Online Vibration Signal Compensation with LSTM and Low-Rank Approximation
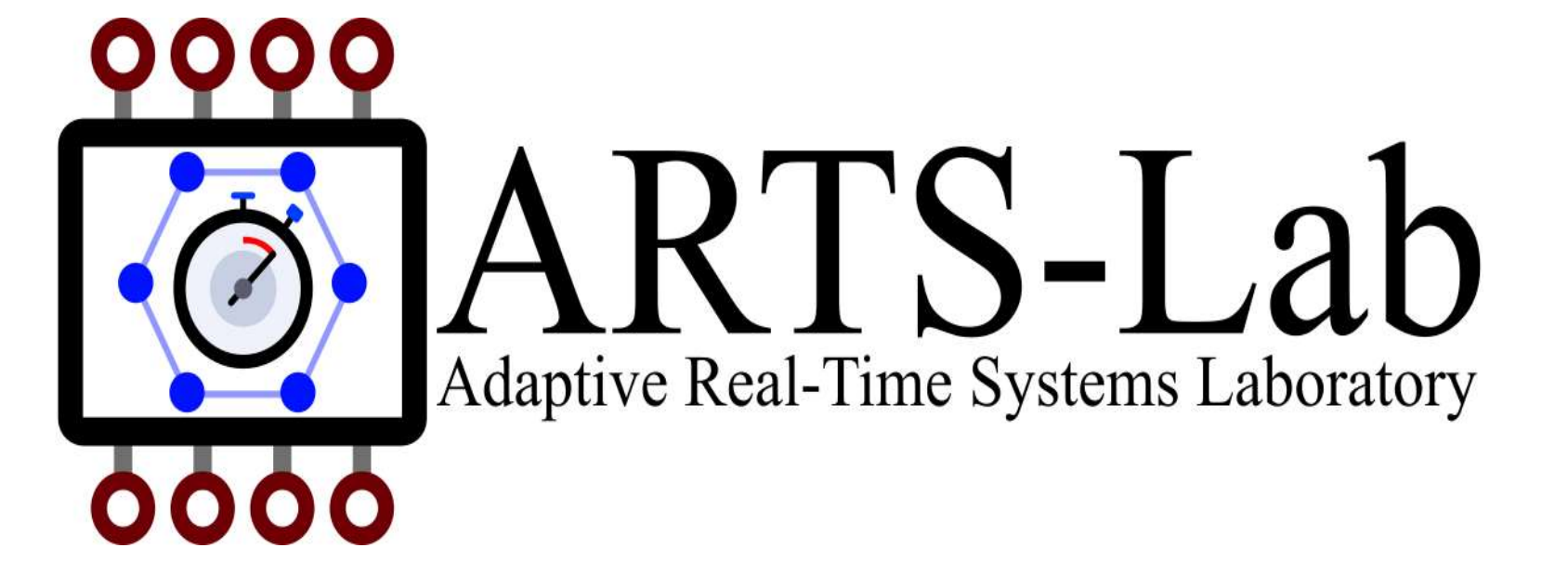
Joshua McGuire[1,3], Joud Satme[1], Daniel Coble[1,4], Jason Bakos[3], Austin Downey[1,2]

[1]Department of Mechanical Engineering, University of South Carolina
[2]Department of Civil and Environmental Engineering, University of South Carolina
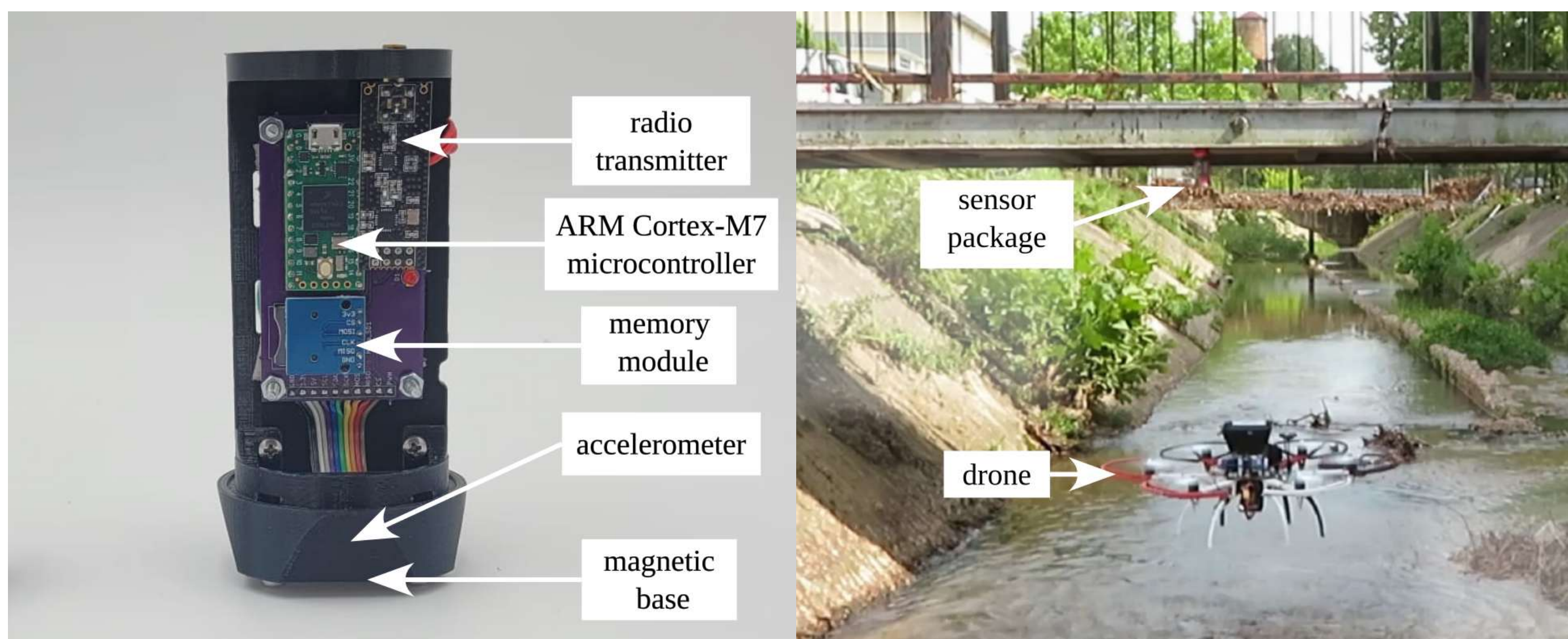[3]Department of Computer Science and Computer Engineering, University of South Carolina
[4]Department of Mechanical Engineering and Materials Science, Duke University
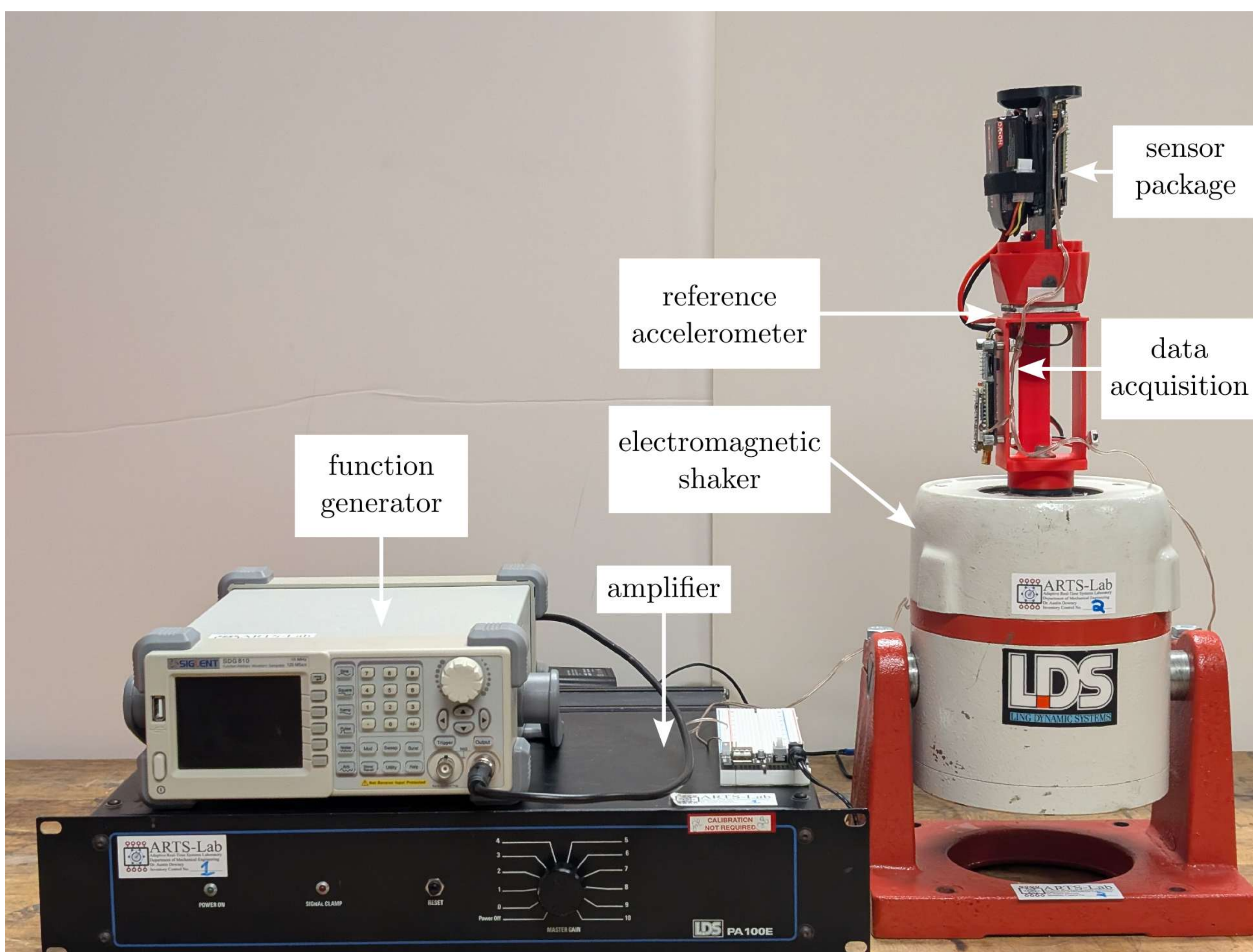
ARTS-Lab
Adaptive Real-Time Systems Laboratory

Background

SHM sensing node deployment

radio transmitter
ARM Cortex-M7 microcontroller
memory module
accelerometer
magnetic base
sensor package
drone

Drone-deployable sensor package

sensor package
reference accelerometer
data acquisition
function generator
electromagnetic shaker
amplifier
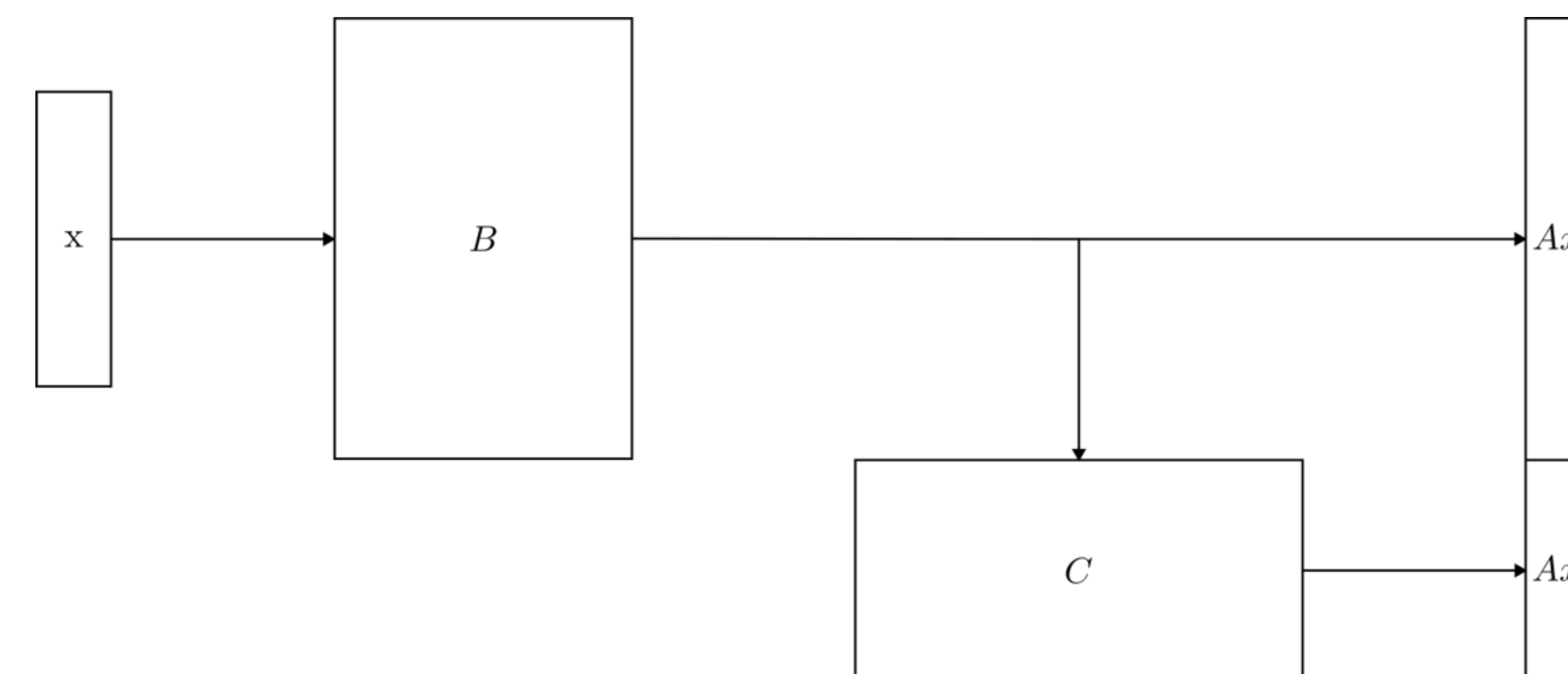
Experimental setup

Degrees-of-Freedom Decomposition

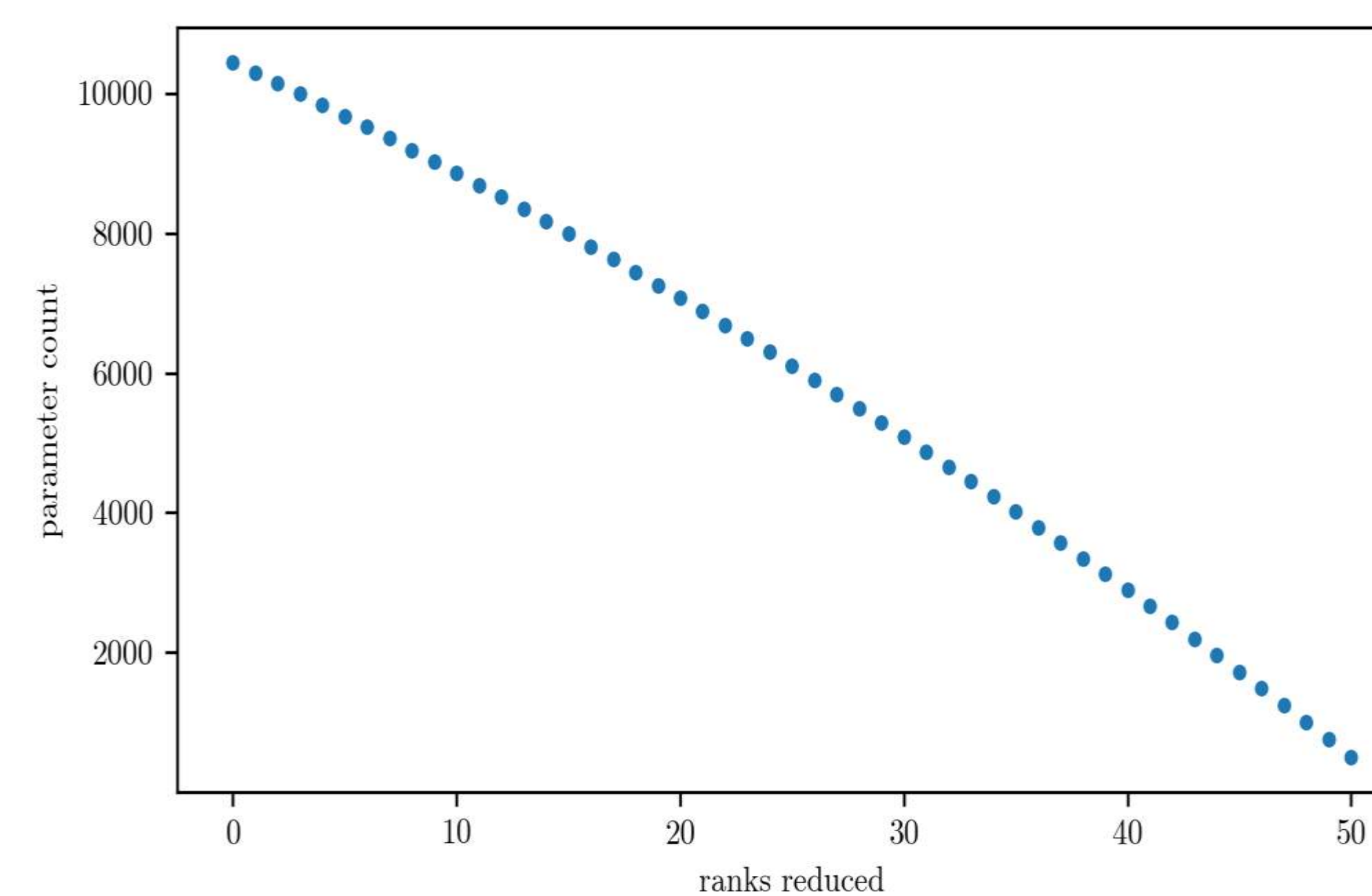$$Ax_1 = Bx \qquad Ax_2 = Cx_1 \qquad Ax = P \begin{bmatrix} Ax_1 \\ Ax_2 \end{bmatrix}$$

$$U = \begin{bmatrix} U_1 \\ U_2 \end{bmatrix} \qquad B = U_1 \Sigma V^{\mathrm{T}} \qquad C = U_2 U_1^{-1}$$

$$B: r \times n \qquad C: (m-r) \times r$$
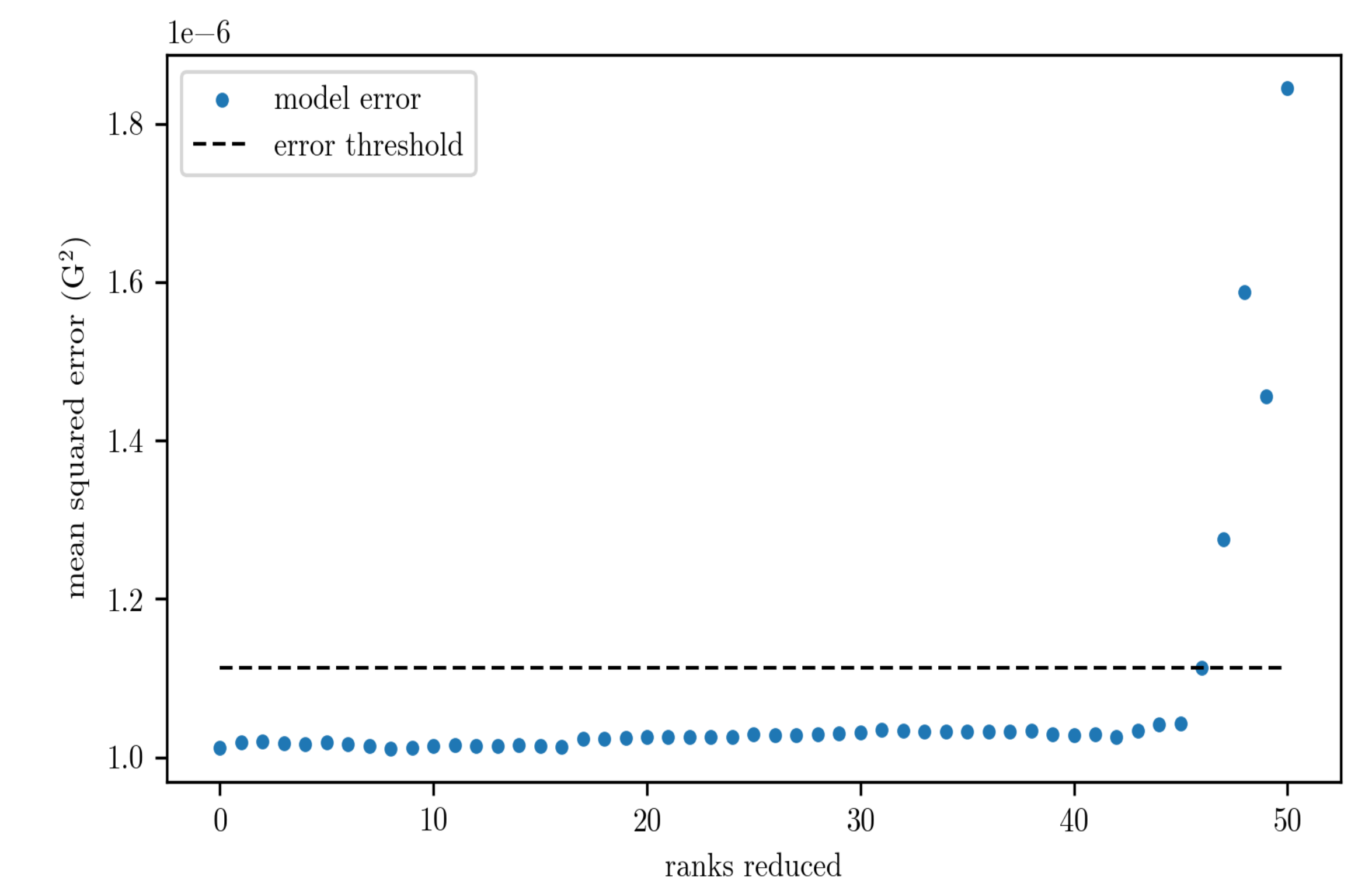
Degrees-of-freedom decomposition definition

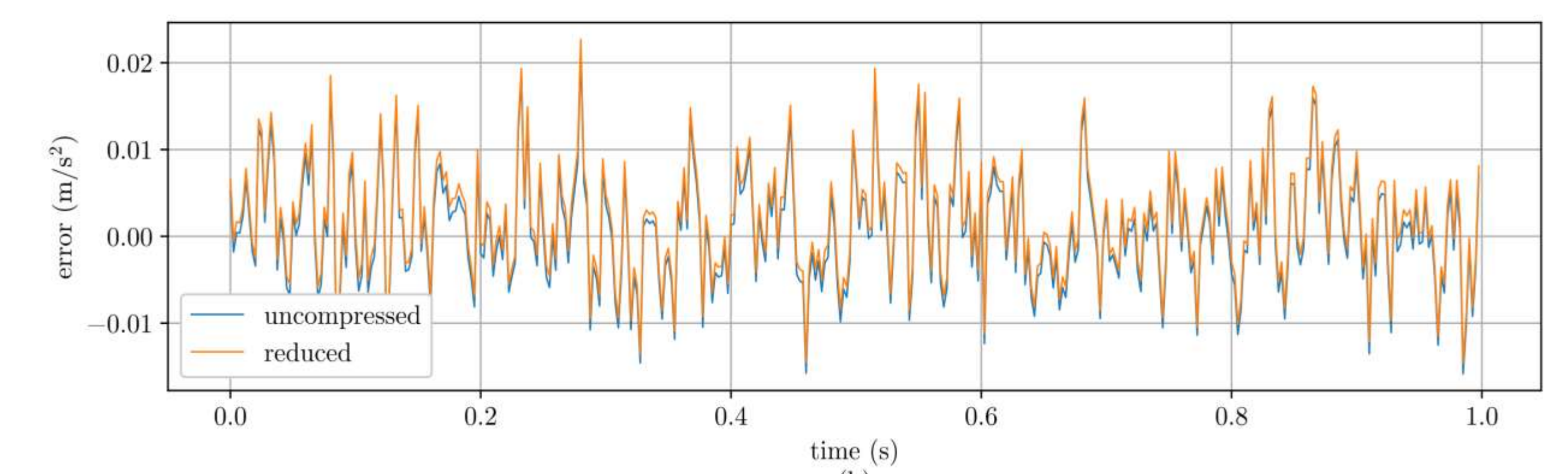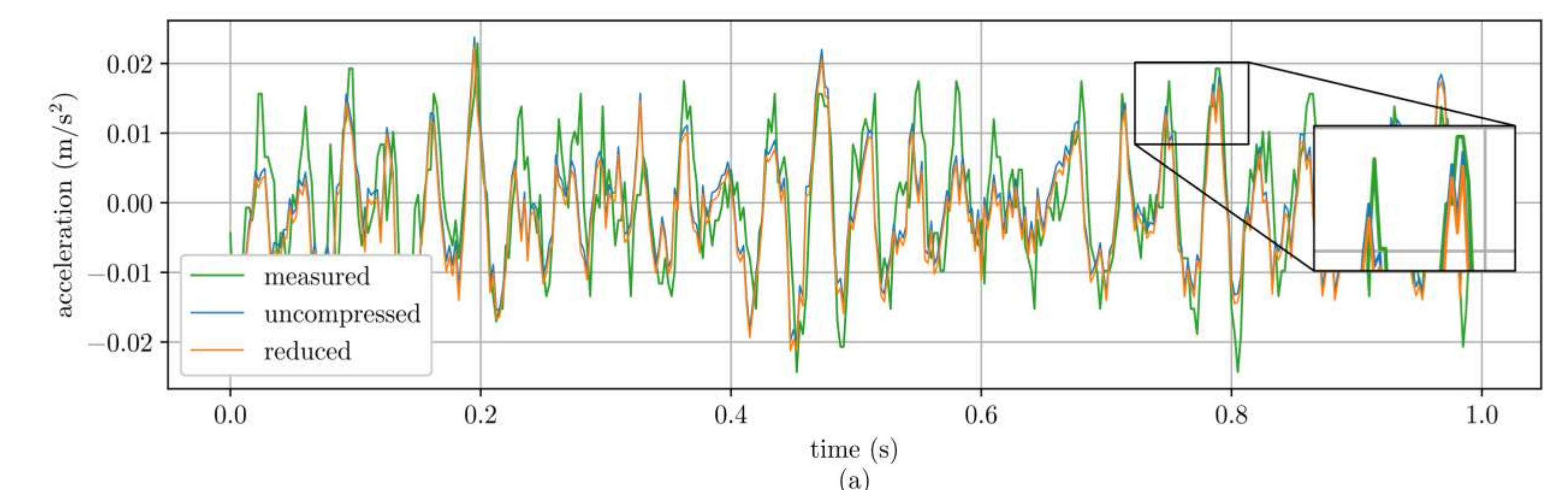Degrees-of-freedom matrix-vector multiplication

Compensation model parameter count

- Reduces the number of parameters and operations required for inference
- Removes barrier-to-entry associated with direct use of SVD
- Generalizable to any application requiring matrix-vector multiplication

Performance

Error by reduction amount

Model performance

Conclusion

- LSTM is shown to be an effective non-linear compensator
- The LSTM weight matrix was reduced from rank 51 to rank 6 using truncated SVD
- Degrees-of-freedom decomposition allowed for significant spatial and computational savings
  - Memory footprint improved to 6,884B from 41,804B
  - Inference latency improved to 40μs from 201μs

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