Conference or Workshop Item:

Rigby, S. orcid.org/0000-0001-6844-3797 (2025) Blast from the past: The importance of prior knowledge in Machine Learning for blast protection. In: 15th International Conference on Shock and Impact Loads On Structures, 11-13 Jun 2025, Gothenburg, Sweden.

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Blast from the past:

The importance of prior knowledge in Machine Learning for blast protection

A WORLD TOP 100 UNIVERSITY

Professor Sam Rigby
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Structure and purpose of talk

1. Discuss the importance of **prior knowledge** in designing and training machine learning methods
2. Main message: approach the problem **as an engineer**, not a data scientist
3. Overview how experimental work at TUoS has been used to generate prior knowledge and ultimately inform **predictive model** development
4. A brief look at some **recent examples**

I am doing a keynote presentation called "Blast from the past: The importance of prior knowledge in machine learning for blast protection". Can you provide a brief explanation of "prior knowledge" in a way that explains my terrible pun?

Absolutely — here's a concise and engaging explanation that plays off your pun and sets up your talk nicely:

"Blast from the past" isn't just a pun — in machine learning, *prior knowledge* means using what we already know, like physics or engineering principles, to guide models when data is limited or uncertain. In blast protection, that past knowledge can make all the difference.

It takes a village…

Core academic team

Prof Andy Tyas

Prof Genevieve Langdon

Dr Richard Curry

Prof Sam Clarke

With special thanks to…

Dr Adam Dennis

Dr Dain Farrimond

Dr Andrew Barr

Dr Tommy Lodge

Lewis Tetlow

Jay Karlsen

… and many more!

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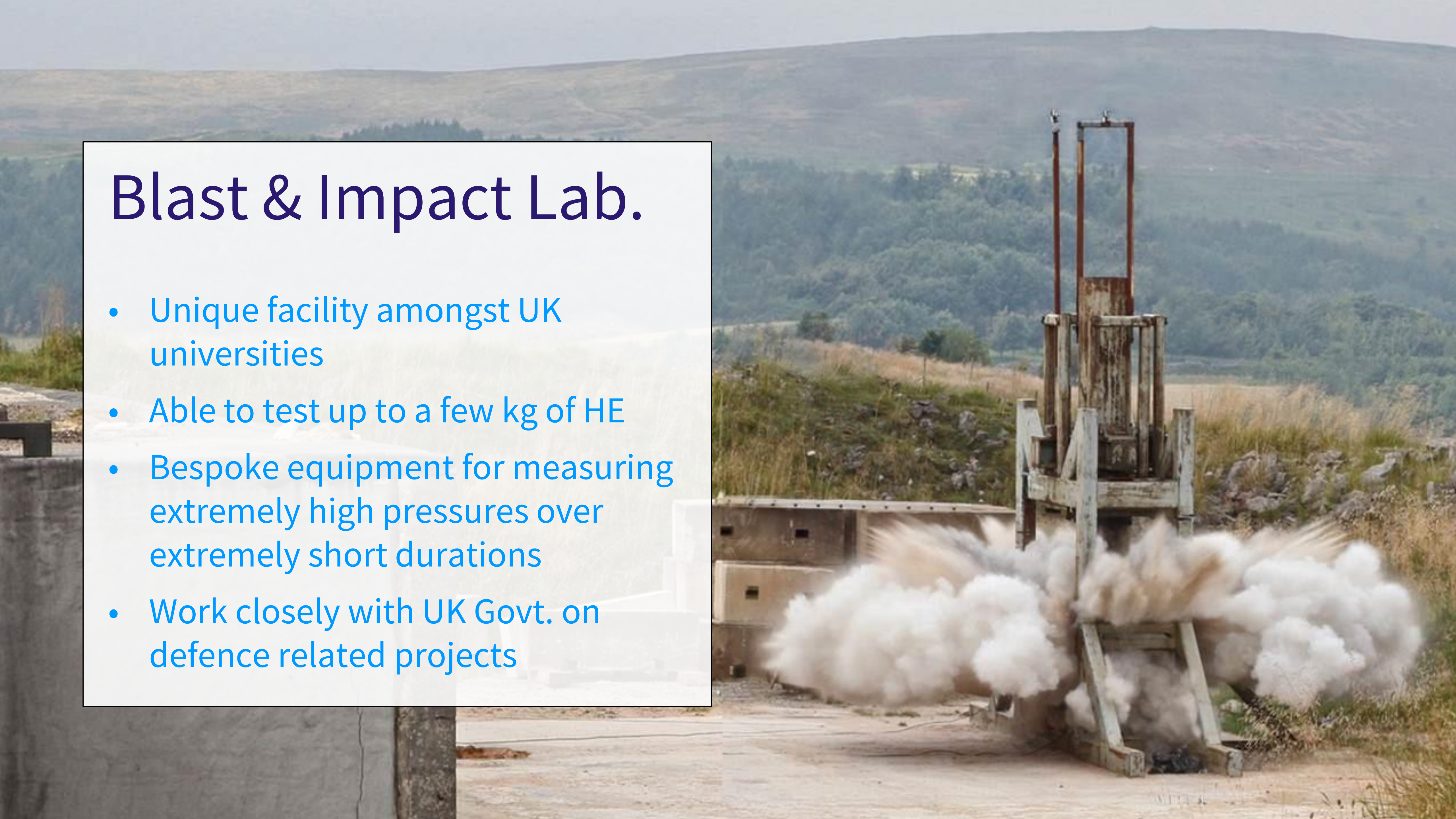

Blast & Impact Lab.

- Unique facility amongst UK universities
- Able to test up to a few kg of HE
- Bespoke equipment for measuring extremely high pressures over extremely short durations
- Work closely with UK Govt. on defence related projects

Part 1 – Establishing the need

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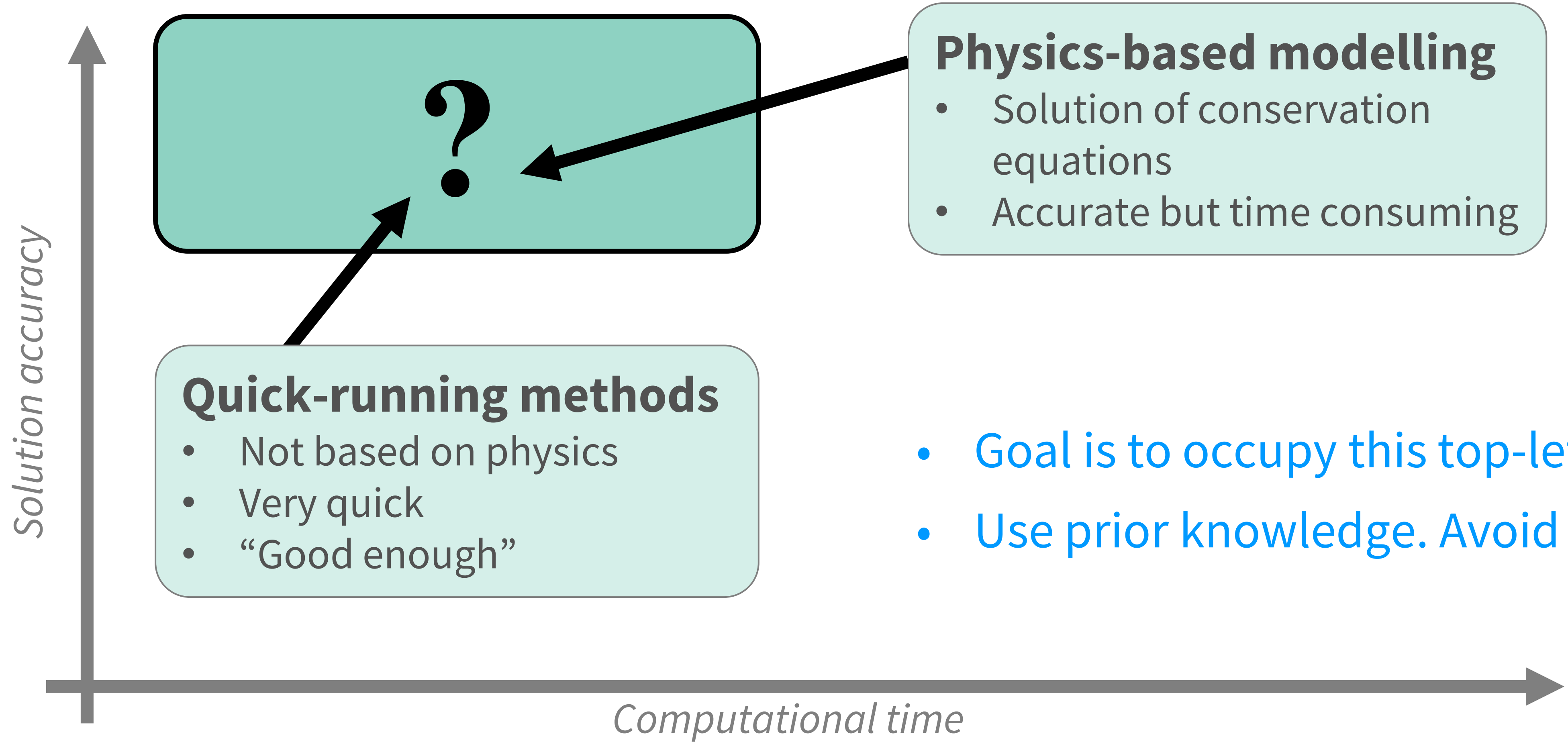
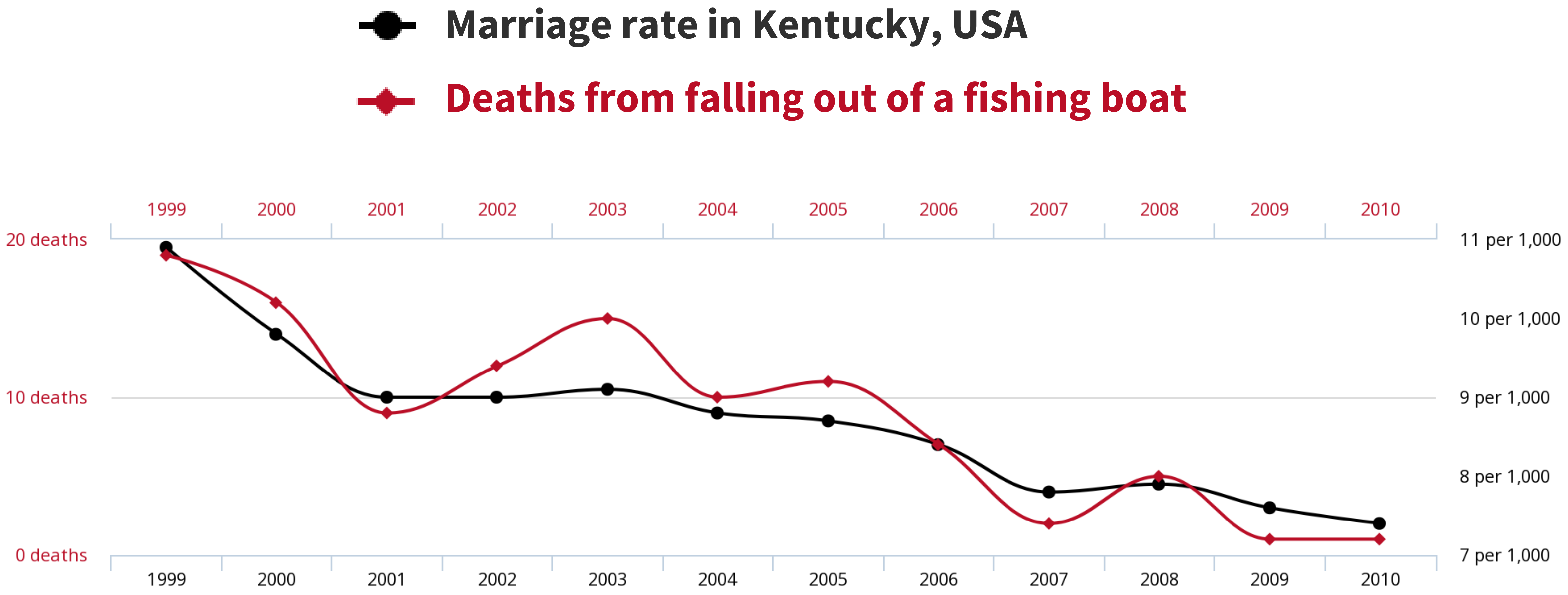
Development of better predictive models



- Goal is to occupy this top-left corner
- Use prior knowledge. Avoid “black boxes”



Physics-informed = no black boxes!

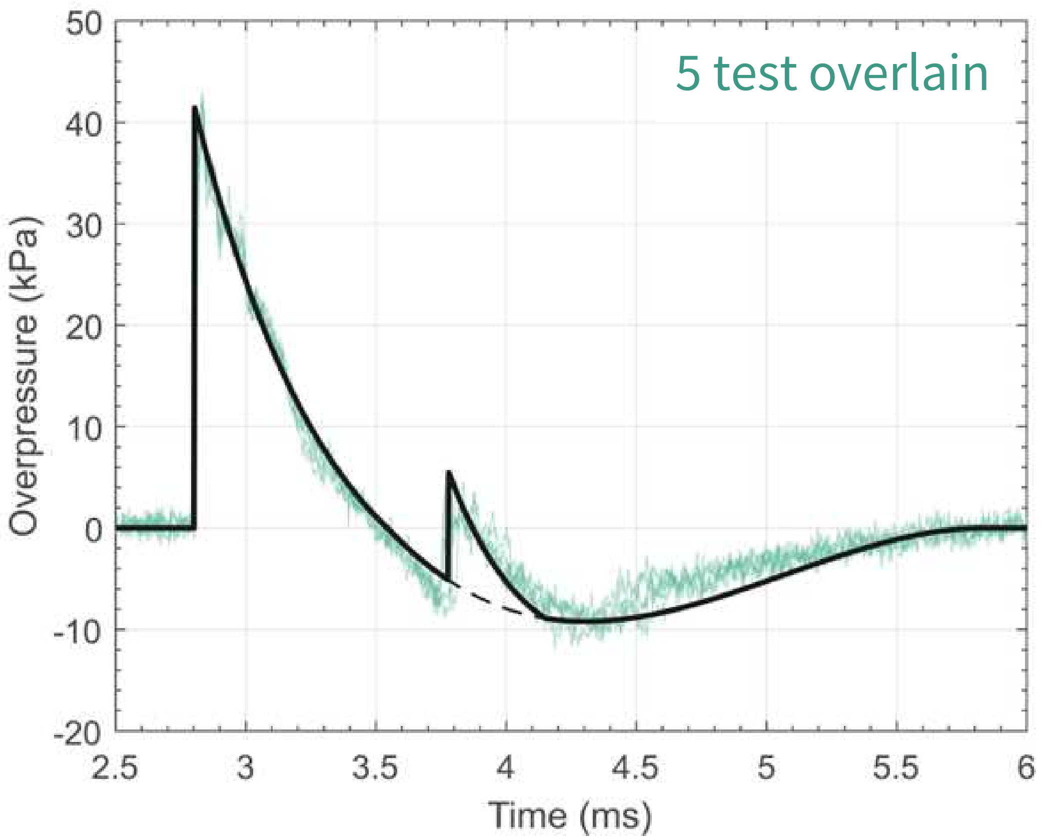
After Tyler Vigen's "*Spurious Correlations*" database

Approach the problem as an engineer,

not a data scientist

Part 2 – Experimental work at TUoS

Far-field



Rigby et al. (2024) Re-visiting the secondary shock. In: *19th ISIEMS*, Bonn, Germany

Remarkable agreement with predictive methods for simple free-field scenarios

Rigby et al. (2014) Validation of semi-empirical blast pressure predictions for far field explosions – Is there inherent variability in blast wave parameters? In: *PSH6*, Tianjin, China

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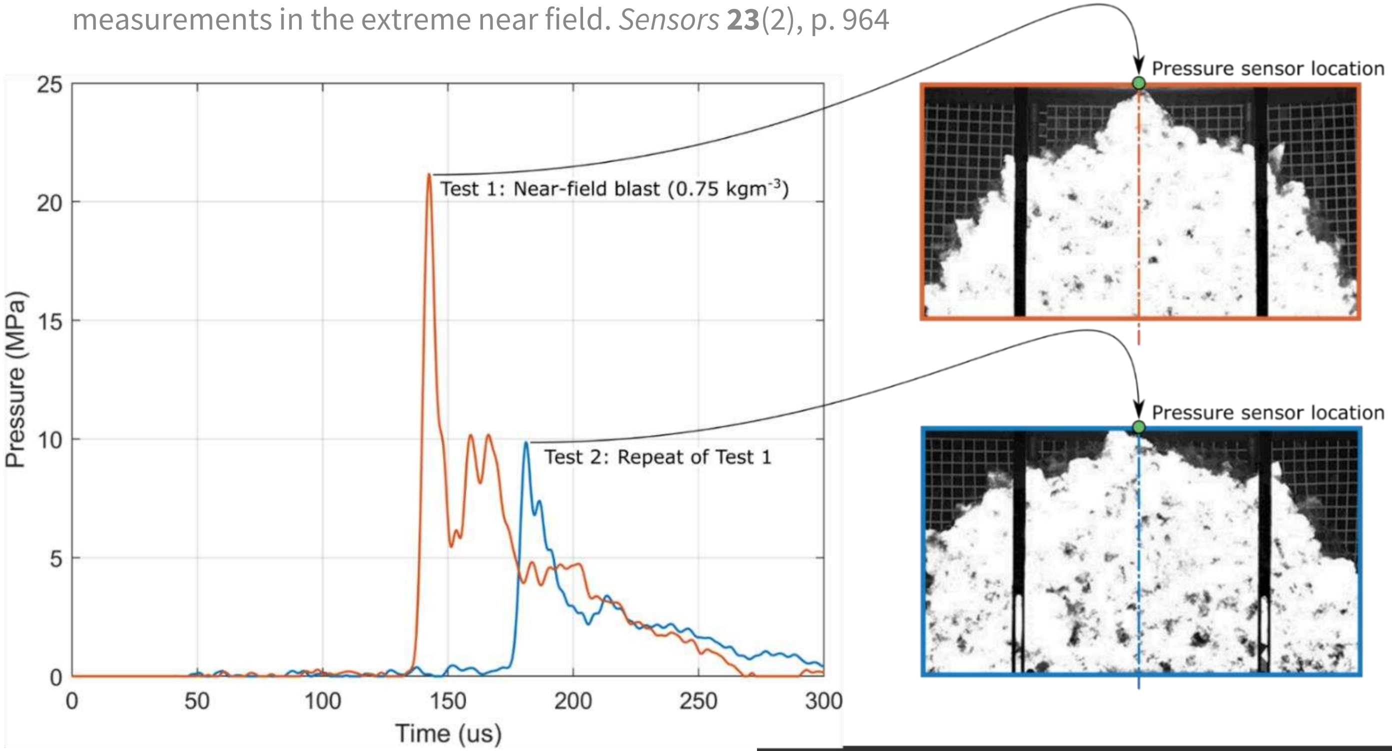
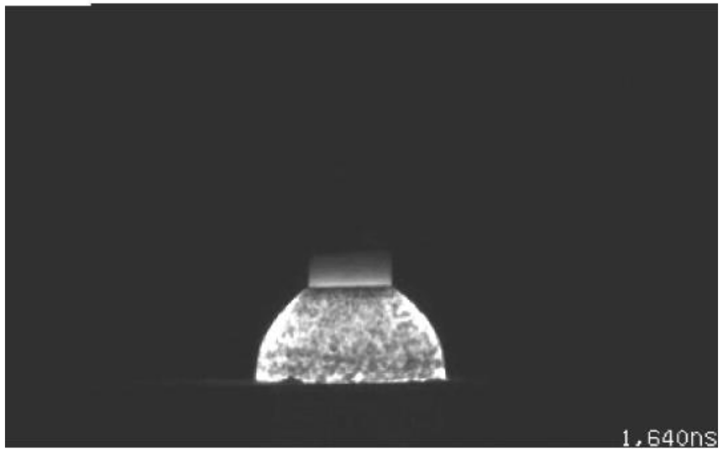
Near-field

Barr et al. (2023) Temporally and spatially resolved reflected overpressure measurements in the extreme near field. *Sensors* **23**(2), p. 964

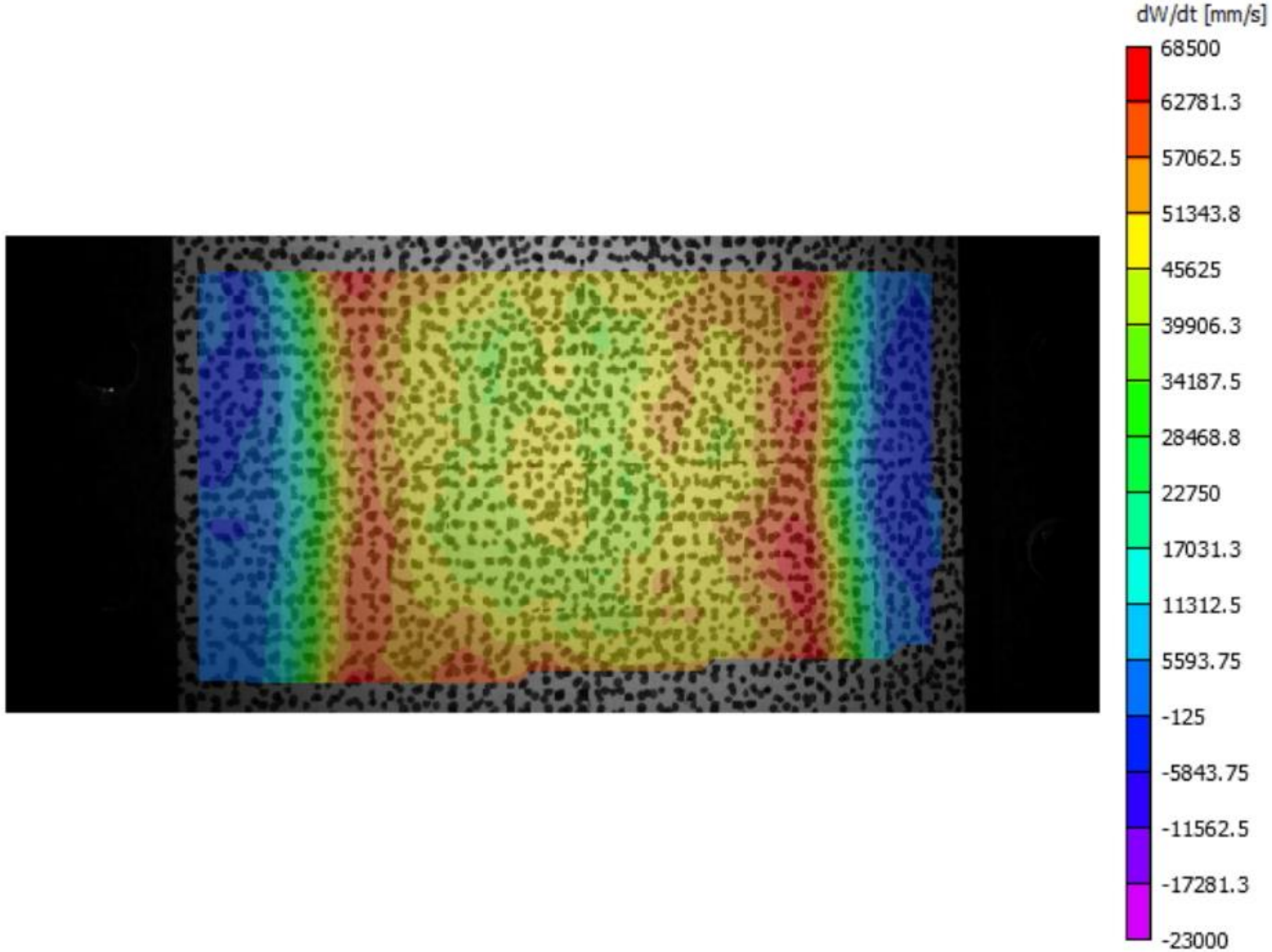


MPa pressures measured at MHz frequencies



Tetlow et al. (2024) Experimental assessment of near-field blast loading using Digital Image Correlation. In: 19th *ISIEMS*, Bonn, Germany

Digital Image Correlation



100,000 fps
Displacements measured at >2000 points on plate, per test

Part 3 – Recent examples

Example problem #1:

Current predictive models lack the sophistication required to model blast-structure interaction in complex environments

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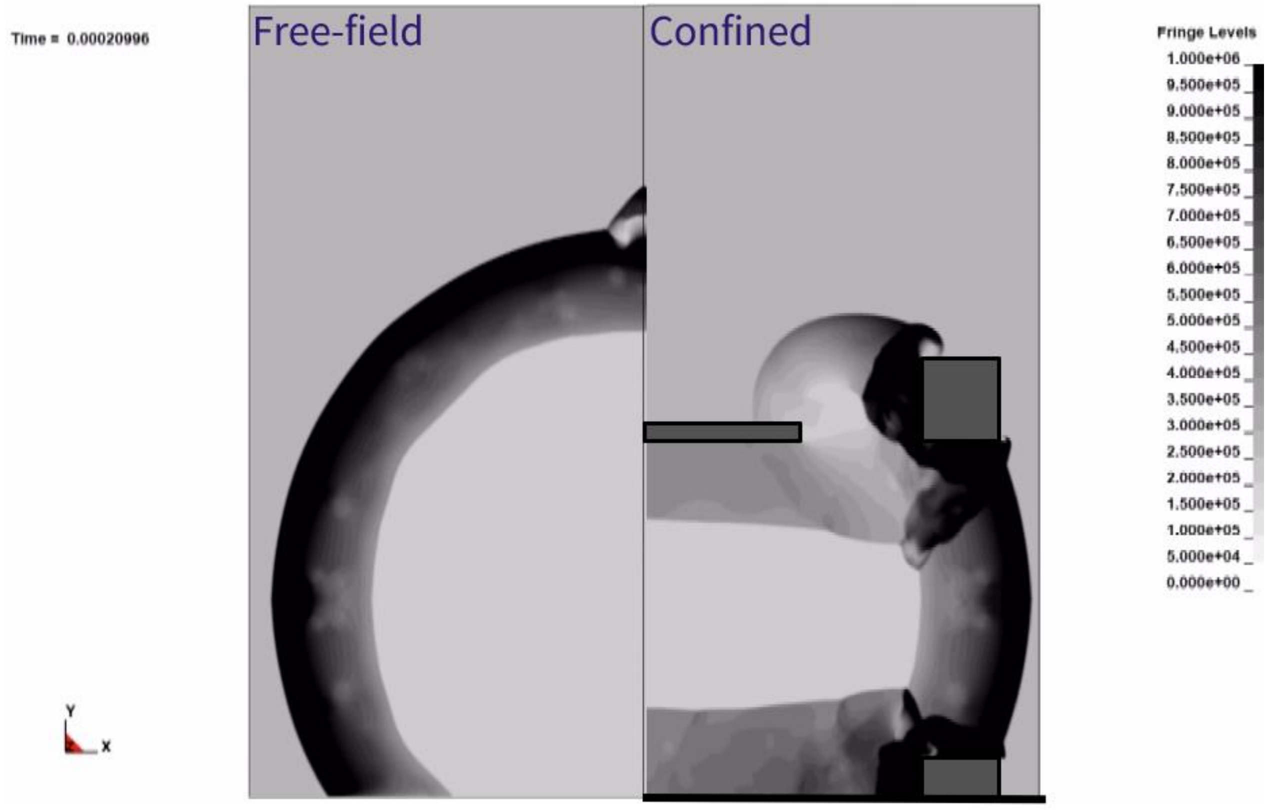
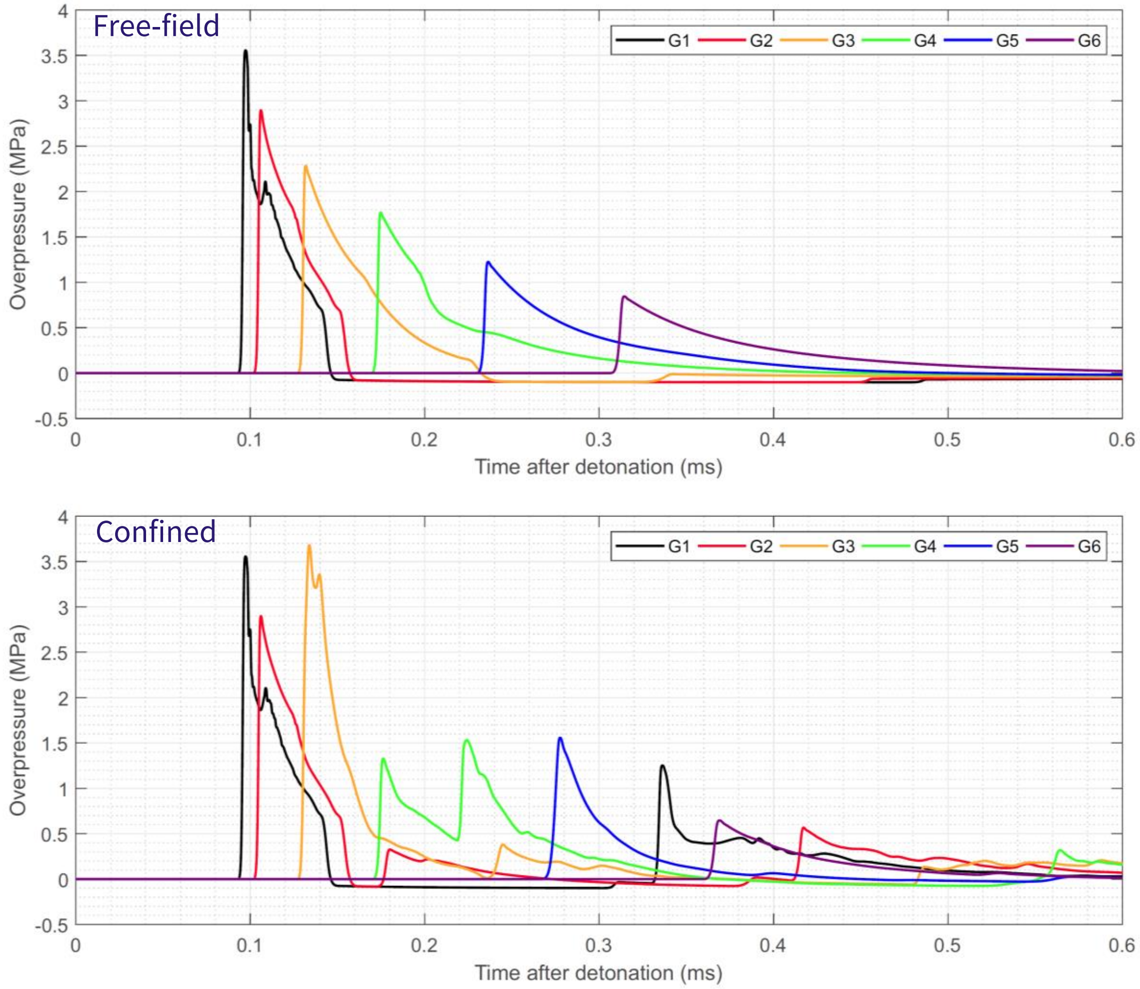
Blast loading in complex environments





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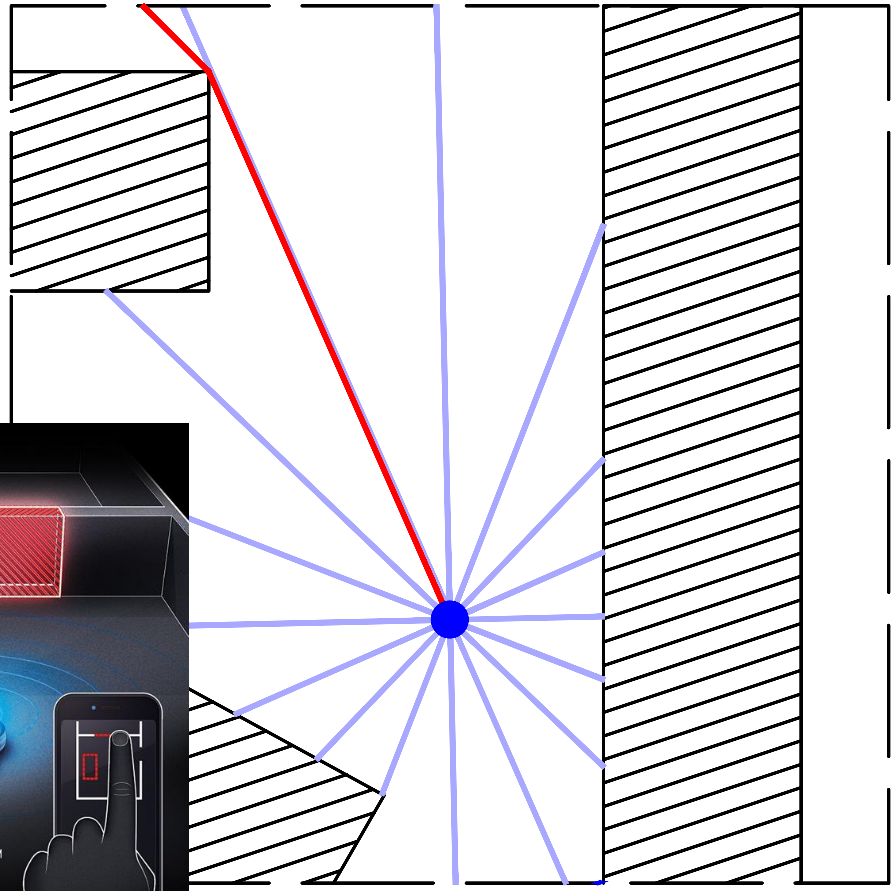
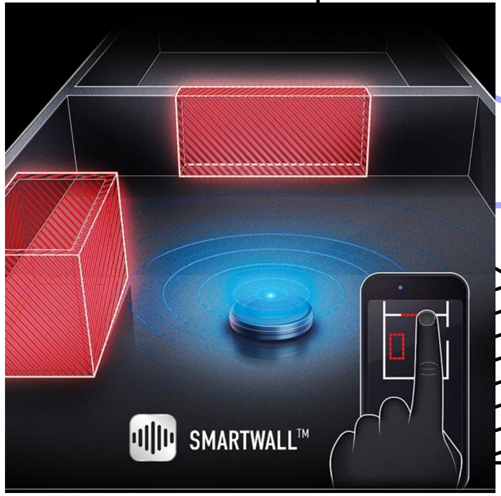
Direction-encoded neural network

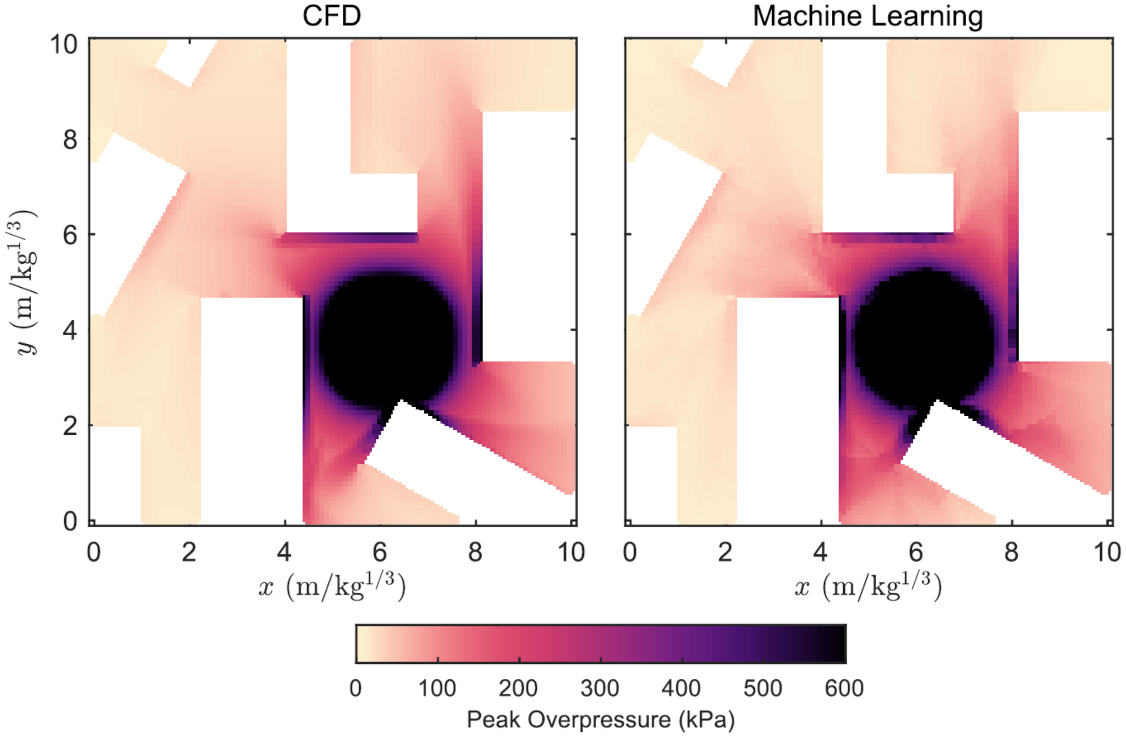
- Can we give a network *more* information about its surroundings, in a way that relates to the *physics* of the problem?
- Incorporate aspects of **prior knowledge** and **feature engineering**
- Designed an ANN in a way that was strongly aligned with the physics
- Location and proximity of obstacles, sampling previous data, etc.

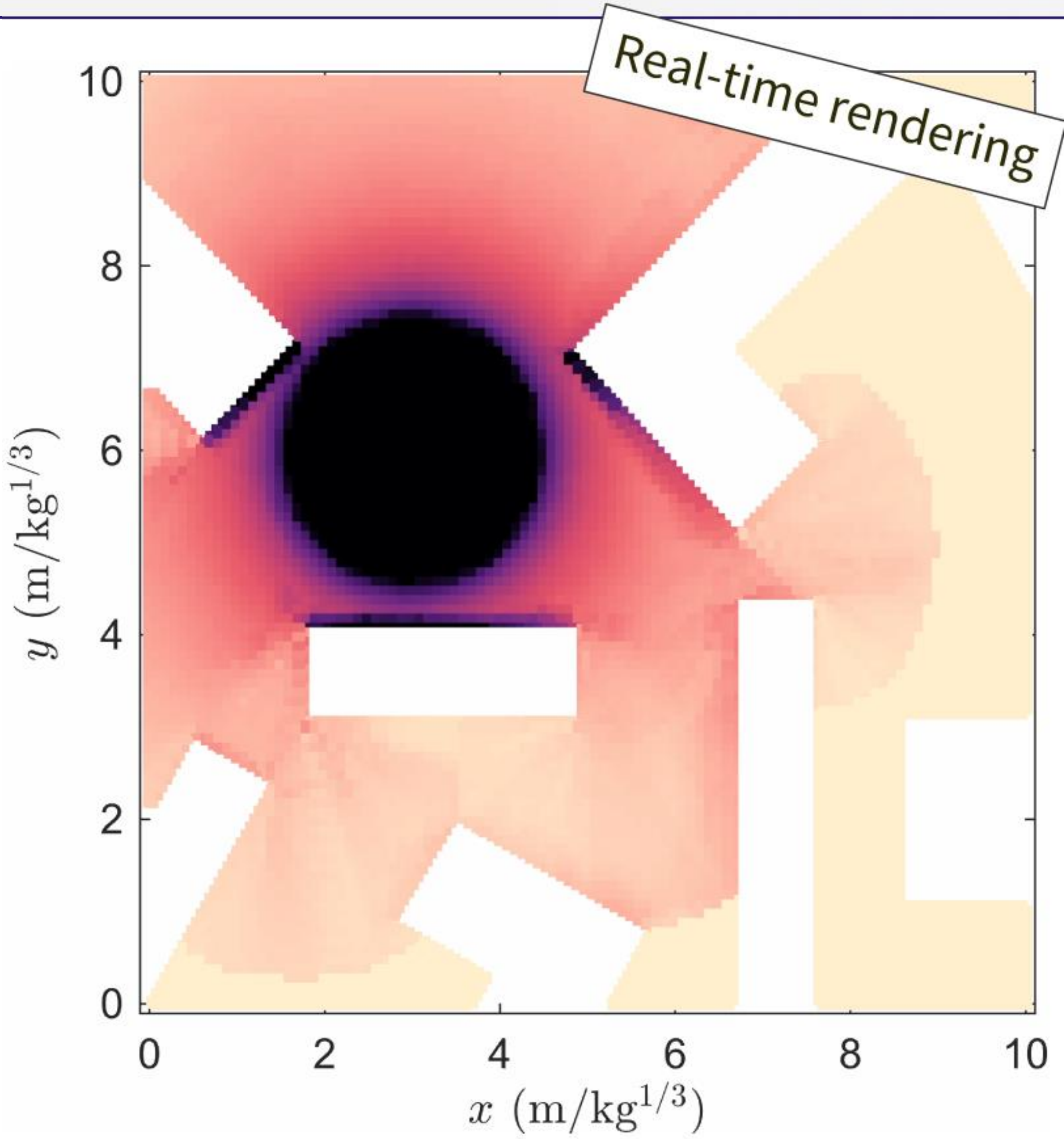




Dennis & Rigby (2023) The Direction-encoded Neural Network: A machine learning approach to rapidly predict blast loading in obstructed environments. *International Journal of Protective Structures* **15**(3), p. 455–483

- Highly generalisable as based on prior knowledge of underlying physics
- Able to match numerical model data, typically within 5%
- Run time ~10s compared to ~45mins for CFD



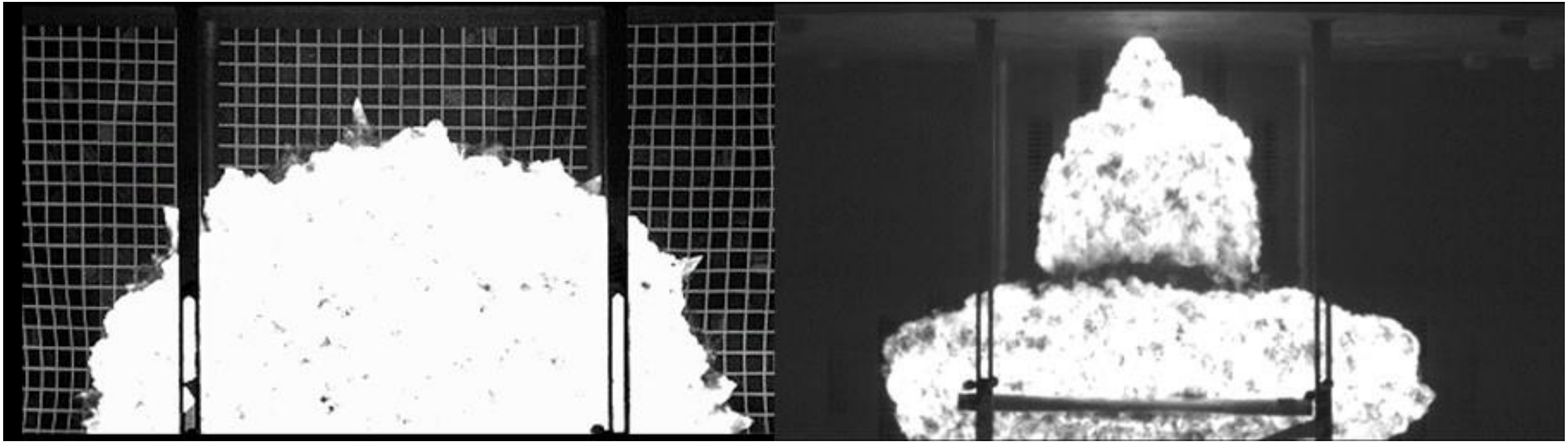


Dennis (2024) A direction-encoded machine learning approach for peak overpressure prediction in urban environments. In: *19th ISIEMS*, Bonn, Germany

Example problem #2:

Addressing data scarcity in blast engineering.
Can we leverage existing models to build new ones?

Transfer learning



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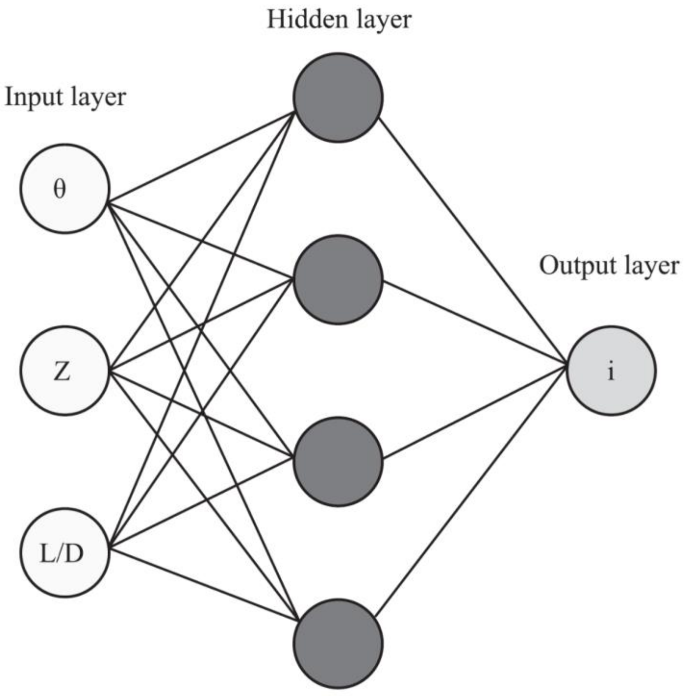
Transfer network

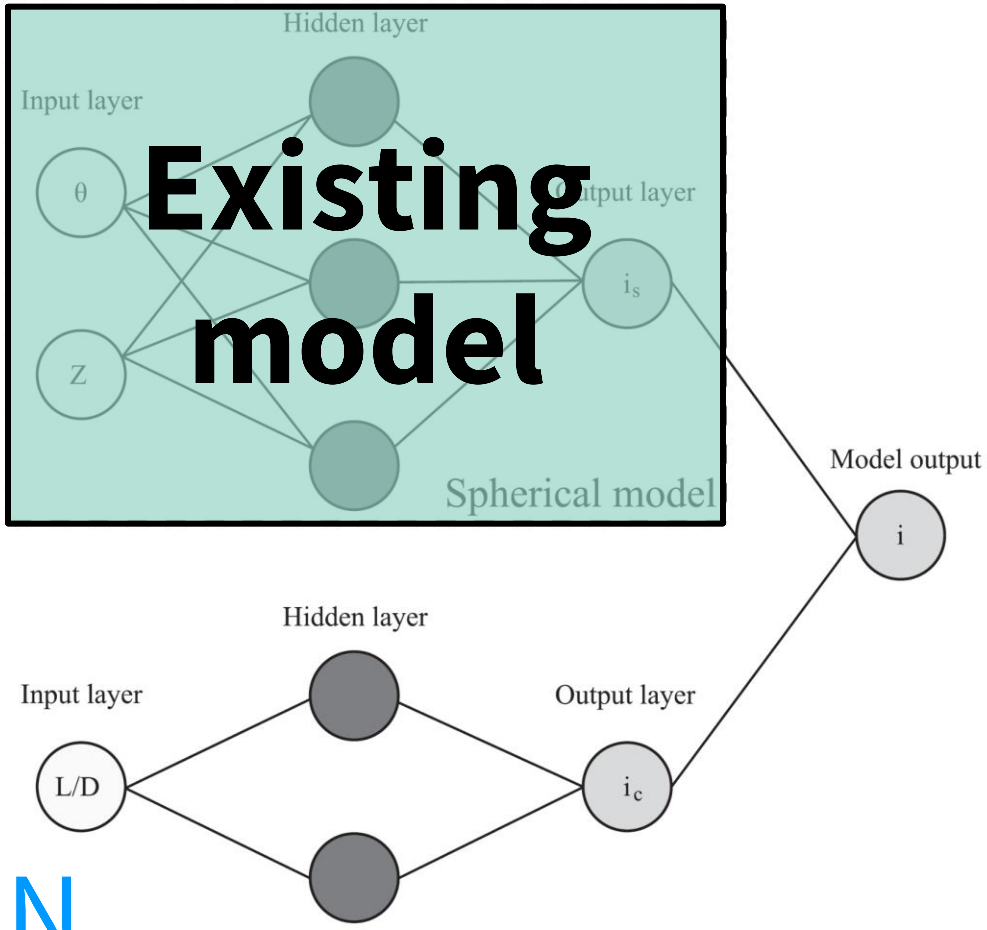
(a)



ANN

vs

(b)



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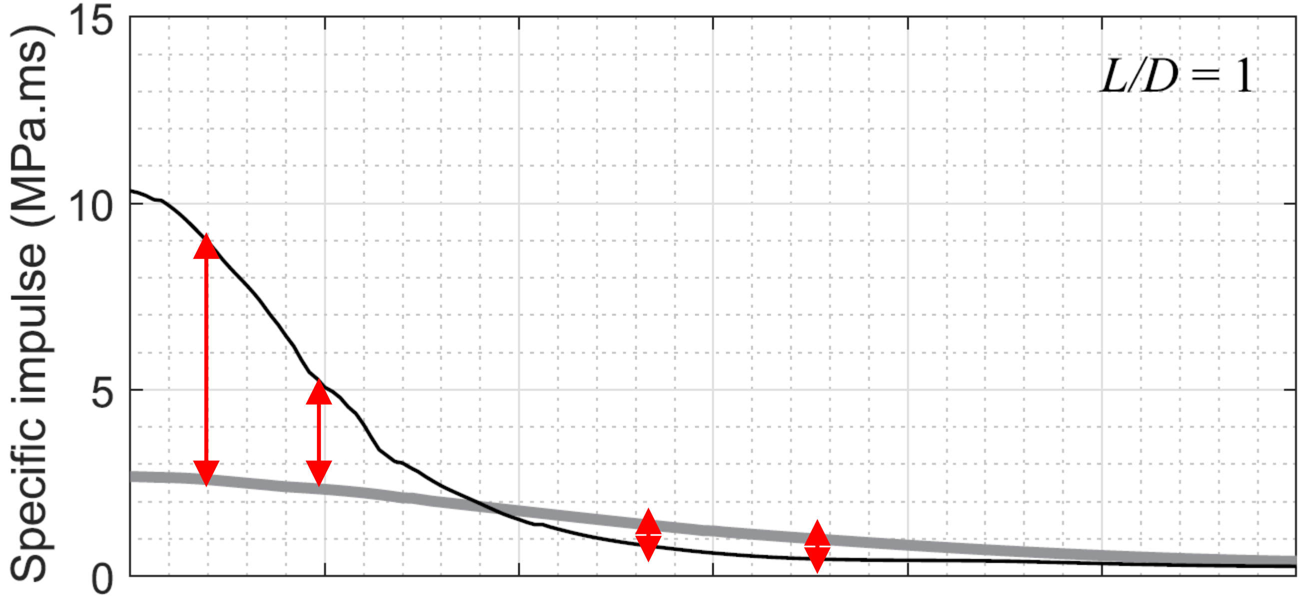
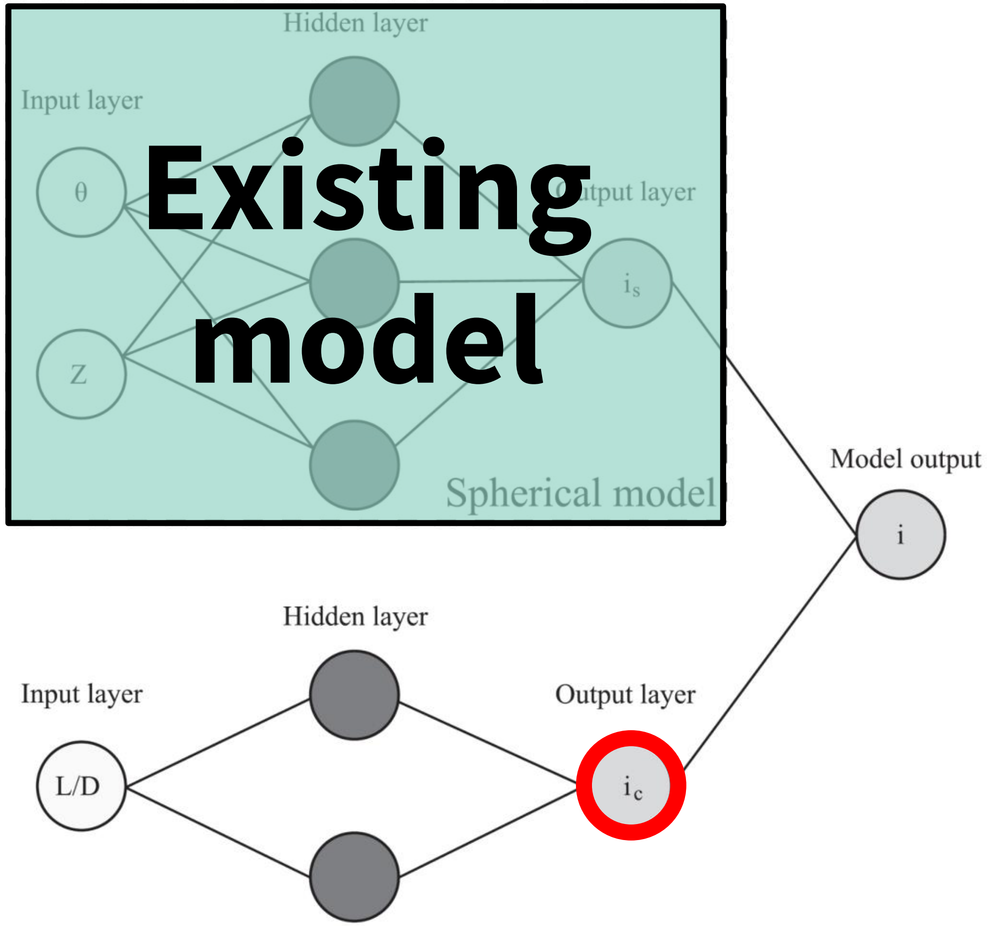
Transfer network



(b)



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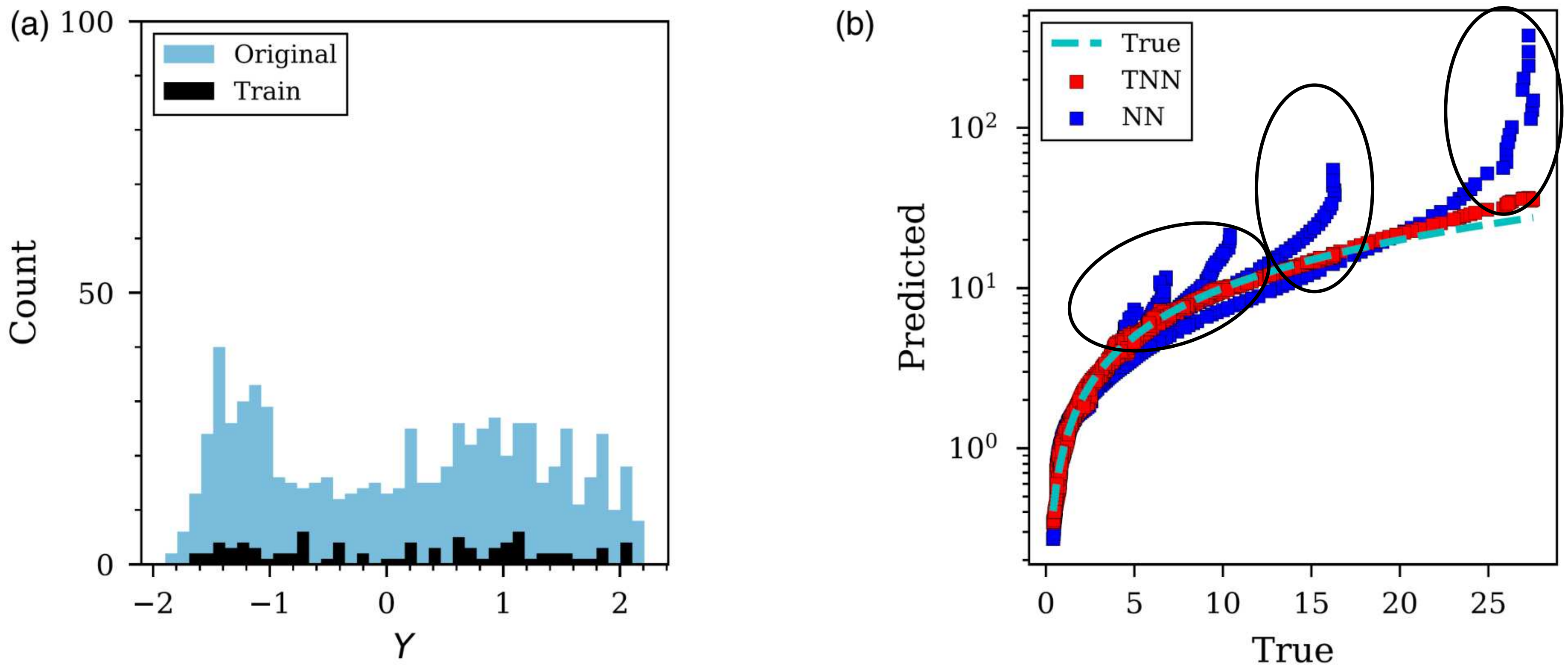
Pannell et al. (2023) Application of transfer learning for the prediction of blast impulse.
International Journal of Protective Structures **14**(2), p. 242–262

Stress testing

TNN trains quicker and performs much better than NN under stress testing
(e.g. 90% data removed)



Example problem #3:

Accurate solution of the “forward model” is computationally expensive, making iteration impractical

Can we use prior knowledge/physics-based methods to speed it up?

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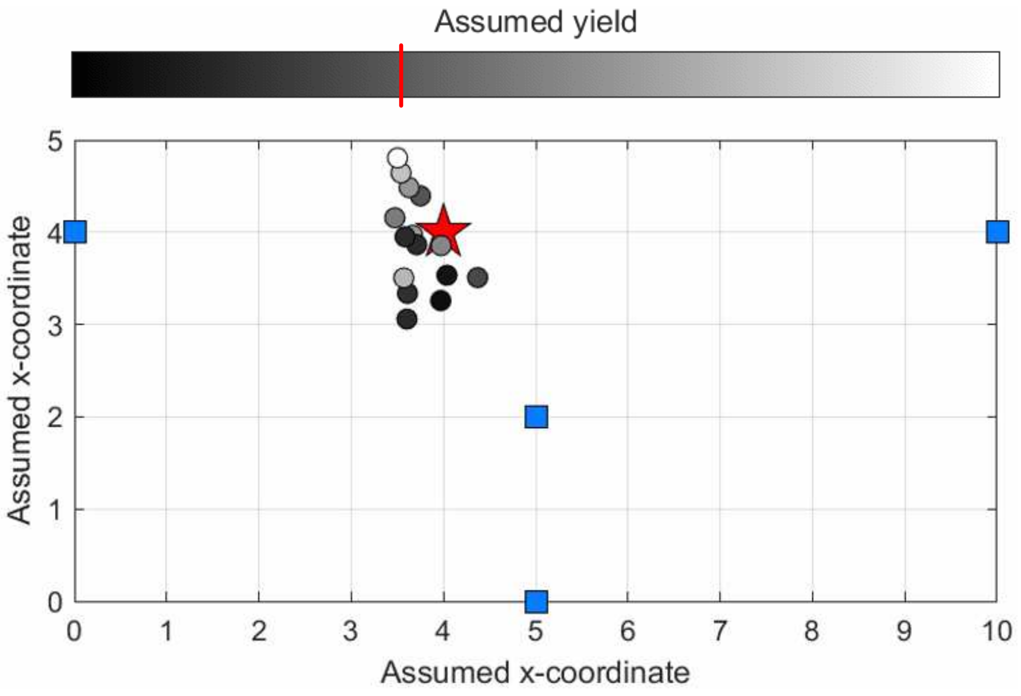
Work across a range of fidelity

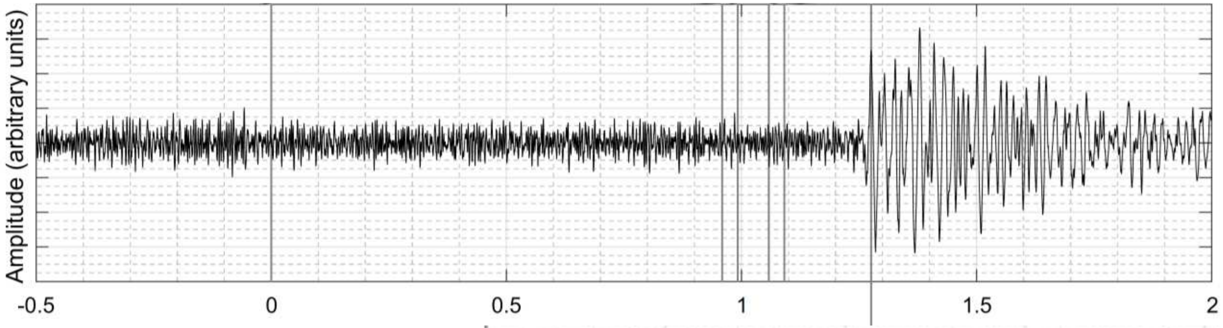


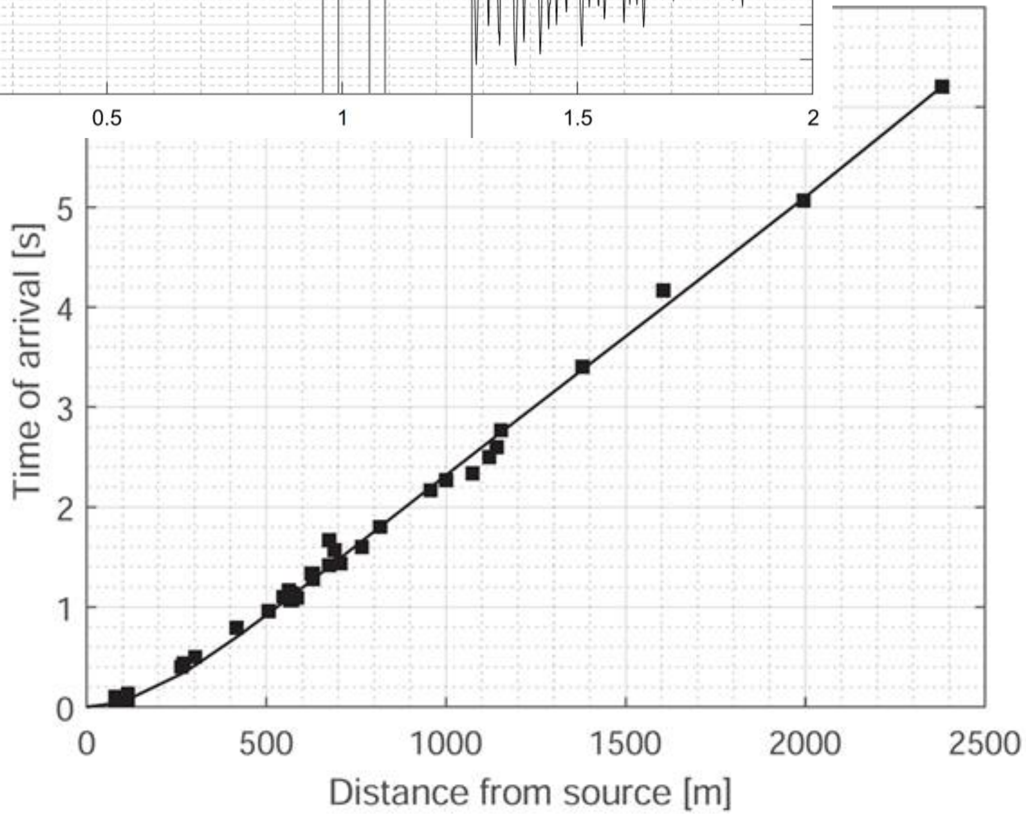
↑ Using a **Genetic Algorithm** and simple, physics-based forward method to determine origin and yield of an explosion

Karlsen & Rigby (2024) The role of AI in engineering: Towards rapid inverse blast analysis. In: *4th CONFAB*, London, UK

Rigby et al. (2020) Preliminary yield estimation of the 2020 Beirut explosion using video footage from social media. *Shock Waves* **30**(6), p. 671–675

Harvesting social media videos to determine time of arrival and estimate yield of Beirut explosion ↓





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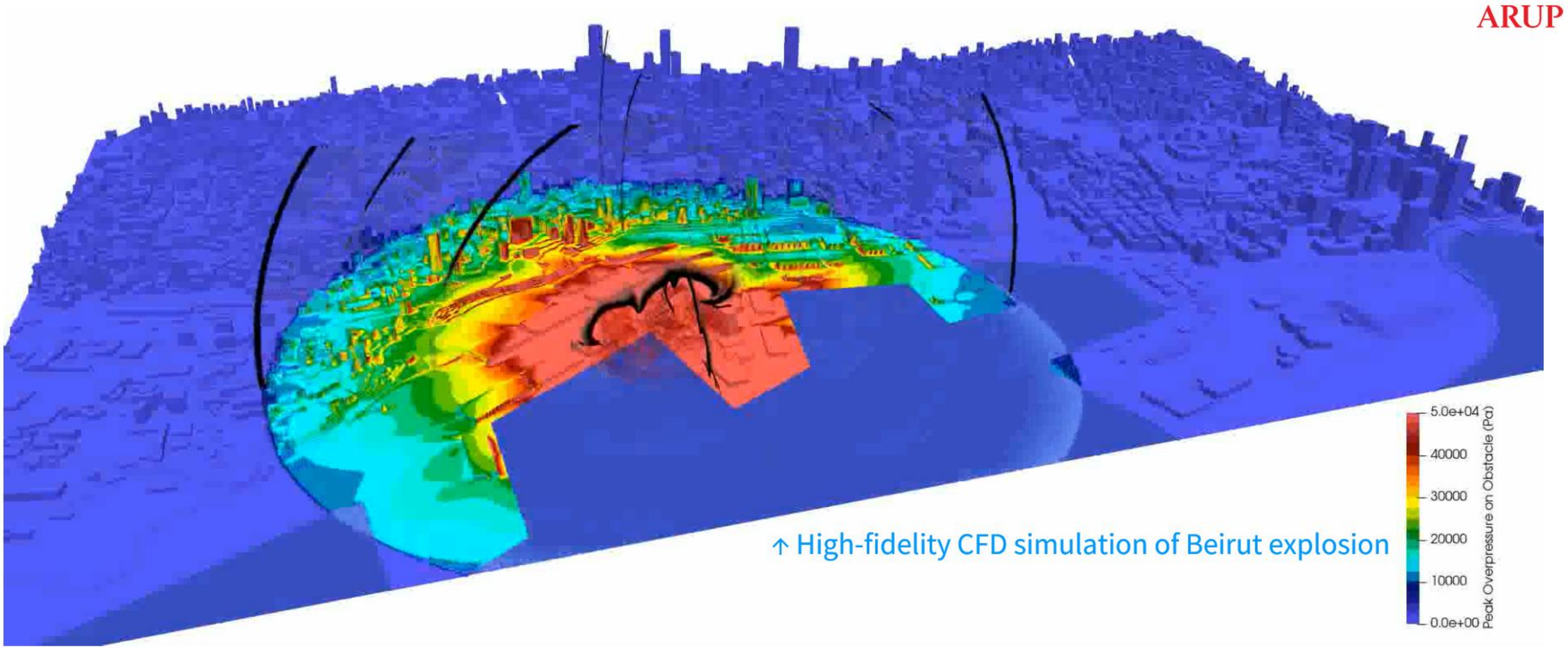
Work across a range of fidelity

Rigby et al. (2024).Consequences of the 2020 Beirut explosion. *Fire and Blast Information Group Technical Newsletter* **88**, p.6–10



↑ High-fidelity CFD simulation of Beirut explosion

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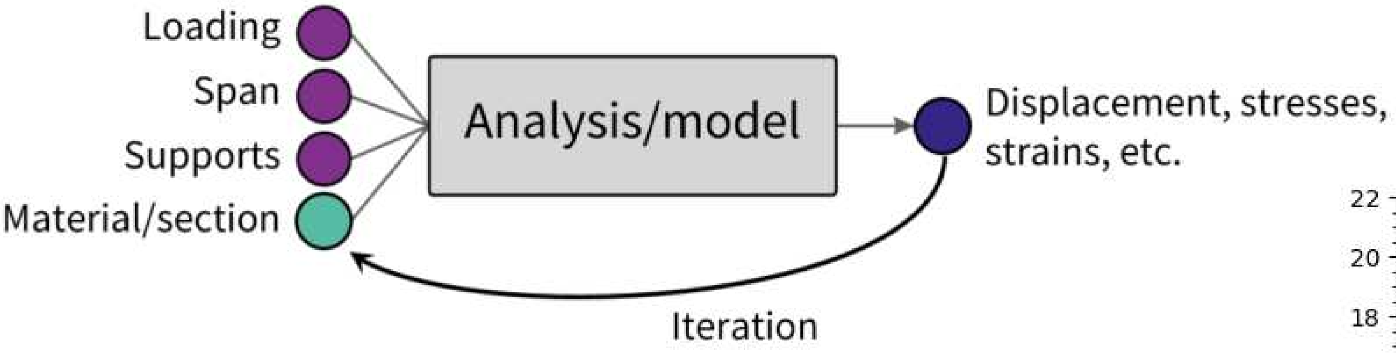
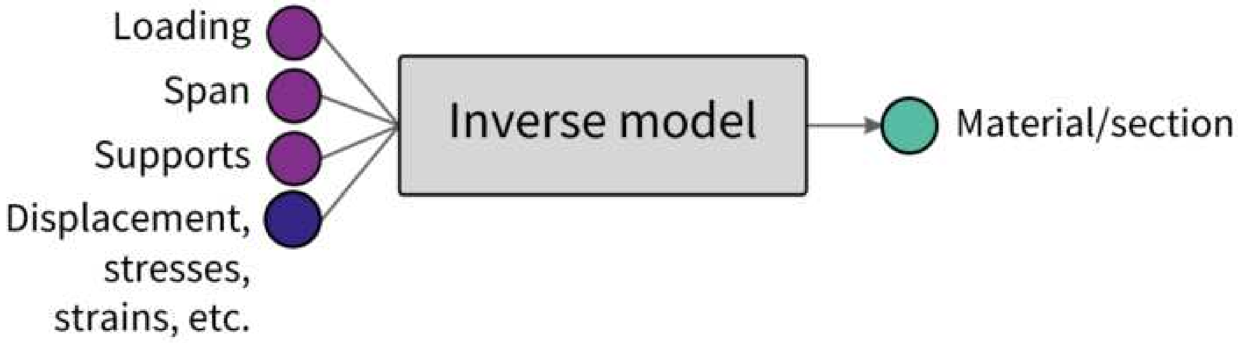
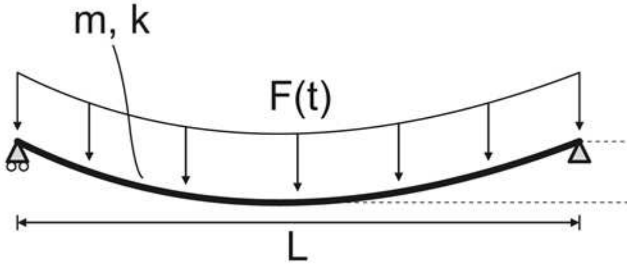
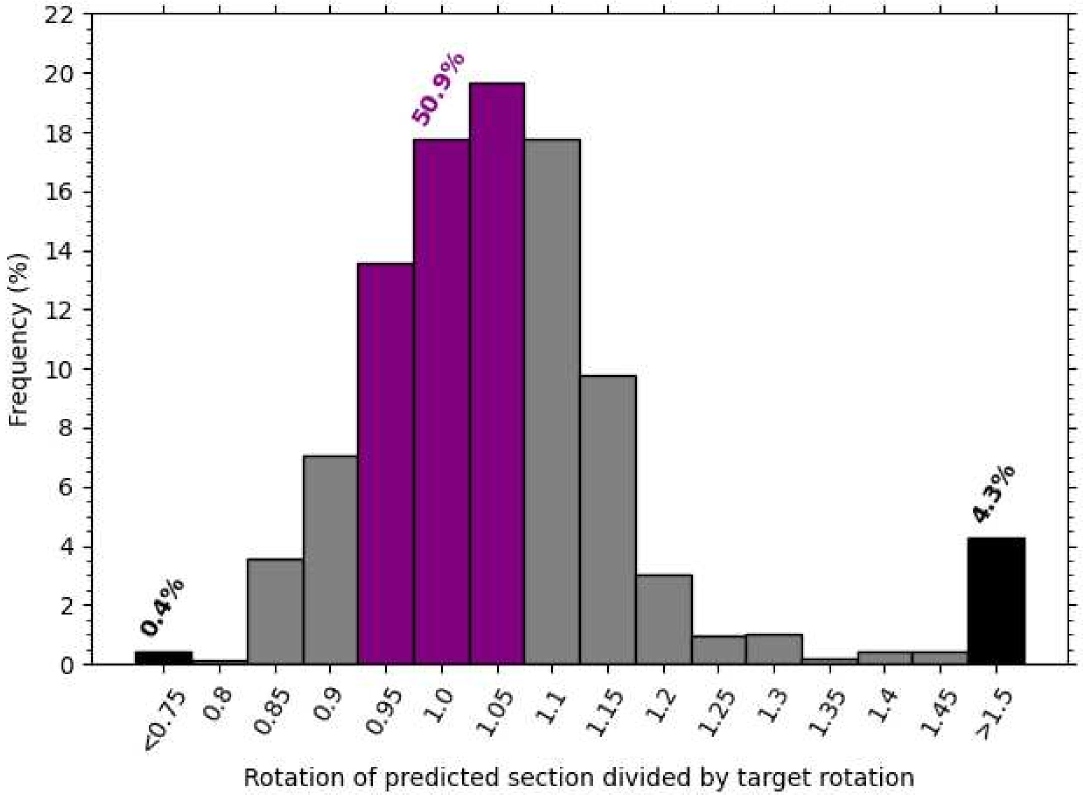
Use of an ANN to solve inverse “design” problems



VS







Rigby et al. (2025).On the use of Artificial Neural Networks for inverse analysis of SDoF response of blast loaded structures. In: *17th SUSI*, Edinburgh, UK

Take-home message:

Engineers already have a diverse toolkit

ML should look to *add* to this toolkit,
rather than *replace* any of the tools

The greatest benefits come from using ML
in conjunction with prior knowledge and existing tools

Concluding remarks

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- Work at TUoS is focussed on detailed and accurate measurement of blast loading and structural response using novel techniques and apparatus
- This provides us with fundamental insights into behaviour, allowing us to apply **prior knowledge** in the design and training of ML/data-driven models
- Previous work has shown this can be a highly advantageous approach for:
    - Blast-structure interaction in complex environments
    - Prediction of near-field blast loads from different charge shapes
    - Assessment of urban blast
    - Rapid solution of inverse problems: design of structural elements under blast

References

1. Barr et al. (2023) Temporally and spatially resolved reflected overpressure measurements in the extreme near field. *Sensors* **23**(2), p. 964
2. Dennis (2024) A direction-encoded machine learning approach for peak overpressure prediction in urban environments. In: *19th ISIEMS*, Bonn, Germany
3. Dennis & Rigby (2023) The Direction-encoded Neural Network: A machine learning approach to rapidly predict blast loading in obstructed environments. *International Journal of Protective Structures* **15**(3), p. 455–483
4. Karlsen & Rigby (2024) The role of AI in engineering: Towards rapid inverse blast analysis. In: *4th CONFAB*, London, UK
5. Pannell et al. (2023) Application of transfer learning for the prediction of blast impulse. *International Journal of Protective Structures* **14**(2), p. 242–262
6. Rigby et al. (2014) Validation of semi-empirical blast pressure predictions for far field explosions – Is there inherent variability in blast wave parameters? In: *PSH6*, Tianjin, China
7. Rigby et al. (2020) Preliminary yield estimation of the 2020 Beirut explosion using video footage from social media. *Shock Waves* **30**(6), p. 671–675
8. Rigby et al. (2024) Consequences of the 2020 Beirut explosion. *Fire and Blast Information Group Technical Newsletter* **88**, p.6–10
9. Rigby et al. (2024) Re-visiting the secondary shock. In: *19th ISIEMS*, Bonn, Germany
10. Rigby et al. (2025) On the use of Artificial Neural Networks for inverse analysis of SDoF response of blast loaded structures. In: *17th SUSI*, Edinburgh, UK
11. Tetlow et al. (2024) Experimental assessment of near-field blast loading using Digital Image Correlation. In: *19th ISIEMS*, Bonn, Germany

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blast waves   structural response   computational analysis   machine learning   data processing

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Preliminary yield estimation of the 2020 Beirut explosion using video footage from social media SE Rigby, TJ Lodge, S Alotaibi, AD Barr, SD Clarke, GS Langdon, A Tyas Shock Waves 30 (6), 671-675	146	2020
The negative phase of the blast load SE Rigby, A Tyas, T Bennett, SD Clarke, SD Fay International Journal of Protective Structures 5 (1), 1-19	121	2014

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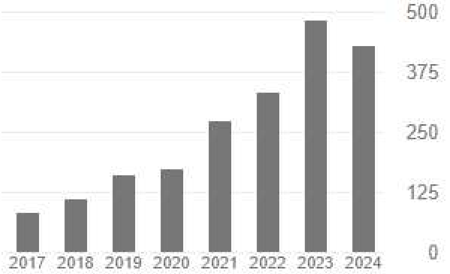

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