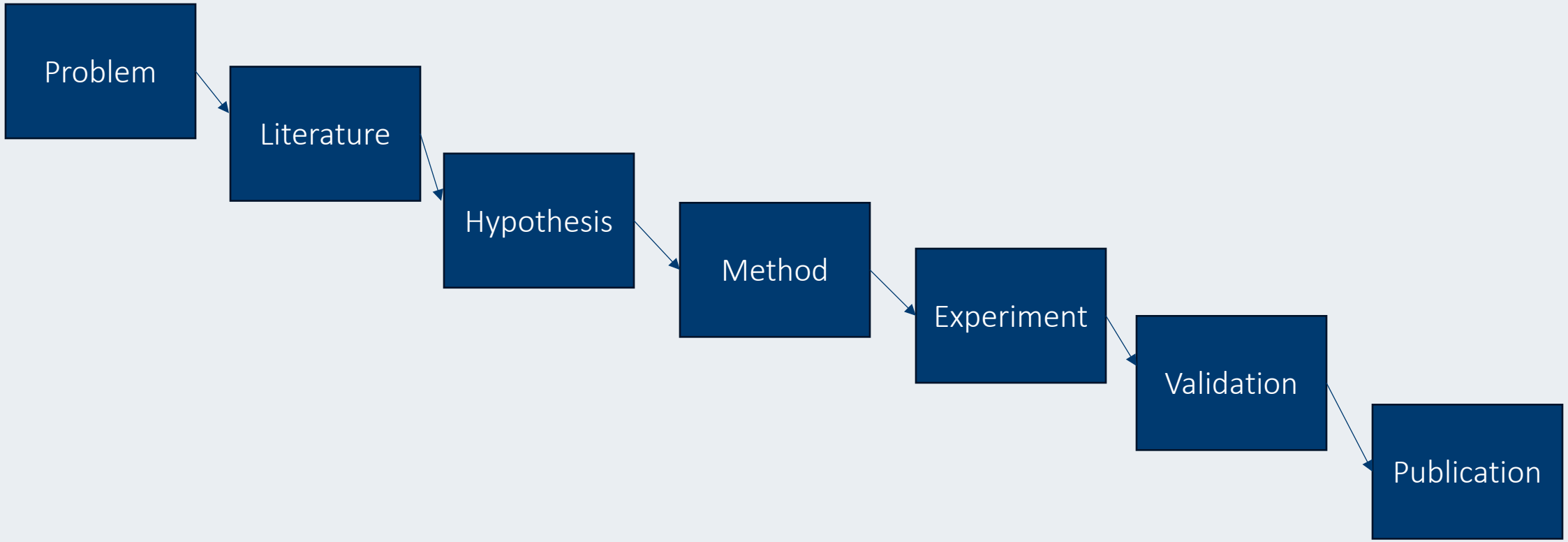


Doctoral Research Expectations

- Original contribution
- International-level publications
- Strong theoretical and experimental foundation

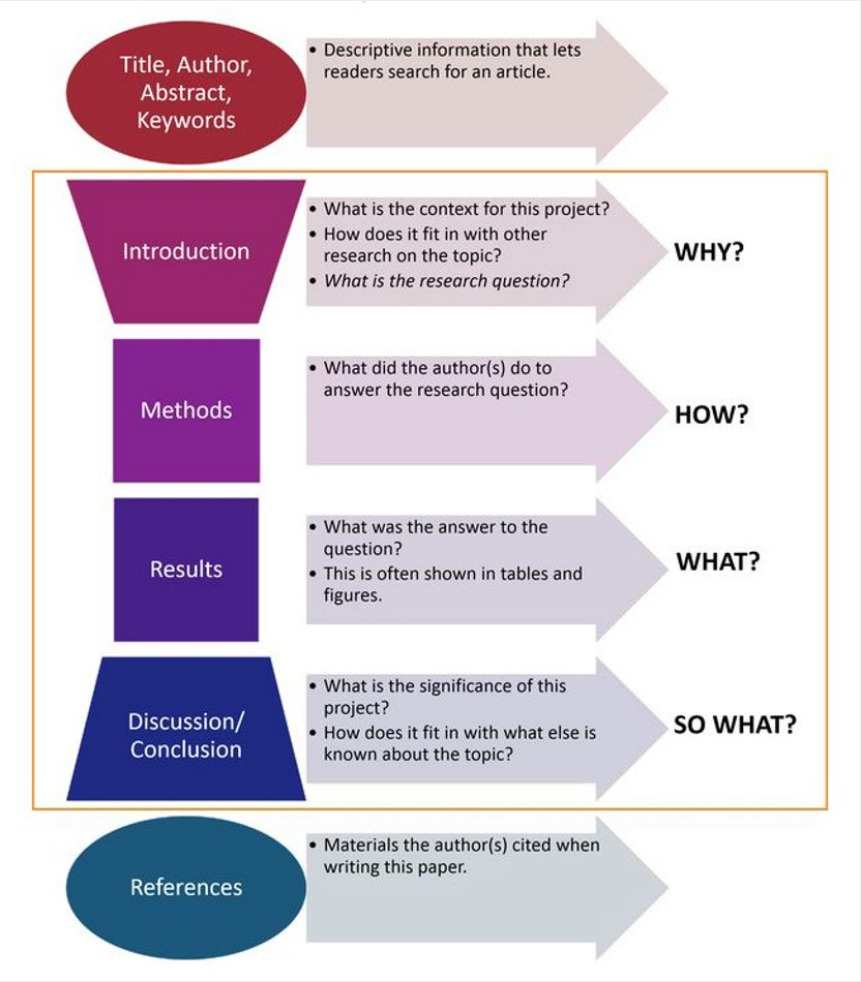


Engineering Research Lifecycle



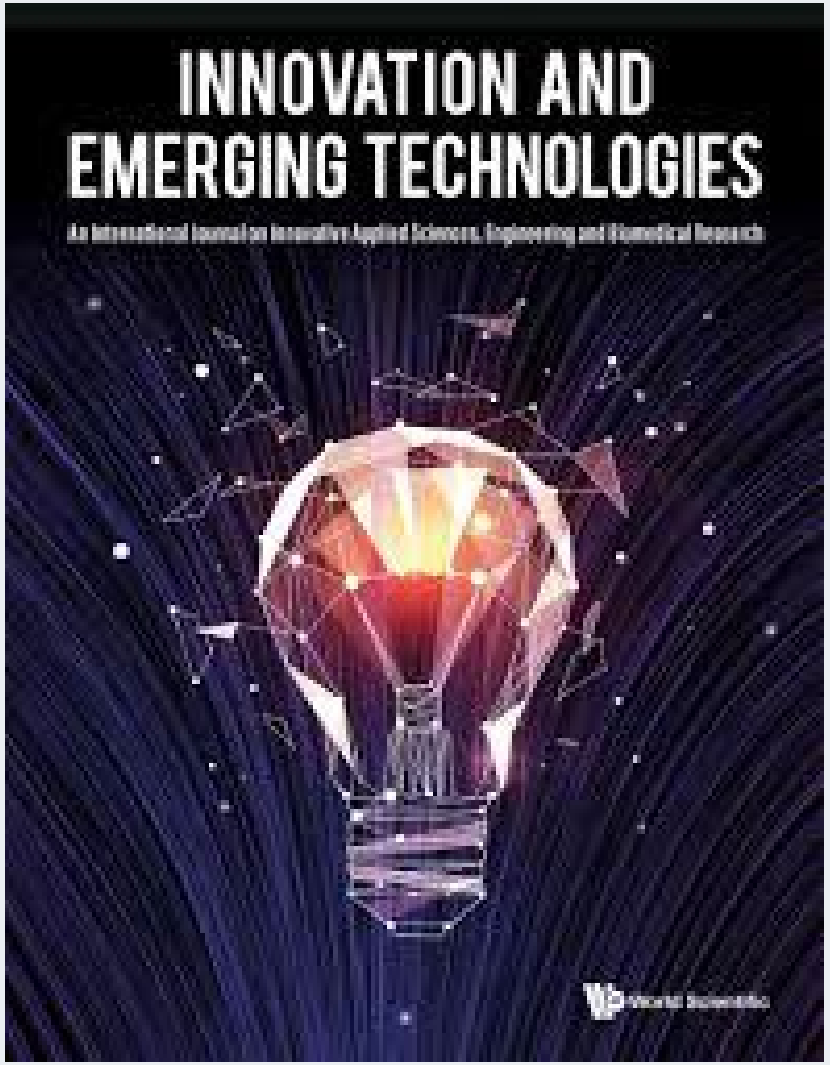
Anatomy of Rigorous Research Design

- **Research Questions (RQs):** Must be focused, narrow,
- and answerable.
- **Literature Review:** Connects methodology to state-of-the-art;
- prevents "reinventing the wheel".
- **Methodology Selection:** Choosing experimental, analytical,
- or simulation approaches.
- **Justification:** Every method choice must be justified based on the RQs.



Identifying Research Problems

- Industry challenges
- Emerging technologies
- Literature gaps
- Policy priorities

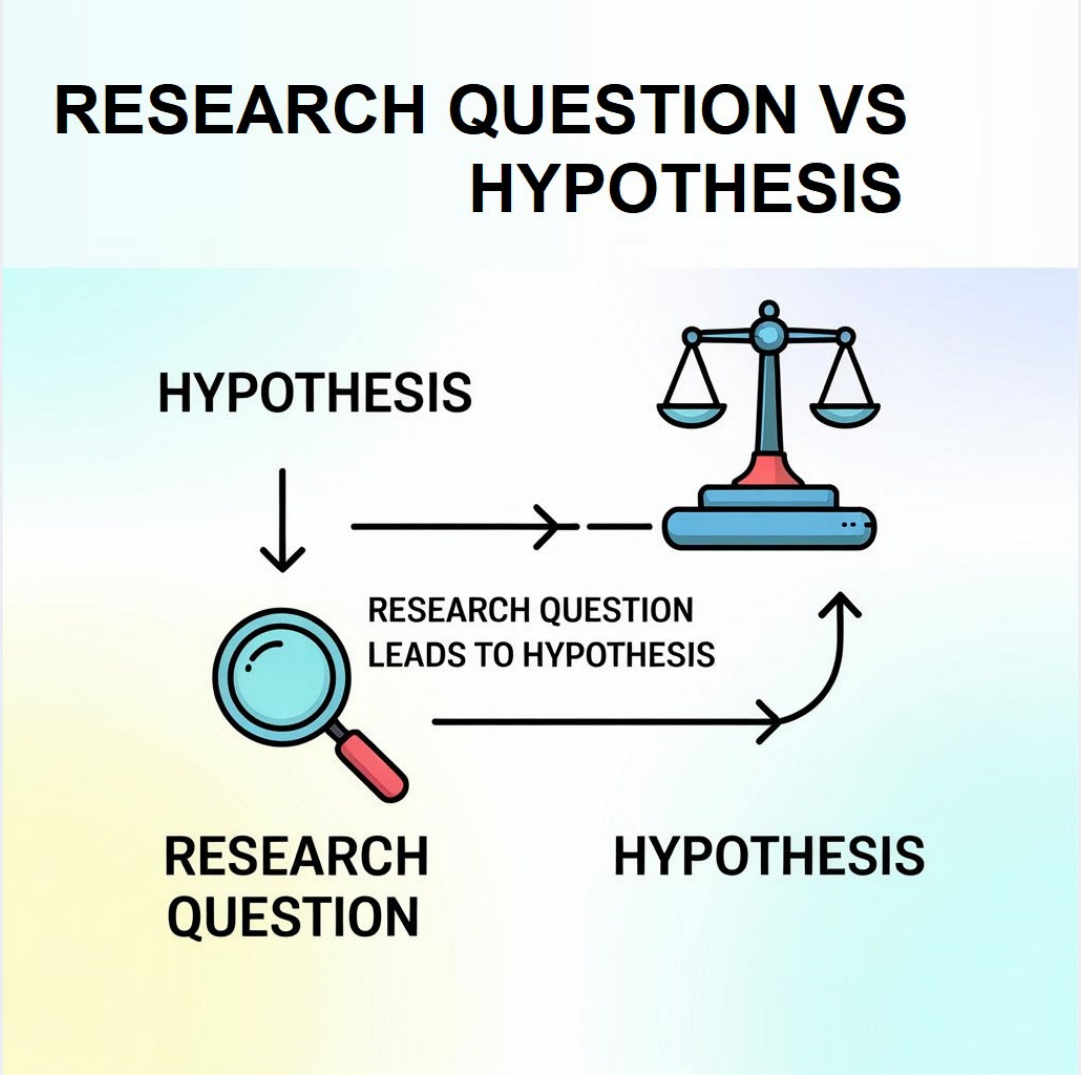


Literature Review Strategy

- Systematic search
- Thematic mapping
- Gap identification

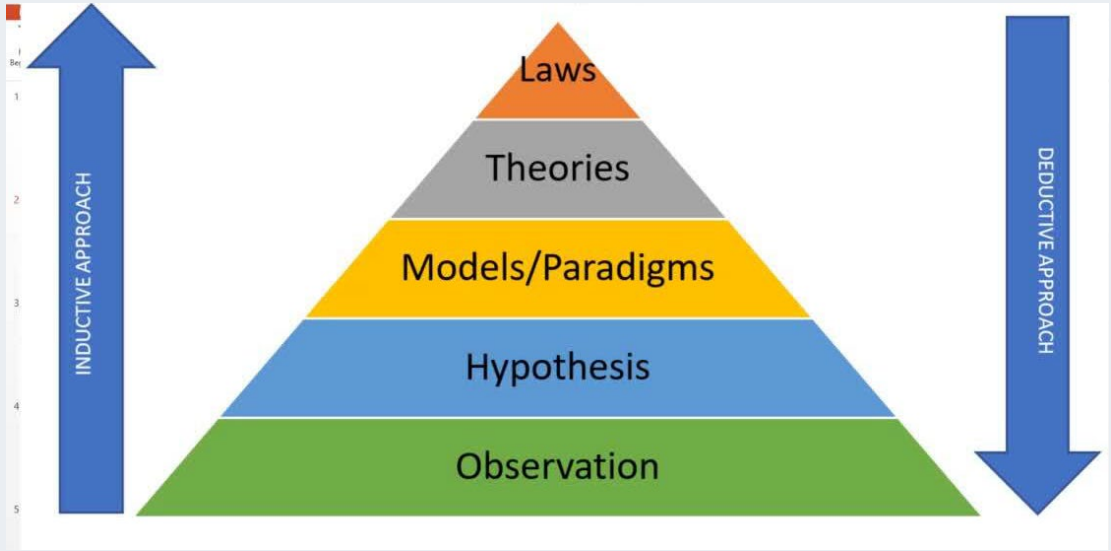
Research Questions and Hypotheses

- Clear
- Measurable
- Testable



Key Research Approaches in Engineering

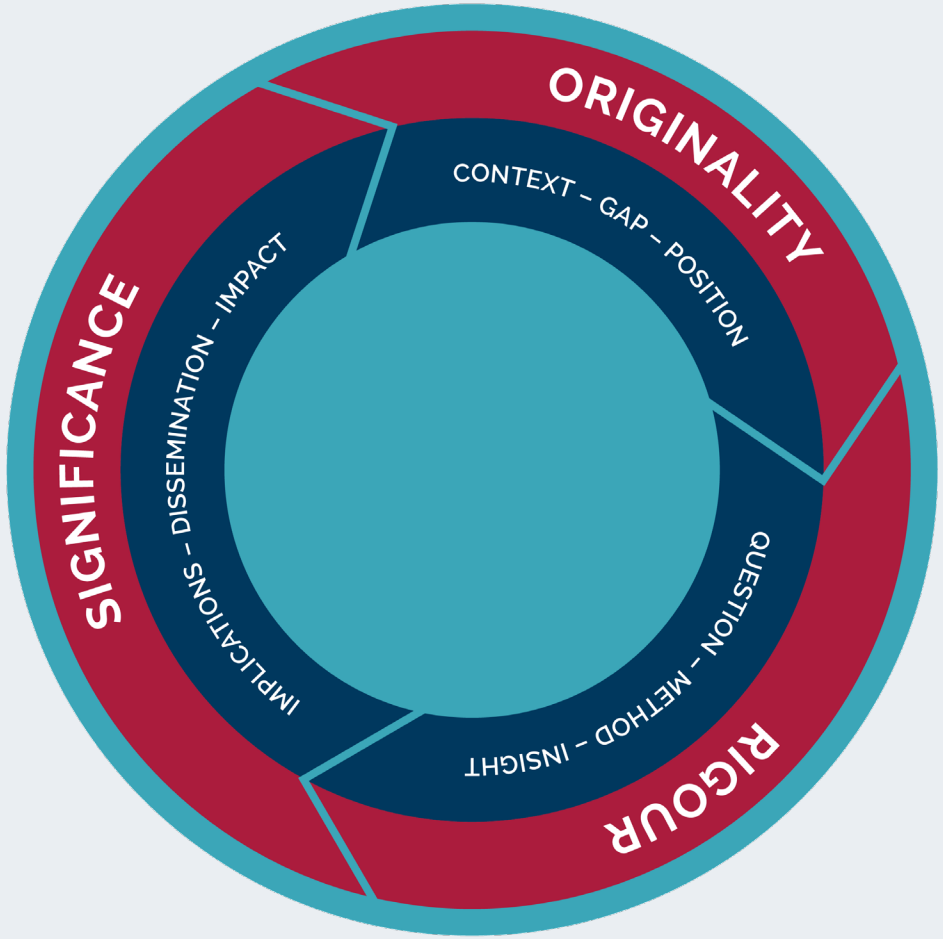
- **Empirical/Experimental:** Laboratory testing, prototypes, case studies.
- **Theoretical/Analytical:** Mathematical proofs, algorithm development.
- **Computational/Simulation:** Numerical modelling, FEA/CFD, software implementation.
- **Design Science Research:** Creating new artifacts (methods, models, tools).



Methodology frameworks

Research Methodology Framework

- Conceptual model
- Experimental design
- Data analysis
- Validation



Quantitative Engineering Research

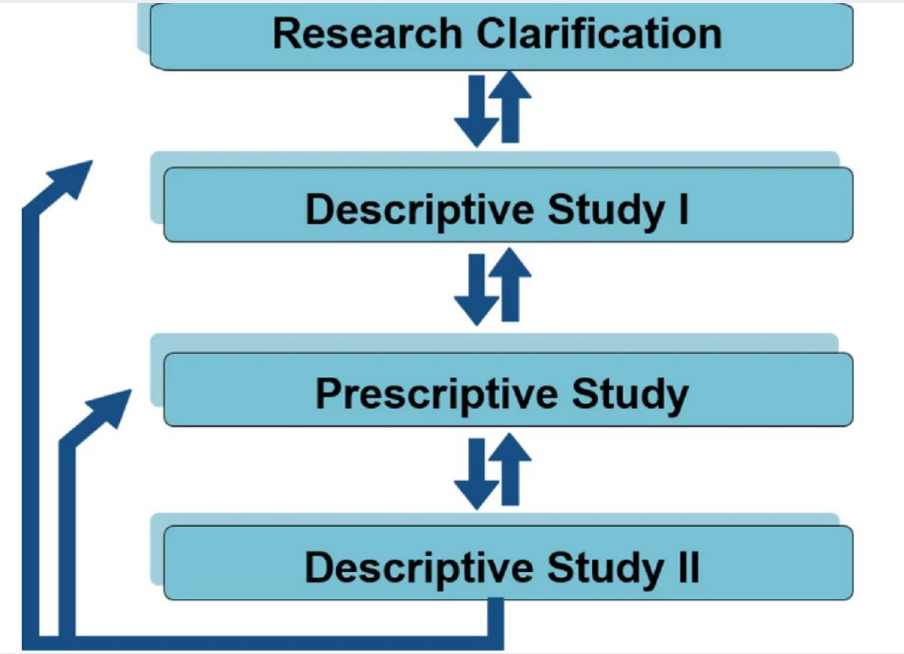
- Mathematical modelling
- Simulation
- Statistical testing

Qualitative Components

- Expert interviews
- Case studies
- Technology adoption research

The Design Research Methodology (DRM)

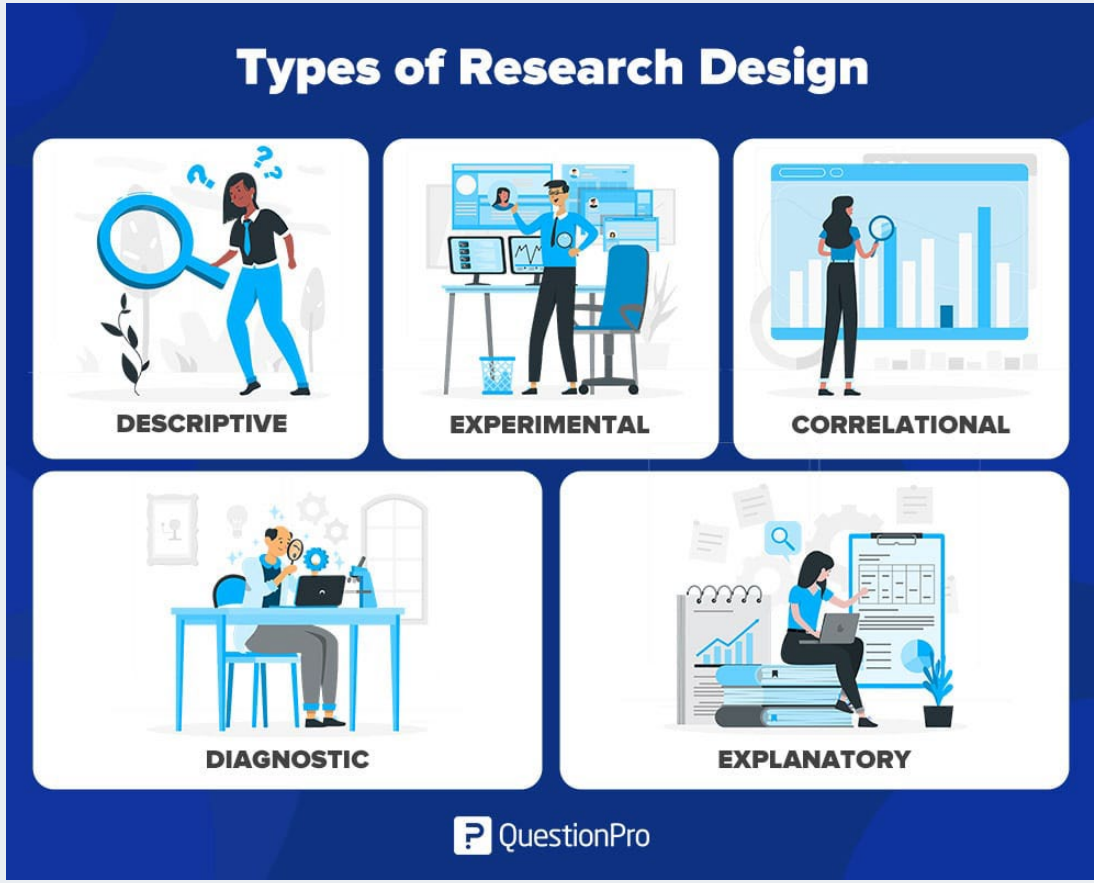
- **Research Clarification:** Define goals and requirements.
- **Descriptive Study I:** Evaluate existing literature and current state.
- **Prescriptive Study:** Develop the new method/model.
- **Descriptive Study II:** Validate the developed method/model.



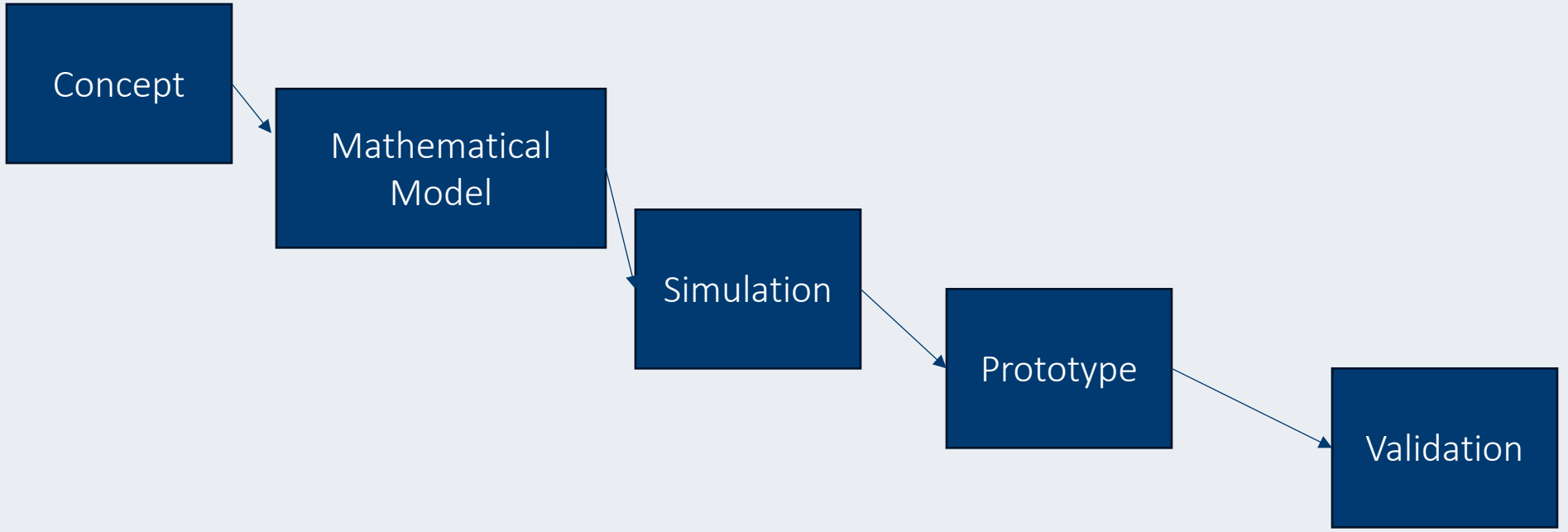
Modelling and experimentation

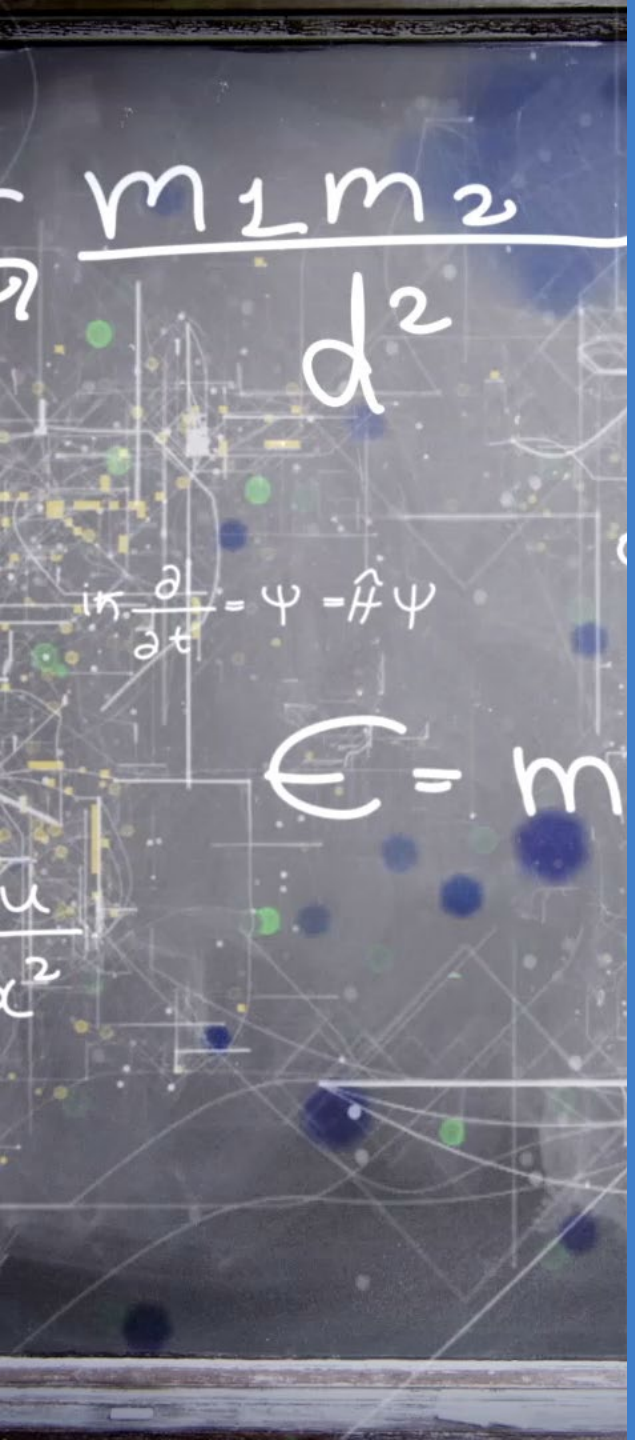
Designing Research Models

- **Types of Models:** Mathematical, computational, physical, or conceptual.
- **Model Building:** Abstraction of real-world phenomena into workable frameworks.
- **Iterative Process:** Re-evaluation of models based on the initial findings and feedback (Relevance Cycle).
- **Model Complexity:** Balancing high fidelity with computational cost.



Engineering Modelling Workflow





Mathematical Modelling

- Define variables
- Establish equations
- Boundary conditions

Computational Simulation

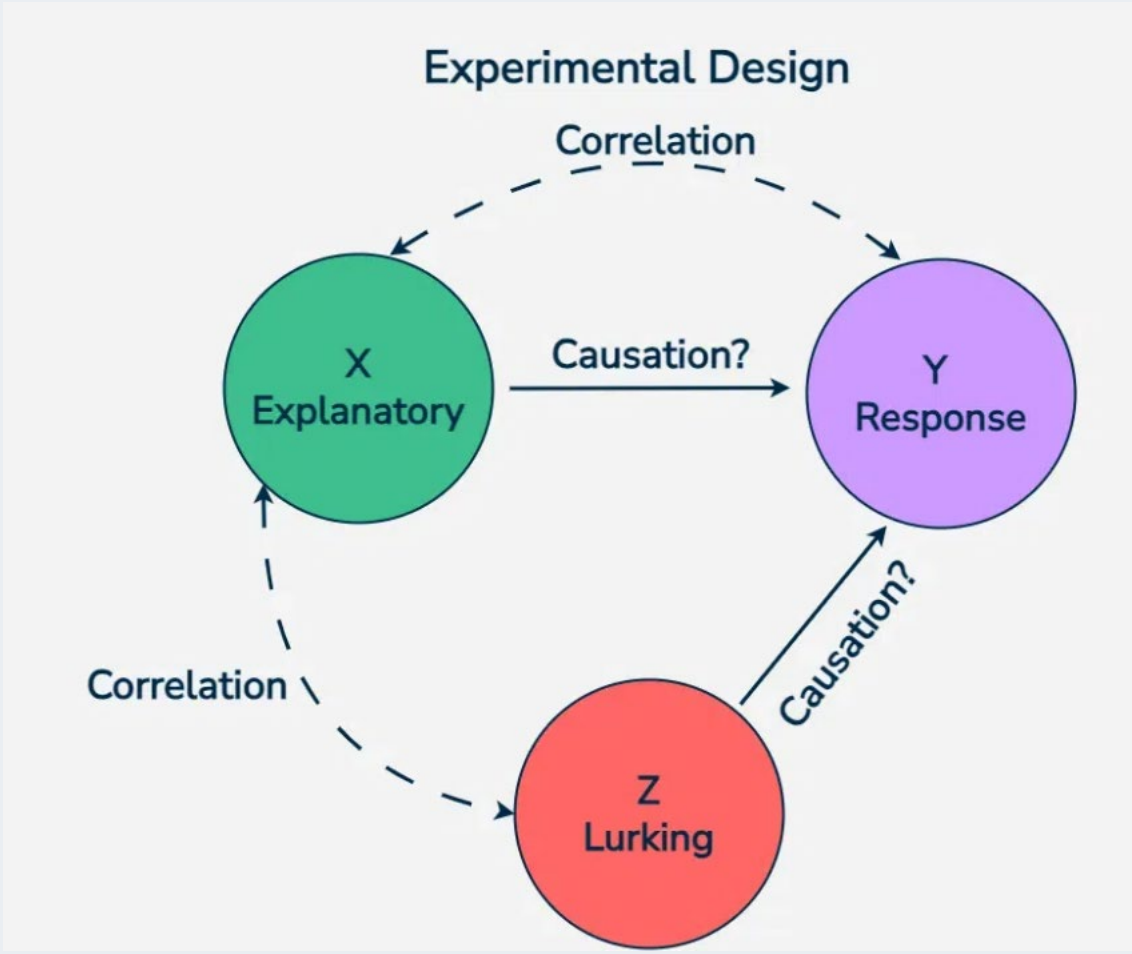
- MATLAB
- Python
- Finite Element Analysis

Digital Twin Concept

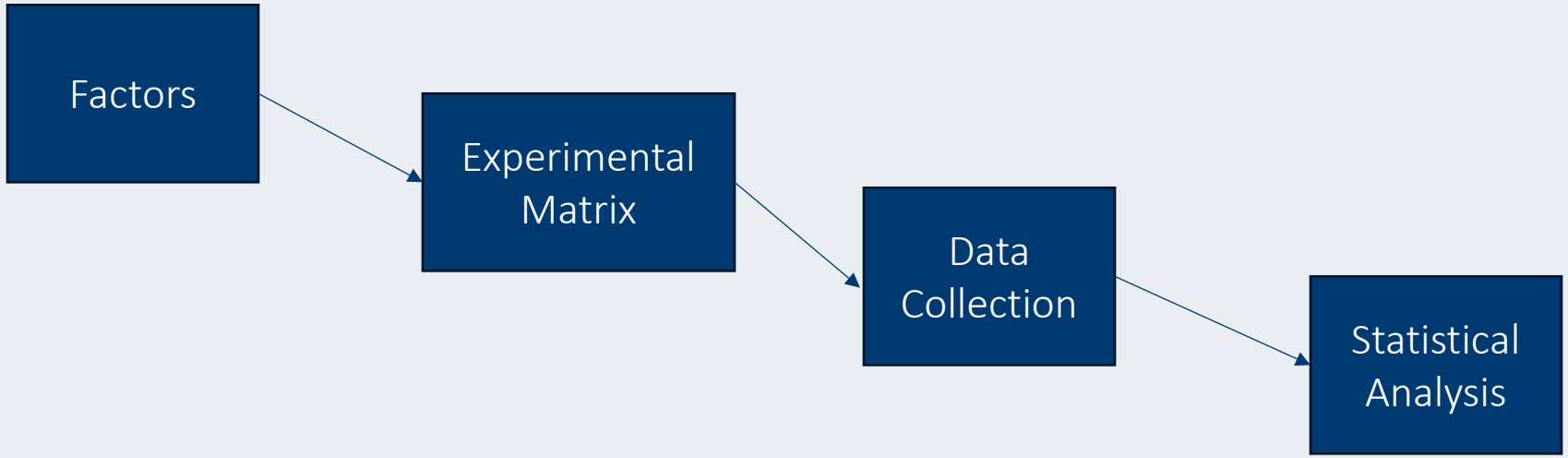
Virtual representation of real engineering systems

Experimental Research Design

- Controlled variables
- Measurement accuracy
- Replication

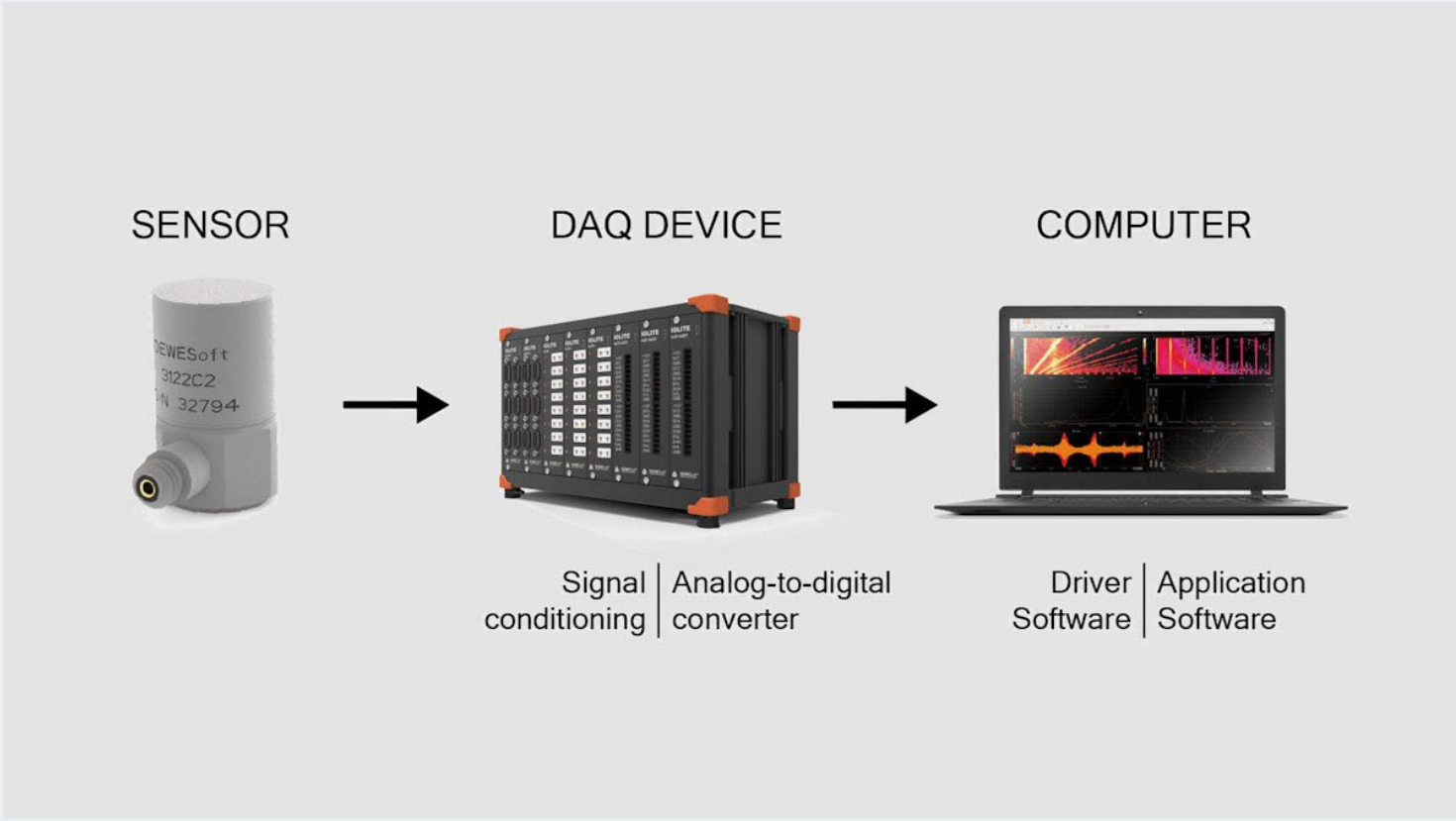


Design of Experiments Chart



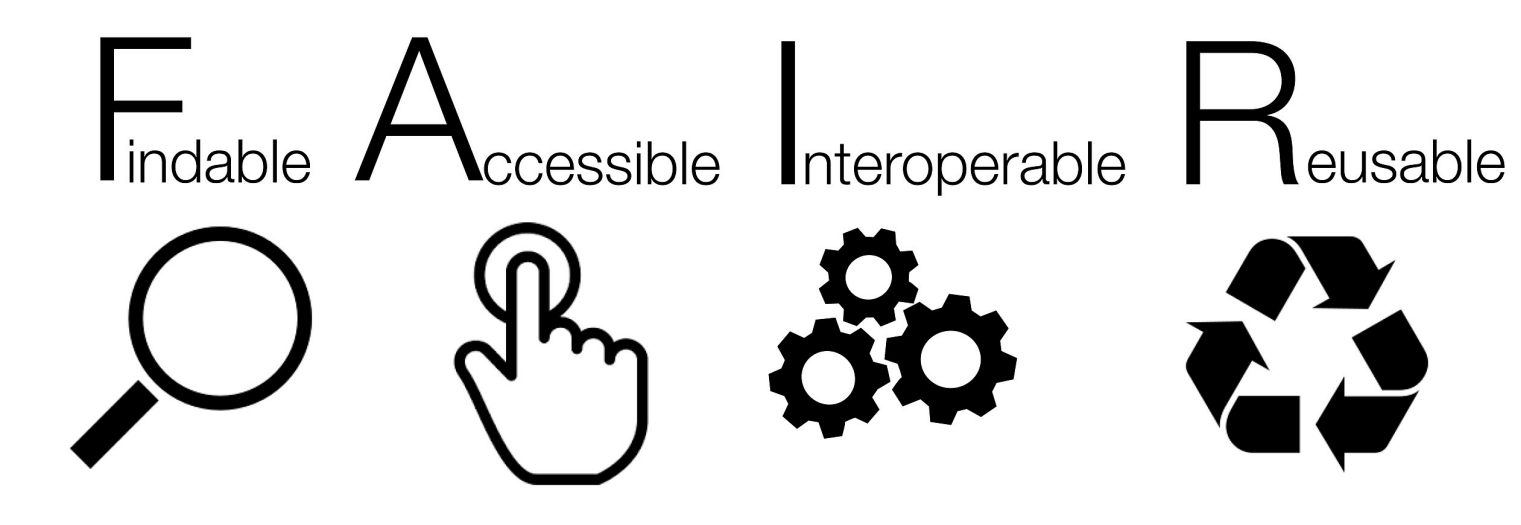
Data Acquisition Systems

- Sensors
- Data loggers
- IoT devices



Research Data Management

- Storage
- Documentation
- Reproducibility

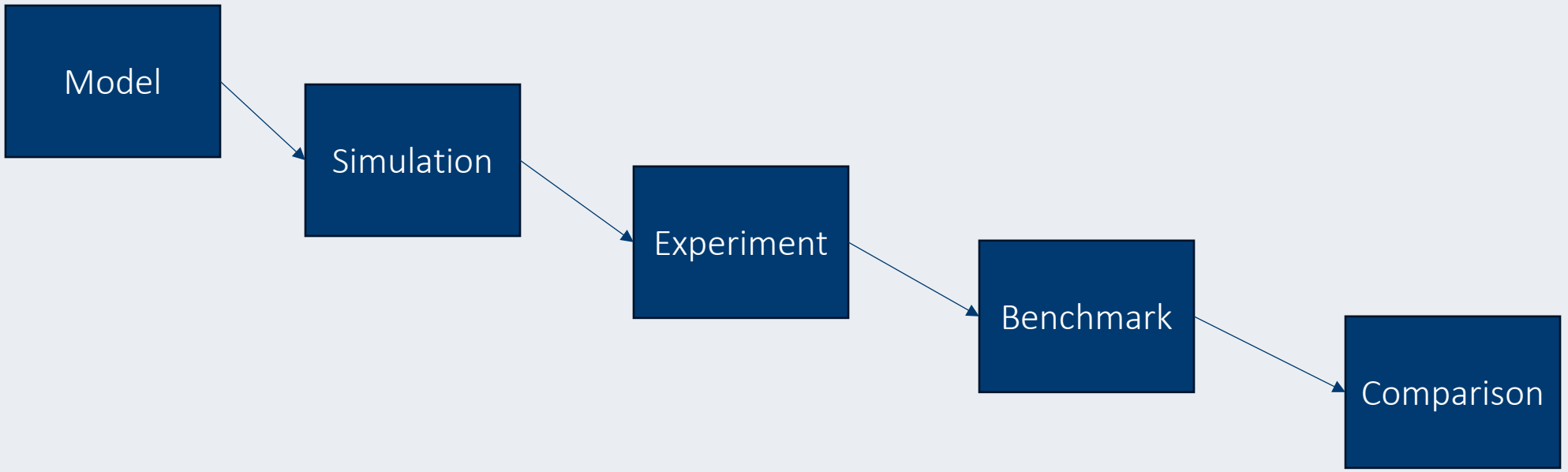


Methods for Rigour - Ensuring Quality

- **Data Collection & Analysis:** Quantitative data analysis, statistical methods.
- **Consistency:** Ensuring methods are consistent with the research paradigm.
- **Documentation:** Detailed descriptions for replicability (essential for DEng level).
- **Ethical Standards:** Avoiding fabrication, falsification, and plagiarism.

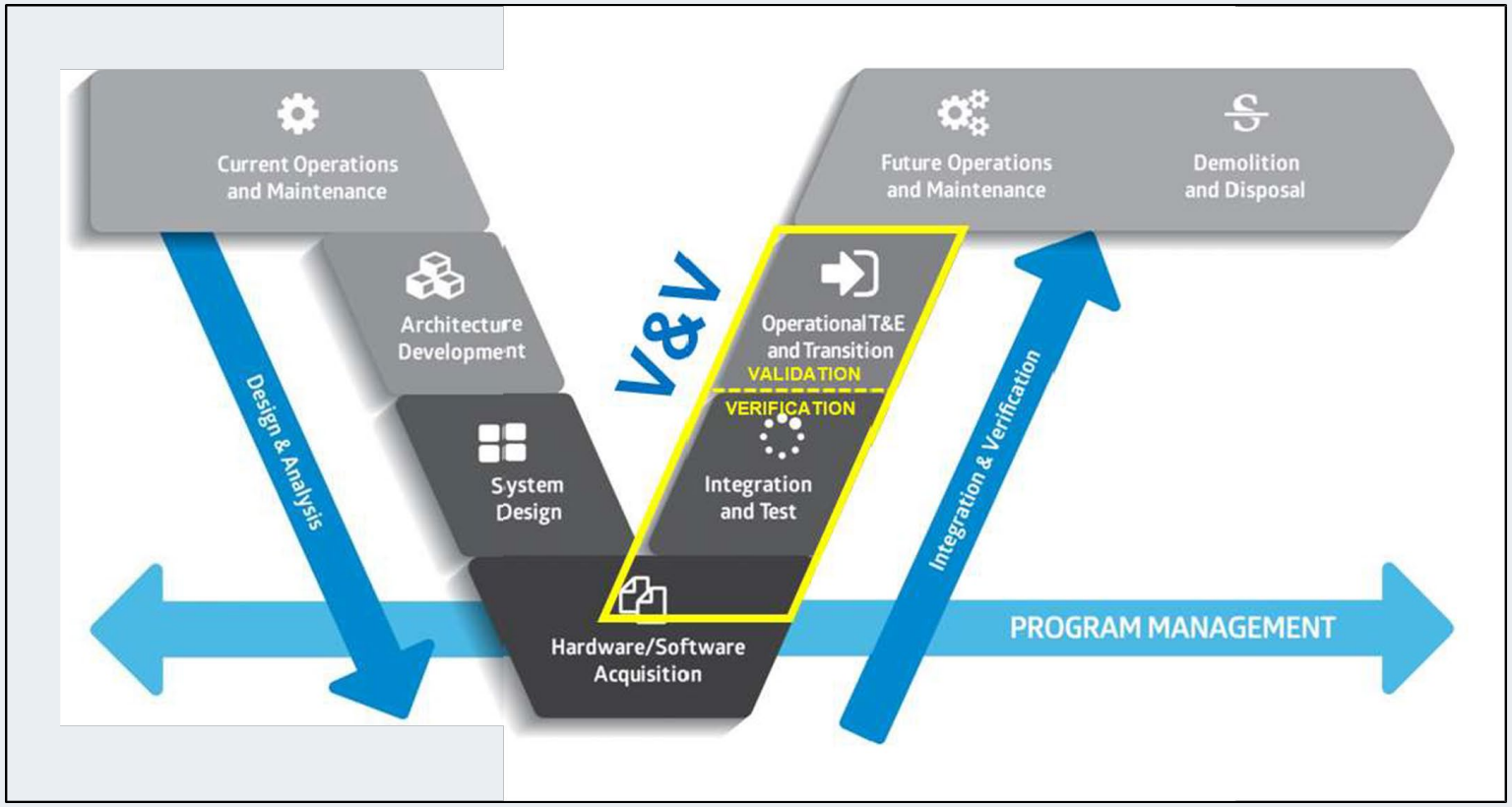
Validation strategies

Engineering Validation Framework



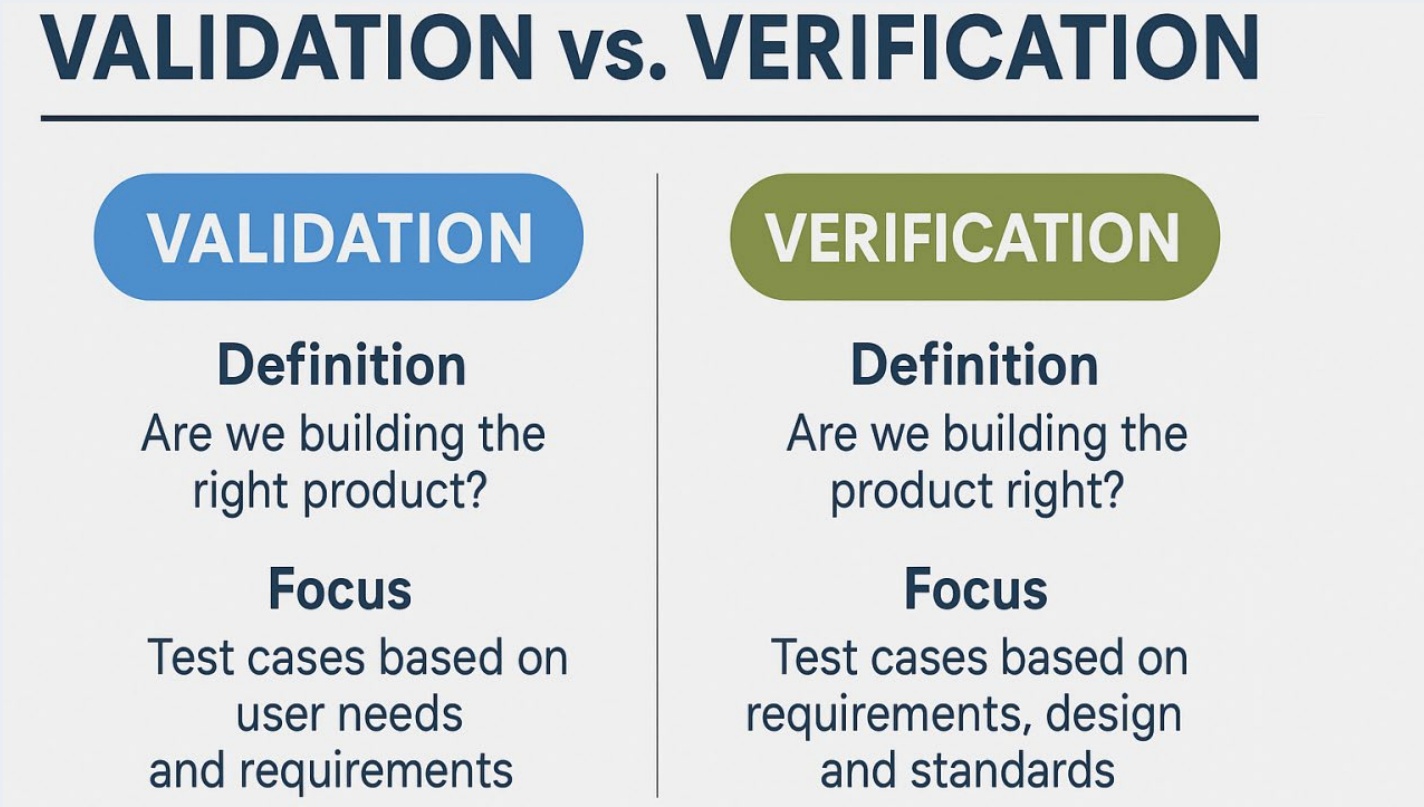
Validation and Verification Strategies

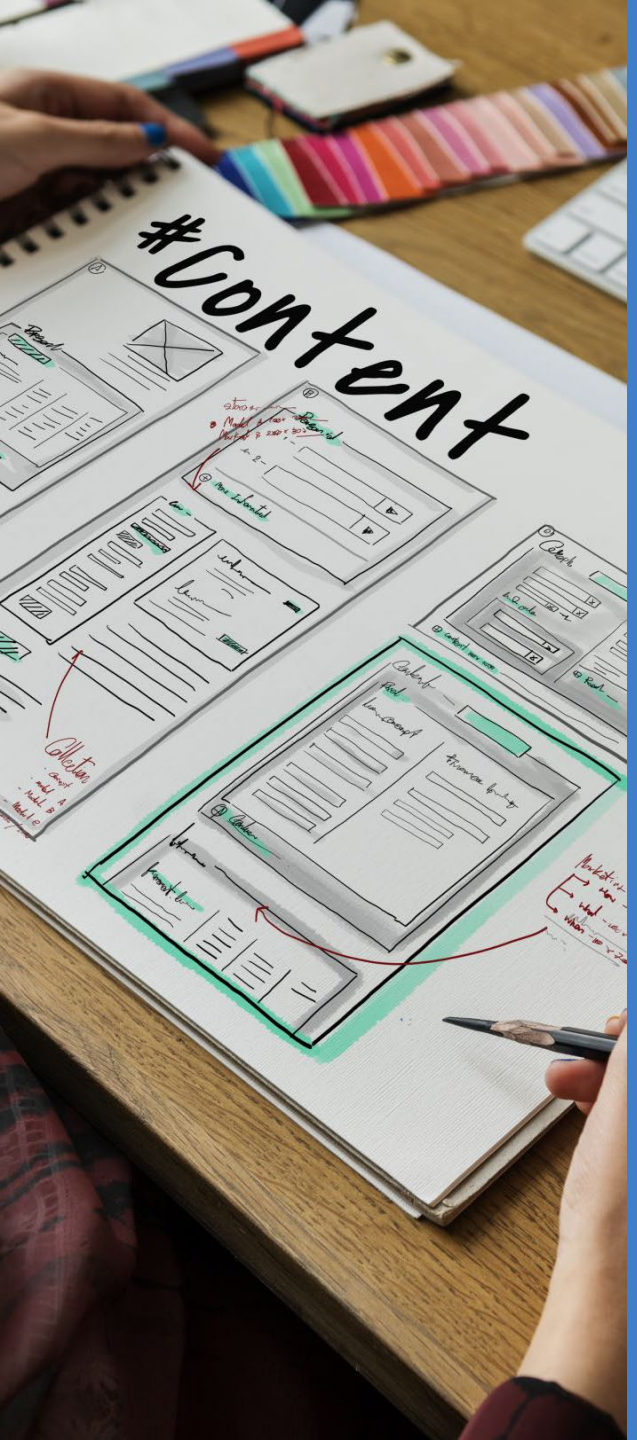
- **Verification:** "Did I build the model right?" (Mathematical/Code accuracy).
- **Validation:** "Did I build the right model?" (Comparison with physical reality/data).
- **Methods of Validation:**
  - Experimental comparison
  - Expert review/opinion
  - Analytical benchmarking
  - Operational testing



Verification vs Validation

- Verification: built correctly
- Regression Validation: represents reality



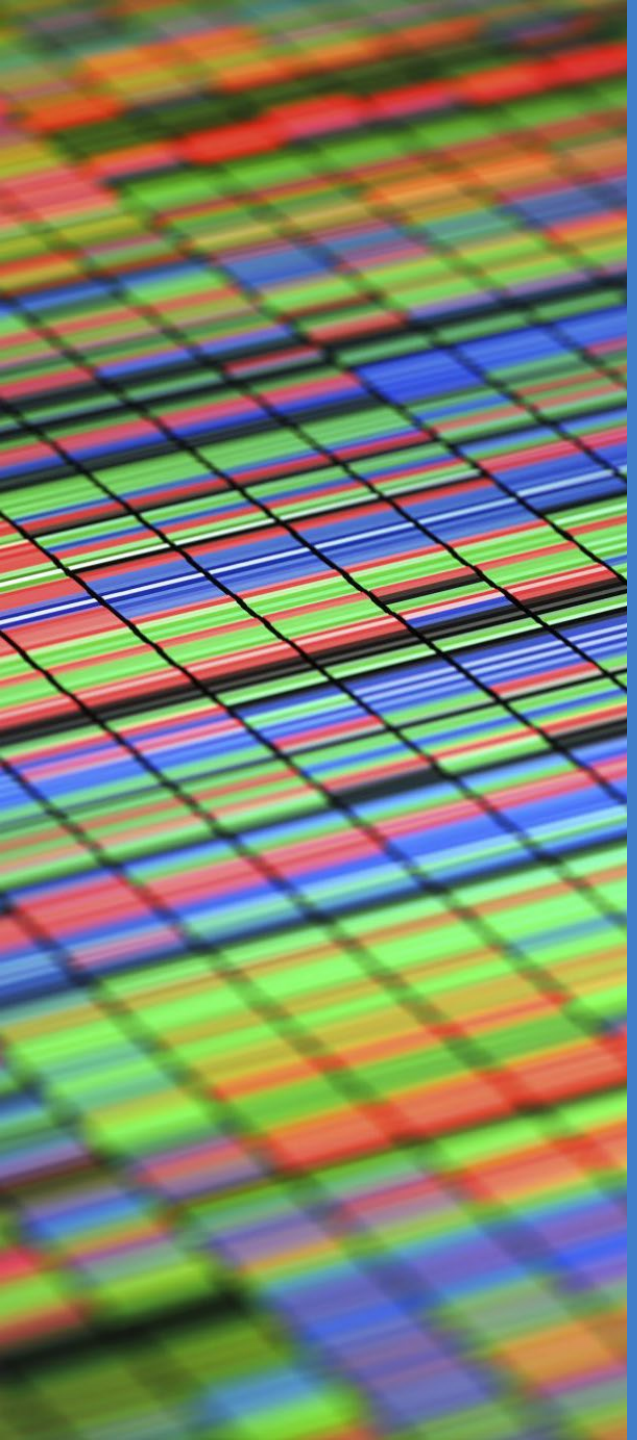


Statistical Analysis

- Regression
- Hypothesis testing
- Confidence intervals

Uncertainty Analysis

- Measurement error
- Sensitivity analysis



Risk in Research Projects

- Technical risk
- Data risk
- Timeline risk

DEng Thesis Structure

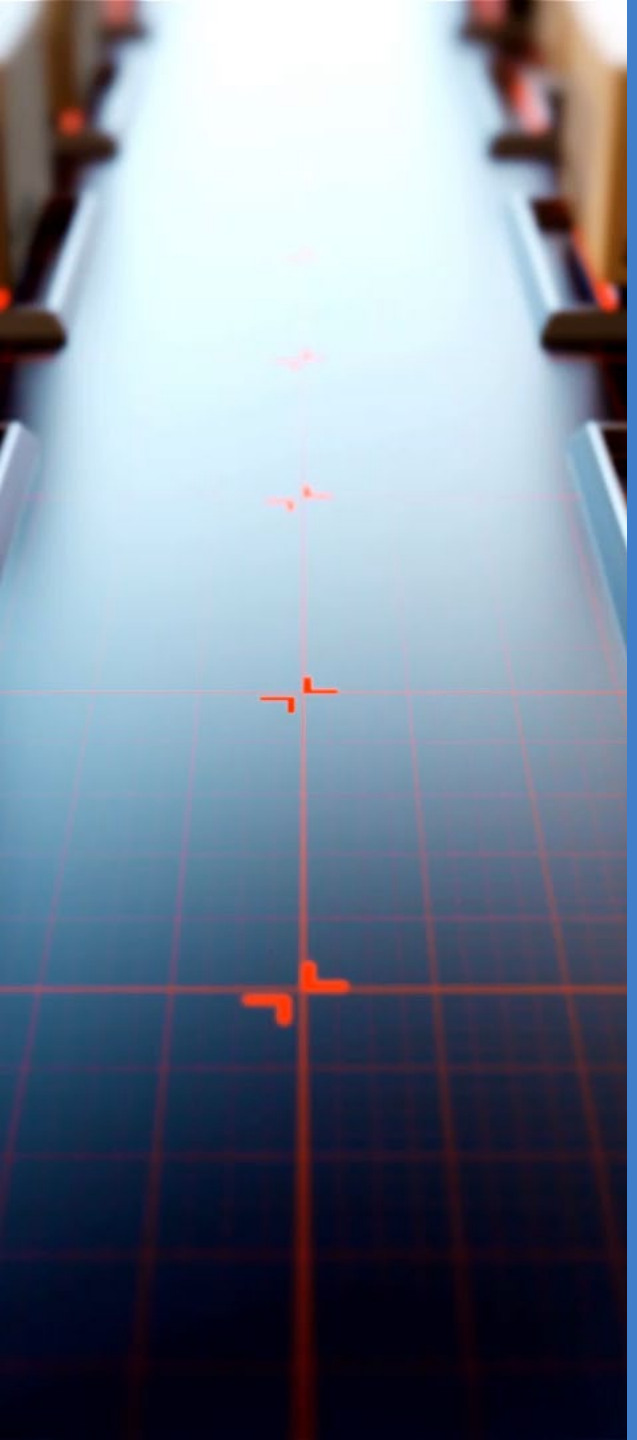
- Introduction
- Literature Review
- Methodology
- Results
- Discussion
- Conclusions

Publication Strategy

- Conferences
- Journals
- Collaborative research

Research Ethics

- Integrity
- Data honesty
- Safety



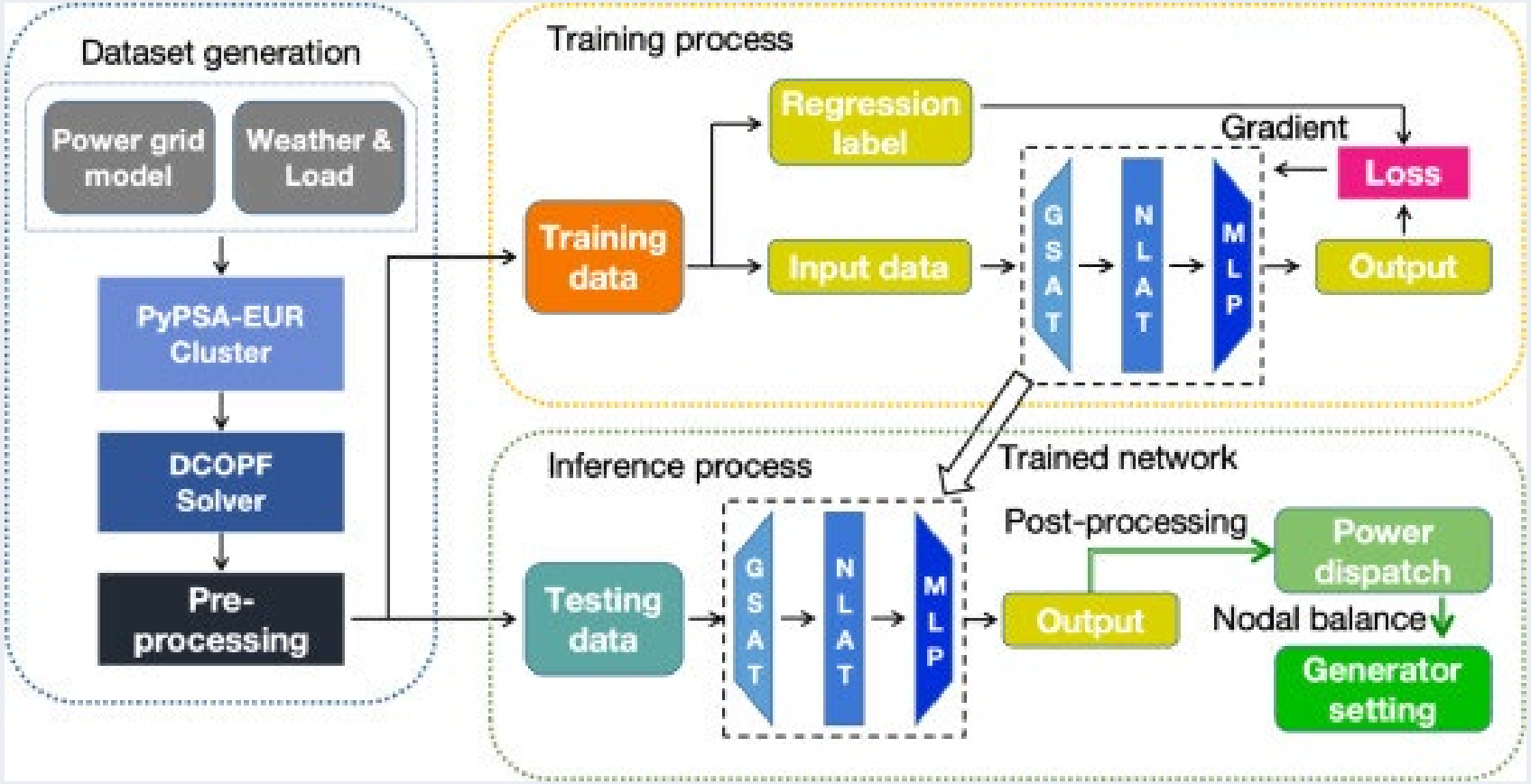
AI in Engineering Research

- Machine learning models
- Predictive analytics
- Intelligent systems

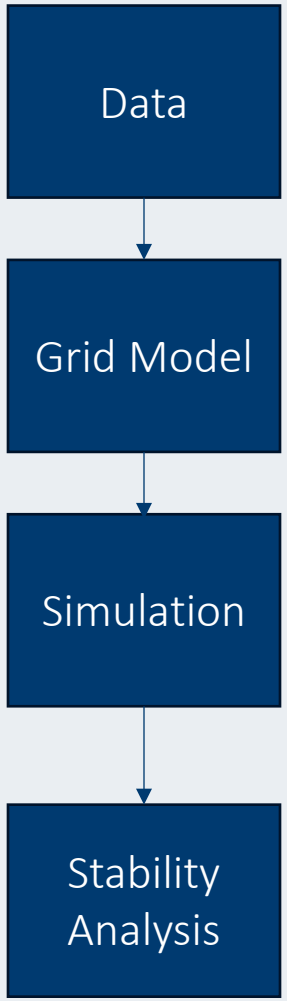
Case studies

Case Study: Power Systems

Optimal power flow and renewable integration research

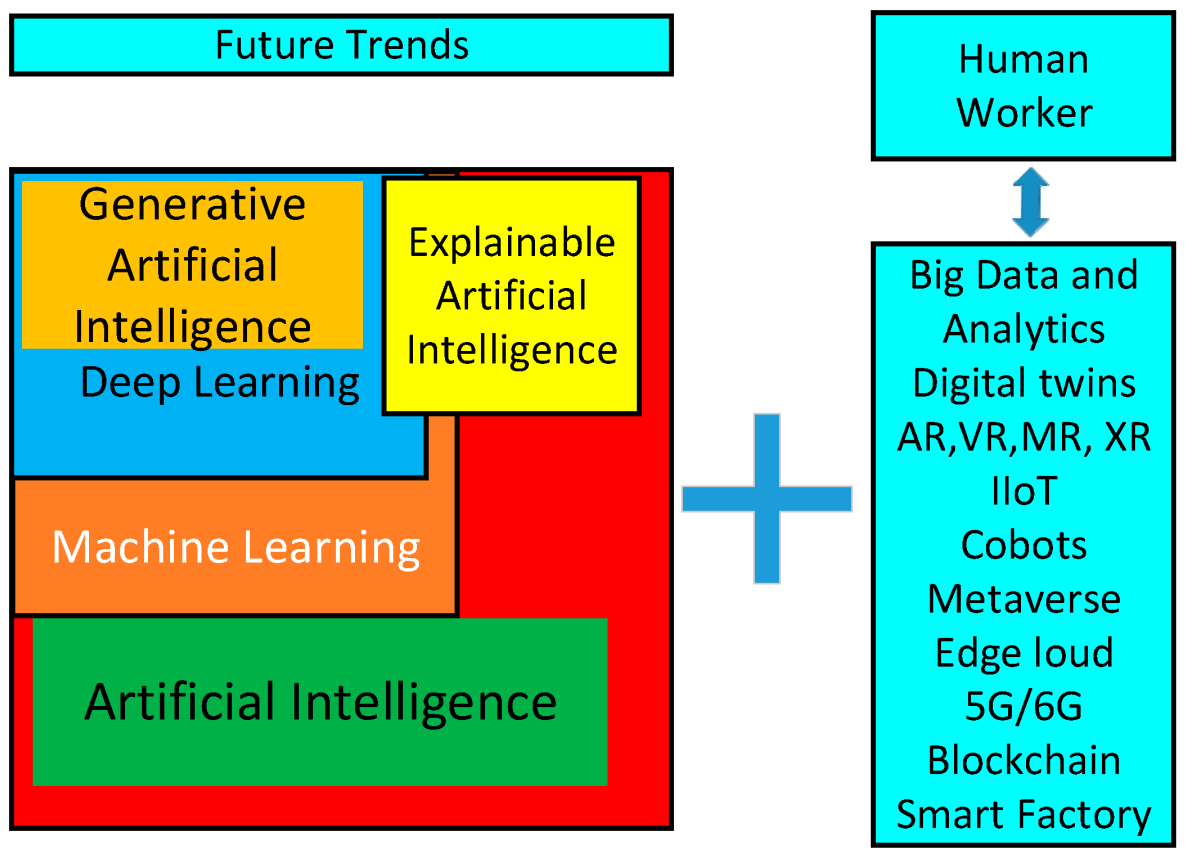


Power System Research Workflow

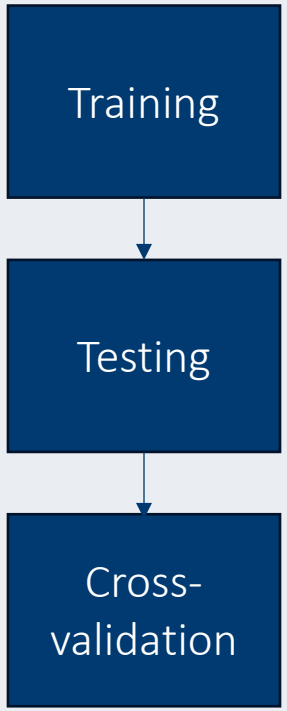


Case Study: AI Engineering

Deep learning for predictive maintenance

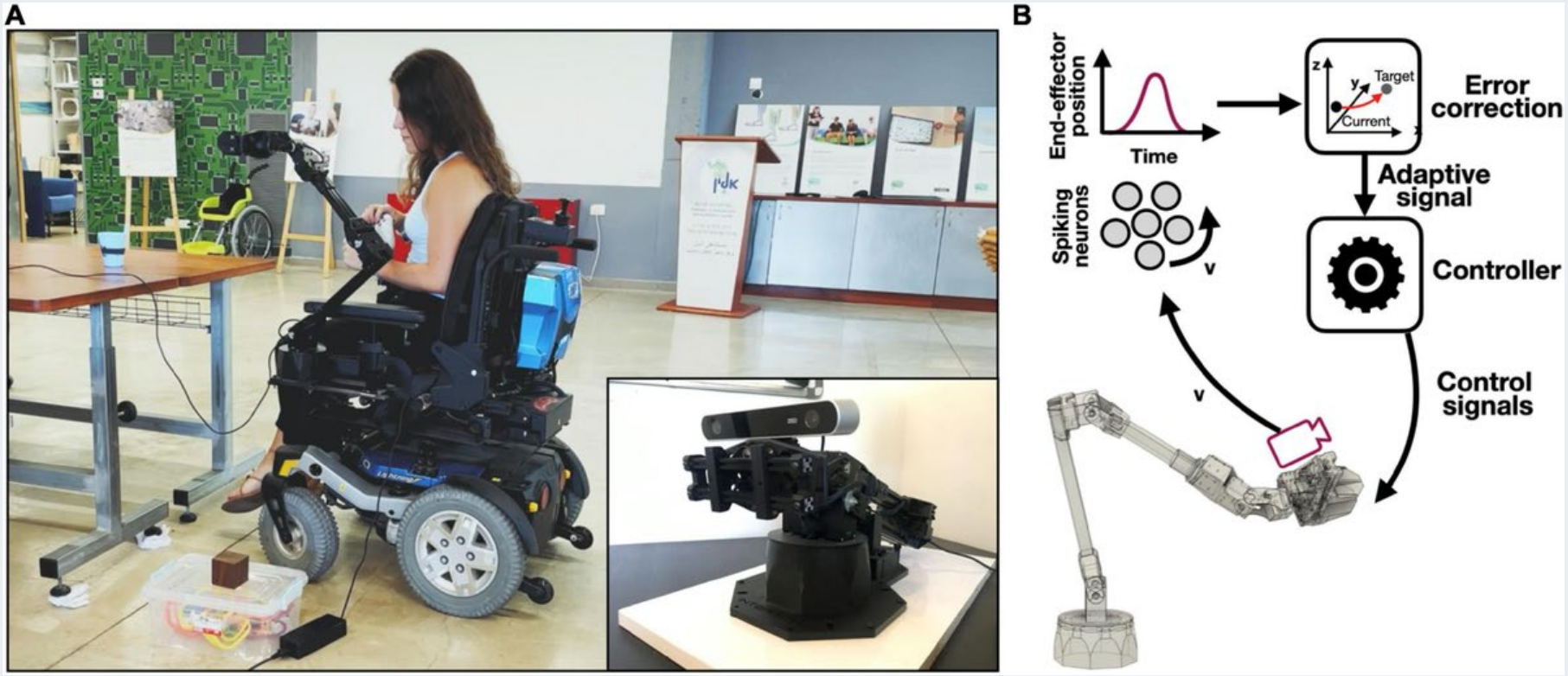


AI Model Validation

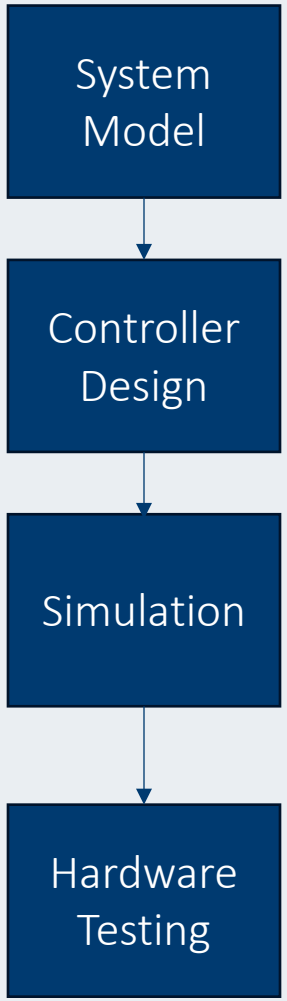


Case Study: Control Systems

Adaptive control for robotics



Control System Research Workflow

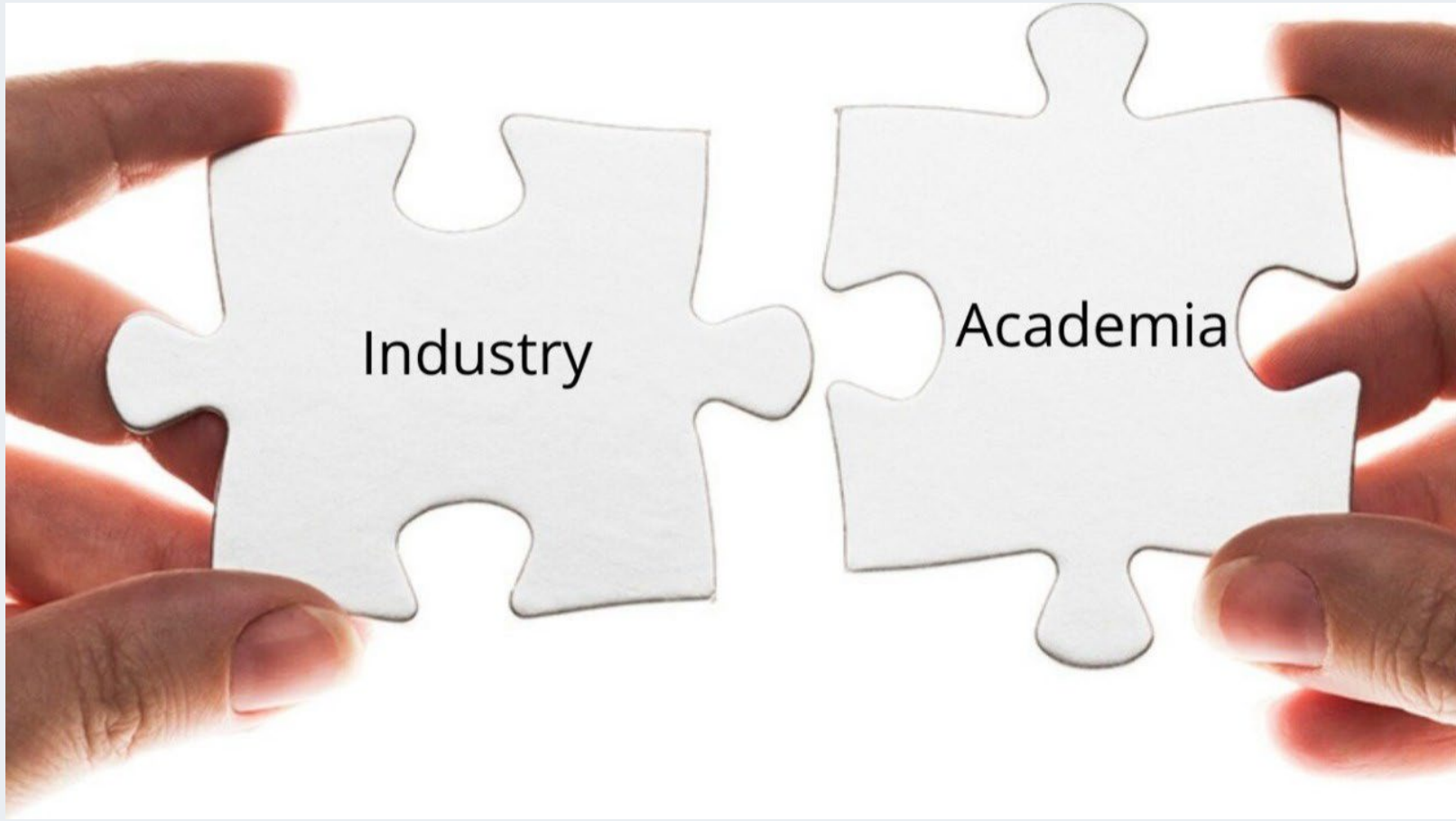


Interdisciplinary Engineering Research

Engineering + AI + Sustainability

Industry Collaboration

- Data access
- Real-world testing
- Funding



Research Infrastructure

- Laboratories
- Simulation tools
- HPC computing

Final Thoughts

Common Research Pitfalls

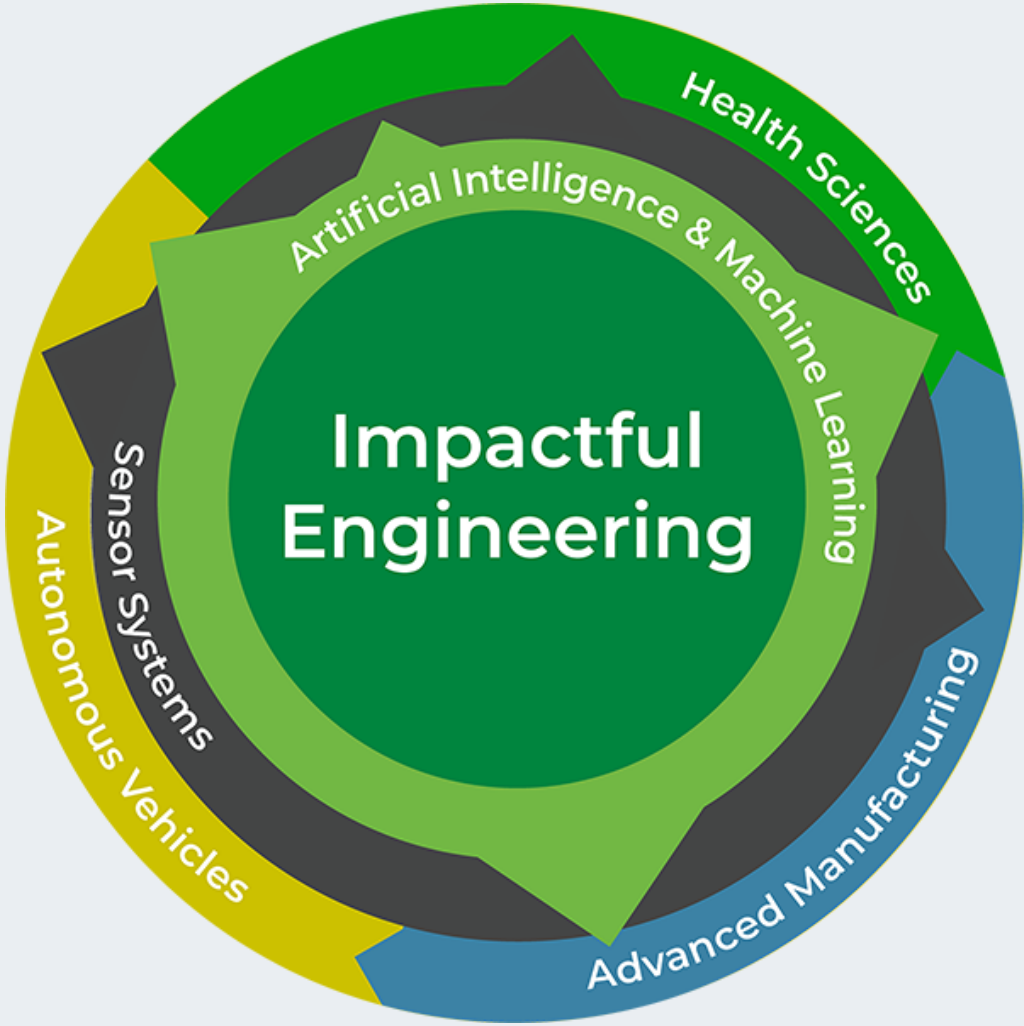
- **Lack of Detail:** Methodology must allow for replication.
- **Disconnected Methodology:** Failure to link methods back to RQs.
- **Over-reliance on Simulations:** Lack of physical validation.
- **Neglecting Uncertainty:** Failure to quantify errors in data or models.

Skills for Doctoral Success

- Critical thinking
- Persistence
- Communication

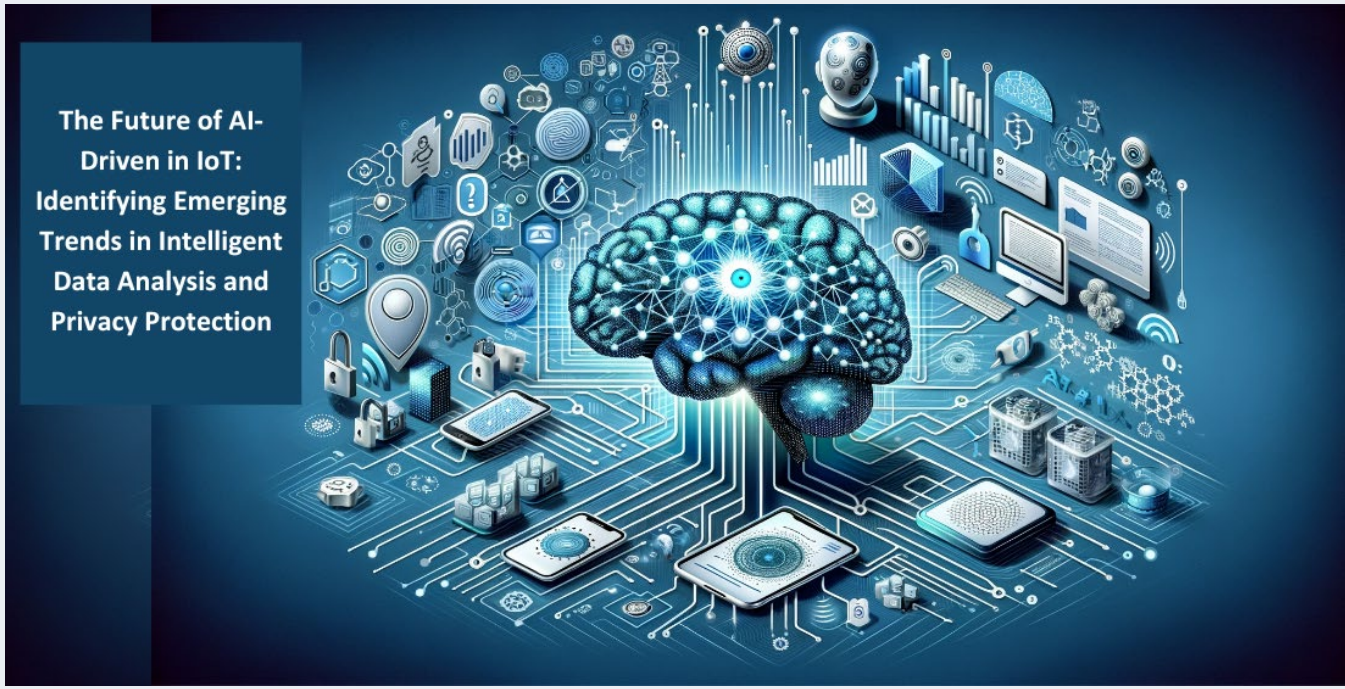
Impactful Engineering Research

- Societal benefit
- Industry adoption
- Policy influence



Future Engineering Research Trends

- Smart grids
- Autonomous systems
- Sustainable technologies



Key Takeaways

- Rigour requires clear, justified, and validated methods.
- Doctoral research must create new knowledge.
- Iterate between theory, simulation, and experimentation.
- Always document and validate!

Final tips

Rigorous methodology + strong validation

= impactful research

Thank You!

Email feedback to Akhtar.Kalam@eit.edu.au

Upcoming courses

Courses	Start Date
Doctor of Engineering (online) 36 months	28 July 2025
On-Campus – Doctor of Engineering 36 months Perth/Melbourne	4 August 2025

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All upcoming Doctoral Webinars:
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7 May: Tools of the Trade: Simulation, Experimentation, and Data Analytics

4 June: Research Integrity, Safety, and Ethics in Engineering

2 July: Supervisory and Industry Collaboration: Working as a Research Engineer

6 August: Managing the DEng: Planning, Time, and Resources

3 September: Communicating Engineering Research: Writing and Presenting Effectively

1 October: From Lab to Field: Translating Research into Real-World Engineering Applications

5 November: Resilience, Reflection, and the Doctoral Mindset

3 December: Building Your Research Identity: Patents, Publications, and Professional Pathways

Survey

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