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MODELLING FOR MATERIALS PROCESSING
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Coupling simulation, sparse measurements and reconstruction in materials-processing flows

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Primary topic: Data-driven methods / Non-invasive measurements in MHD & ETP • **Keywords:** magnetohydrodynamics; electrothermal processing; inverse problems; flow diagnostics

Many materials-processing systems combine electromagnetic forcing, heat transfer, phase interfaces and opaque working media. Consequently, numerical models can resolve quantities that are difficult to observe directly, while experiments often provide only sparse or projected measurements. This example illustrates the intended MMP 2027 extended-abstract format through a generic model–measurement–reconstruction workflow. The purpose is not to prescribe a rigid article structure, but to show the level of technical detail that fits comfortably within the two-page limit.

MODEL AND RECONSTRUCTION WORKFLOW

Consider an incompressible electrically conducting liquid governed by

$$\nabla \cdot \boldsymbol{u} = 0, \tag{1}$$

$$\rho\,(\partial_t \boldsymbol{u} + \boldsymbol{u}\cdot\nabla\boldsymbol{u}) = -\nabla p + \mu\nabla^2\boldsymbol{u} + \boldsymbol{J}\times\boldsymbol{B}, \tag{2}$$

with electromagnetic and thermal submodels selected according to the process regime. A forward computation produces a state vector $\boldsymbol{x}$, whereas a measurement system observes only

$$\boldsymbol{y} = \mathcal{H}(\boldsymbol{x}) + \boldsymbol{\varepsilon}, \tag{3}$$

where $\mathcal{H}$ represents the diagnostic transfer operator and $\boldsymbol{\varepsilon}$ denotes measurement error. Reconstruction can then be posed as a regularized inverse problem

$$\widehat{\boldsymbol{x}} = \arg\min_{\boldsymbol{x}} \|\mathcal{H}(\boldsymbol{x}) - \boldsymbol{y}\|_2^2 + \lambda\,\mathcal{R}(\boldsymbol{x}). \tag{4}$$

The regularizer $\mathcal{R}$ may encode smoothness, low-rank structure, physical constraints or a reduced-order representation. Related approaches are widely used in model reduction and data assimilation [1, 2].

For an MMP contribution, the corresponding paragraph should summarize the specific numerical method, experiment, diagnostic system or data-driven model. Where possible, report quantitative settings such as mesh resolution, sampling rate, magnetic-field magnitude, heating power, nondimensional parameters or error metrics. A compact figure is encouraged when it communicates the main result more effectively than additional prose.

RESULT AND SIGNIFICANCE

A strong extended abstract should make the principal result explicit rather than merely promise future work. For example, one could report that a reduced measurement set retains a stated fraction of the reference-field accuracy,

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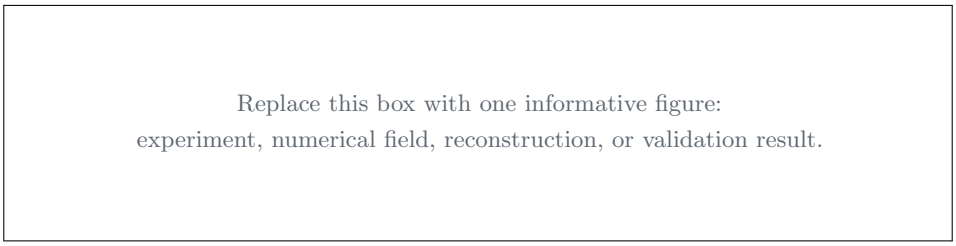


FIG. 1. Example placeholder for a single compact result figure. Captions should explain the displayed quantity and the principal observation.

or that a coupled ETP/MHD simulation reproduces a measured flow or temperature feature within a quantified uncertainty. Comparisons against experiments, reference simulations or established models are particularly valuable.

The MMP 2027 programme spans electrothermal processing, applied and fundamental MHD, CFD and multiphysics methods, non-invasive diagnostics, and data-driven methods. Contributions that connect two or more of these areas are welcome. The template is therefore deliberately neutral with respect to whether the main contribution is theoretical, numerical, experimental or methodological.

Acknowledgements. Acknowledgements are optional and count toward the two-page limit.

[1] P. Holmes, J. L. Lumley, G. Berkooz, and C. W. Rowley, *Turbulence, Coherent Structures, Dynamical Systems and Symmetry*, 2nd ed. (Cambridge University Press, 2012).
[2] S. L. Brunton and J. N. Kutz, *Data-Driven Science and Engineering* (Cambridge University Press, 2019).