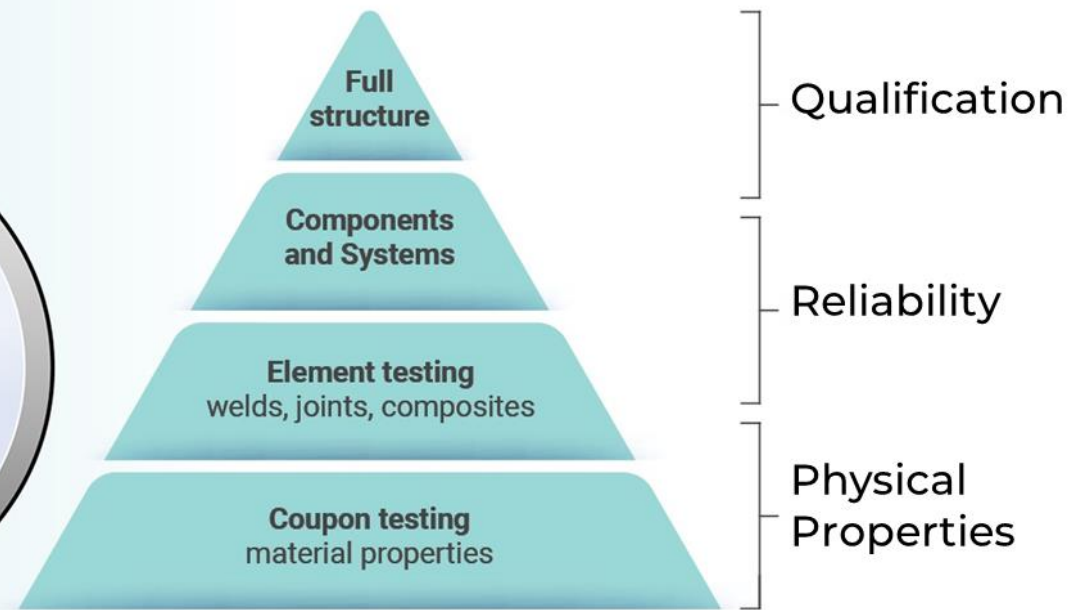
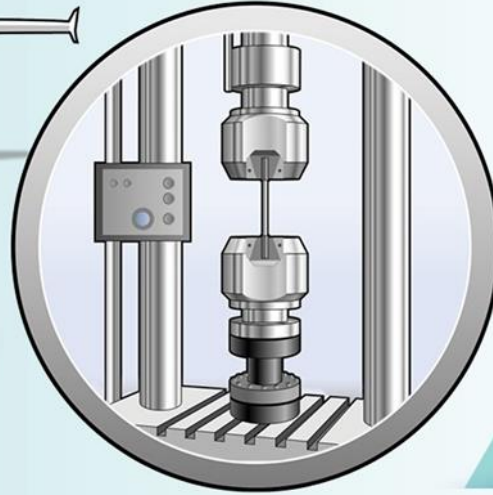
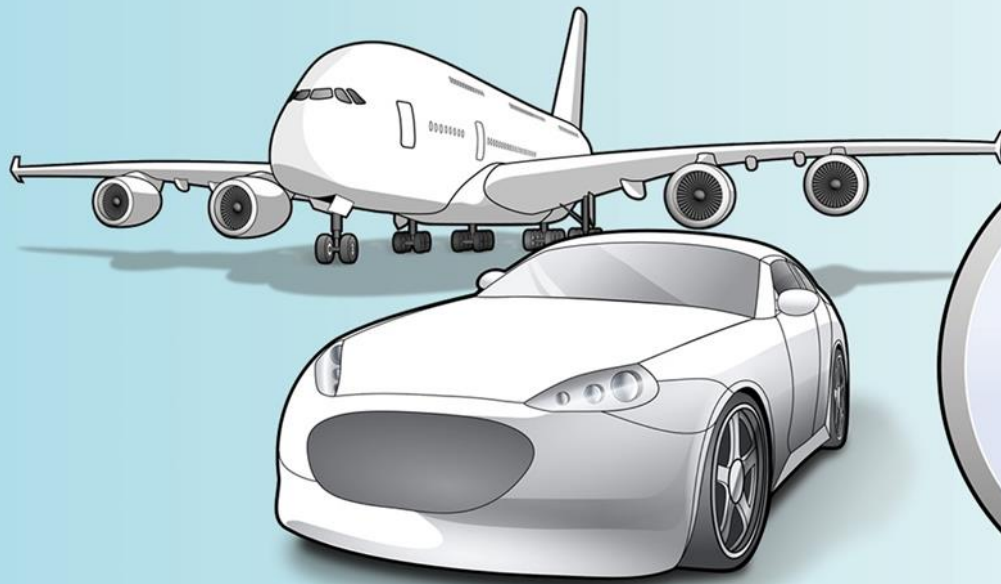




2023 HBK Technology Days

7 November 2023



- University of Sheffield Laboratory for Verification and Validation aircraft digital twin research and capability

Dr. Timothy Rogers,
Senior Lecturer in Mechanical Engineering,
University of Sheffield

University of Sheffield Laboratory for Verification and Validation aircraft digital twin research and capability

Abstract

- This presentation will look at recent work carried out at The University of Sheffield Laboratory for Verification and Validation (<https://lvv.ac.uk/>), in which the dynamics of a Hawk T1A aircraft were investigated with the aim of constructing a digital twin of this legacy asset. The understanding of this aircraft has been approached, in this project, from the viewpoint of structural dynamics. In the presentation the setup of these tests and subsequent analysis will be discussed. Rather than providing a blueprint for the construction of aerospace digital twins, this presentation will outline some of the outstanding questions and challenges with an aim to initiate discussion on where future efforts by academia and industry might be directed.

About the presenter, Dr. Timothy Rogers, Senior Lecturer in Mechanical Engineering, University of Sheffield

- Dr Timothy Rogers is a senior lecturer in the Dynamics Research Group (DRG), part of the Department of Mechanical Engineering at The University of Sheffield. He has completed both his MEng in Mechanical Engineering and his PhD at Sheffield, the title of which was "Towards Bayesian System Identification: With Application to SHM of Offshore Structures". His work focuses on application of Machine Learning and Bayesian statistical methods to problems in structural dynamics, in particular those within nonlinear system identification and Structural Health Monitoring (SHM). His current research interests include: machine learning for structural dynamics and Structural Health Monitoring; Bayesian statistical modelling of structural systems; probabilistic nonlinear system identification; joint input/state/parameter identification.



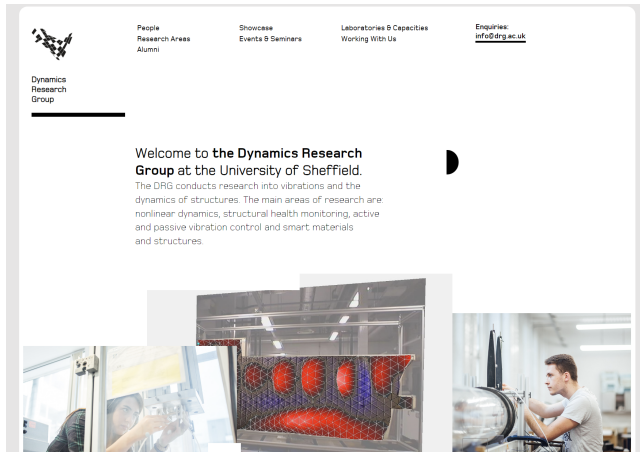
University of
Sheffield

Developing an Aircraft Digital Twin: Challenges in Testing, Verification and Validation

T. J. Rogers, M. Haywood-Alexander, & D. Wagg

November, 2023





LABORATORY FOR VERIFICATION & VALIDATION



Laboratory for
Verification and
Validation

About LVV
Announcements

Capabilities
LVV Events

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Explore 3D space



Welcome to the LVV

The Structural Dynamics Laboratory for Verification and Validation (LVV) is a major **new acoustics and vibration testing facility** funded by the Engineering and Physical Sciences Research Council (EPSRC), the European Regional Development Fund (ERDF) and the University of Sheffield. The facility provides a **unique research offering** to academia and industry. In addition to allowing dynamic testing of full-scale structures in ambient laboratory conditions, the LVV offers the opportunity to test substantial structures, sub-structures and components in **realistic environments**.

Led by the Dynamics Research Group (DRG) in the University's Department of Mechanical Engineering, the laboratory will offer significant benefits across a range of industrial sectors including energy, aerospace, automotive, renewables and civil engineering.



Things the DRG has been interested in for 20+ years:

- ▶ Accurate modelling of physical systems:
 - Nonlinear Dynamics
 - Damping
 - Acoustics
- ▶ Using models to understand performance:
 - Structural Health Monitoring
 - Informing design and operation
- ▶ Including data into these processes



We can consider **two** key drivers:

1. A more holistic approach to engineering asset creation and management
2. Increasing “Engineering As A Service”



LONGEVITY OF DIGITAL TWIN RESEARCH

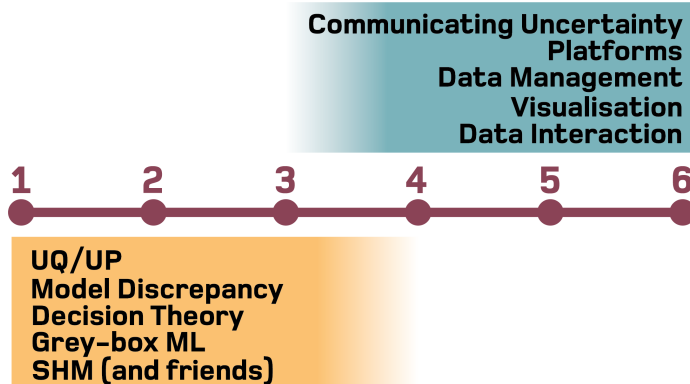
Digital twins have a shelf life. . .



LONGEVITY OF DIGITAL TWIN RESEARCH

Digital twins have a shelf life. . .

But the core technology challenges will remain.



A Case Study



THE HAWK T1A



Aims:

1. Provide a “full-scale” demonstrator/benchmark for aerospace digital twins
2. Understand the dynamic behaviour of the Hawk T1A aircraft
3. Explore the role of digital twins for management of existing assets

Output: Dynamic test data from a range of excitation conditions, with and without simulated performance anomalies, an associated demonstration platform for integration of this test data and exemplar models.



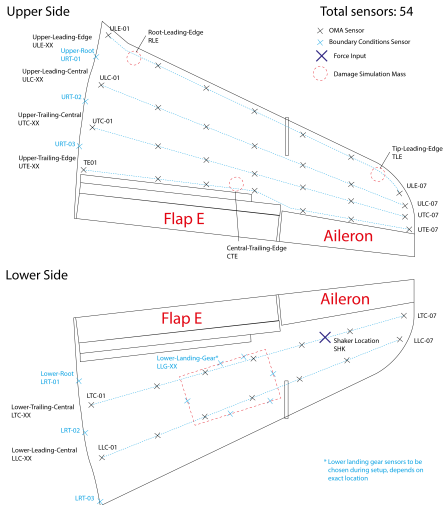
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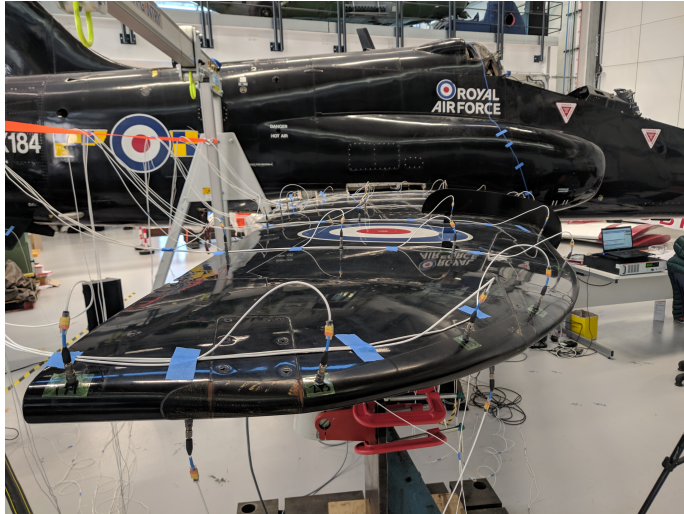


SENSING

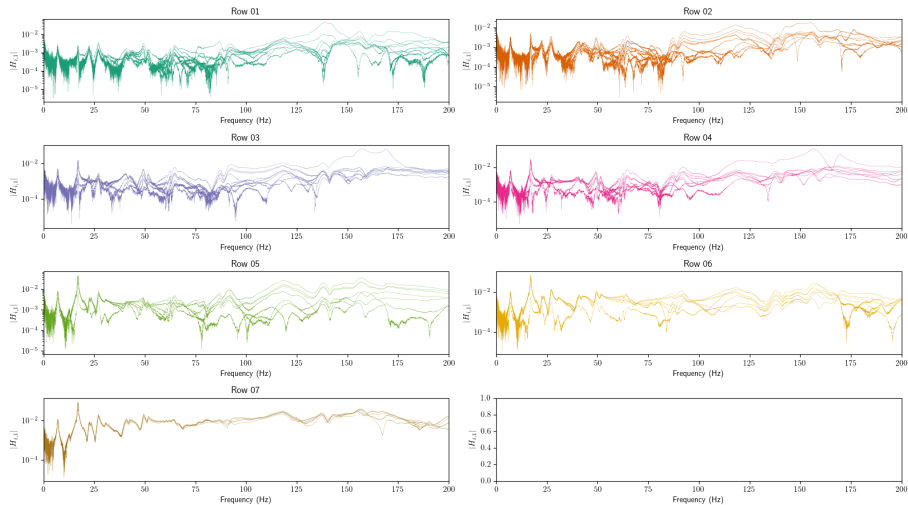




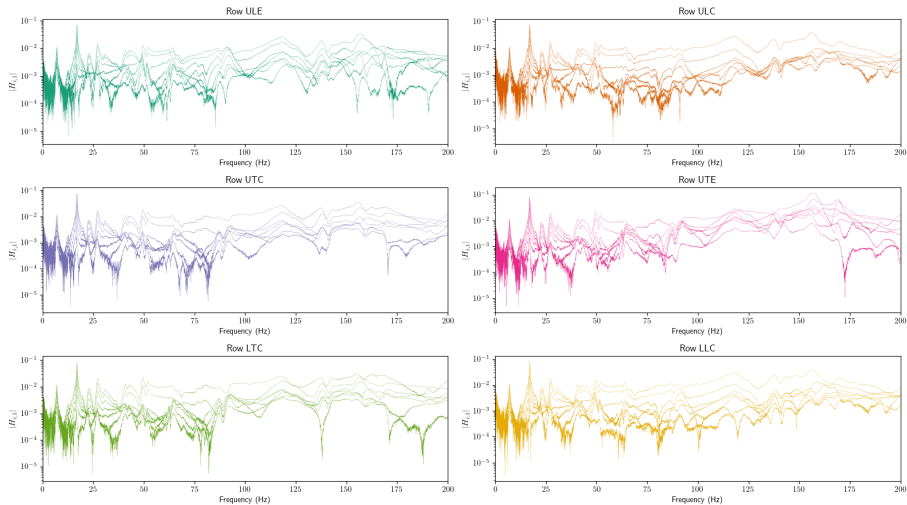
TEST SETUP



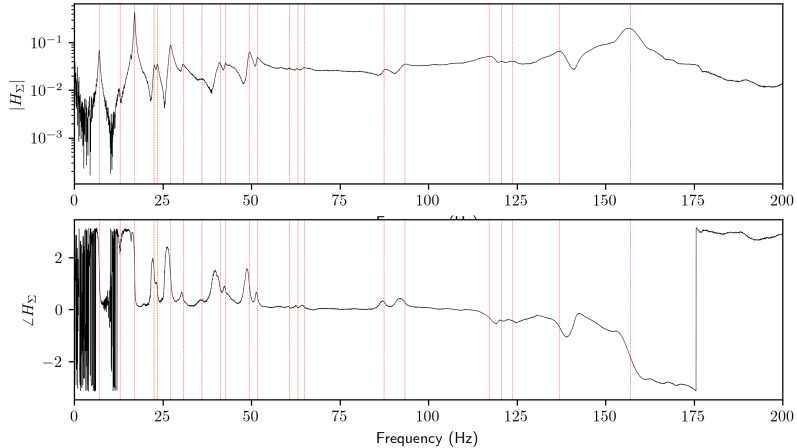
RAW OUTPUTS



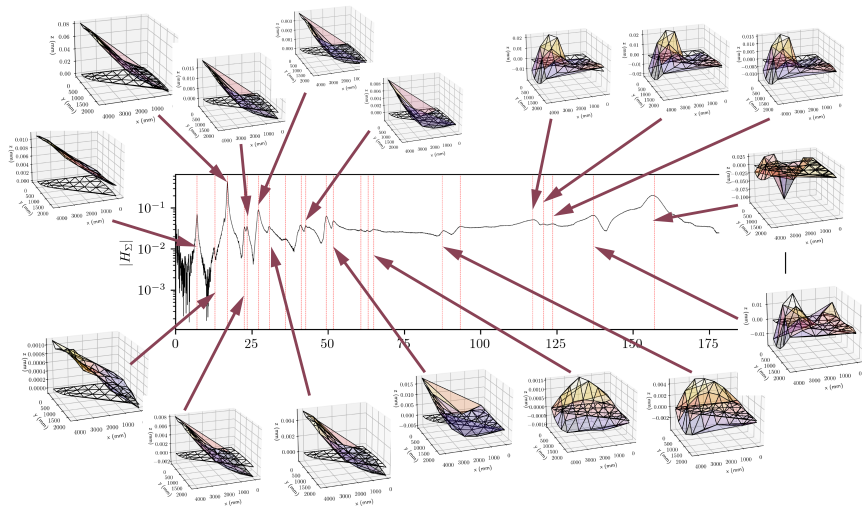
RAW OUTPUTS



SYSTEM IDENTIFICATION

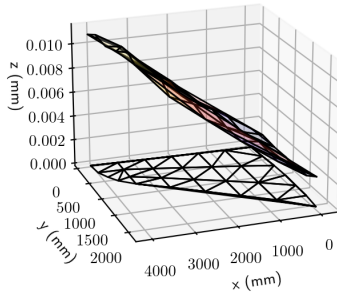


SYSTEM IDENTIFICATION

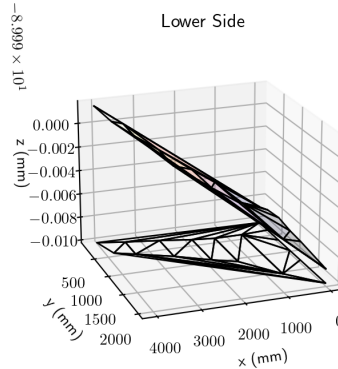


Mode 0 @ 7.021Hz

Upper Side

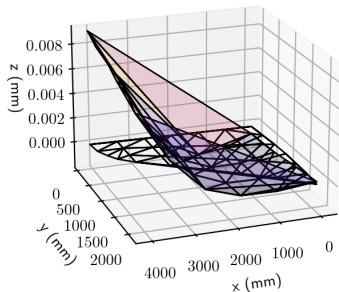


Lower Side

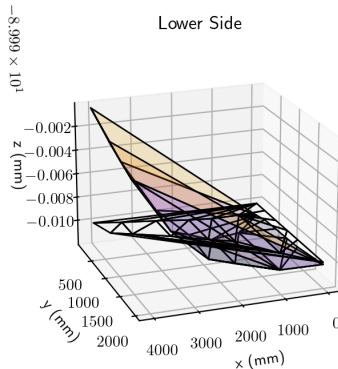


Mode 8 @ 41.196Hz

Upper Side

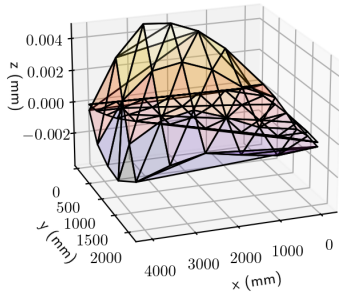


Lower Side

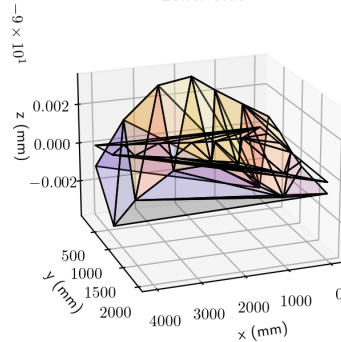


Mode 15 @ 87.451Hz

Upper Side

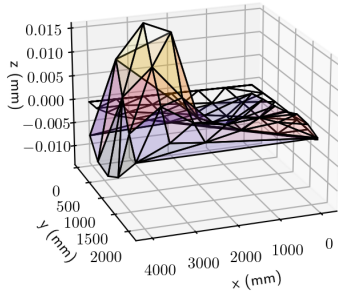


Lower Side

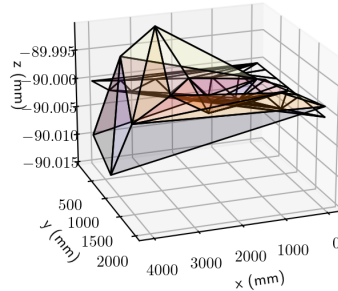


Mode 19 @ 123.681Hz

Upper Side

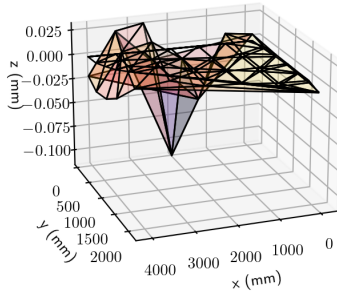


Lower Side

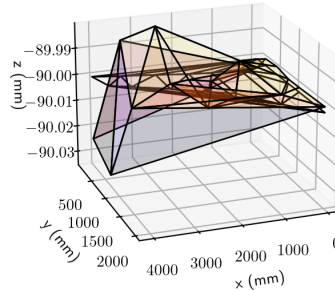


Mode 21 @ 156.994Hz

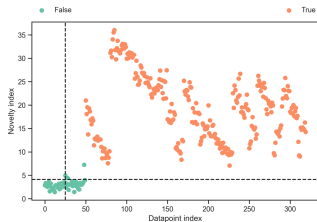
Upper Side



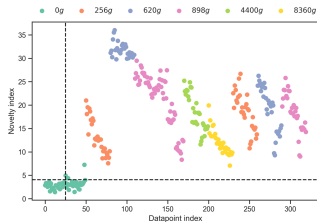
Lower Side



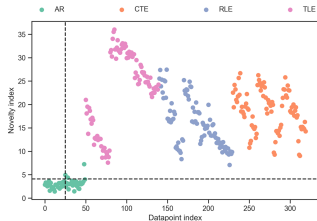
DAMAGE DETECTION



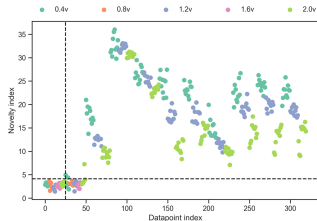
(a) Presence of damage.



(b) Added mass amount.



(c) Damage location.



(d) Excitation level.



OUTSTANDING CHALLENGES

- ▶ Infrastructure for testing and data
- ▶ Operationally representative conditions
- ▶ Automation of analysis
- ▶ Interoperability
- ▶ Multi-physics/multi-scale systems
- ▶ Decision support



- ▶ Please get in touch with me or Charlie Field (c.w.field@lvv.ac.uk)
- ▶ We have a paper under review, preprint at <https://arxiv.org/abs/2310.04478>
- ▶ Technical report and data available at <https://doi.org/10.15131/shef.data.22710040.v1>

Full-scale modal testing of a Hawk T1A aircraft for benchmarking vibration-based methods

Marcus Haywood-Alexander^{a,b,1,*}, Robin S. Mills^a, Max D. Champneys^a, Matthew R. Jones^a, Matthew S. Bonney^a, David Wagg^{a,c}, Timothy J. Rogers^a

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^b*Chair of Structural Mechanics and Monitoring, ETH Zurich, Wolfgang-Pauli-Strasse, Zurich, 8049, Switzerland*

^c*The Alan Turing Institute, London, NW1 2DB, UK*

Abstract

Research developments for structural dynamics in the fields of design, system identification and structural health monitoring (SHM) have dramatically expanded the bounds of what can be learned from measured vibration data. However, significant challenges remain in the tasks of identification, prediction and evaluation of full-scale structures. A significant aid in the roadmap to the application of cutting-edge methods to the demands of in-service engineering structures, is the development of comprehensive benchmark datasets. With the aim of developing a useful and worthwhile benchmark dataset for structural dynamics, an extensive testing campaign is presented here. This recent campaign was performed on a decommissioned BAE system Hawk T1A aircraft at the Laboratory for Verification and Validation (LVV) in Sheffield. The aim of this paper is to present the dataset, providing details on the structure, experimental design, and data acquired. The collected data is made freely and openly available with the intention that it serve as a benchmark dataset for challenges in full-scale structural dynamics. Here, the details pertaining to two test phases (frequency and time domain) are presented. So as to ensure that the presented dataset is able to function as a benchmark, some baseline-level results are additionally presented for the tasks of identification and prediction, using standard approaches. It is envisaged that advanced methodologies will demonstrate superiority by favourable comparison with the results presented here. Finally, some dataset-specific challenges are described, with a view to form a hierarchy of tasks and frame discussion over their relative difficulty.

Keywords: Modal testing, Hawk T1A, Full-scale dynamic testing, Shaker test, SIMO





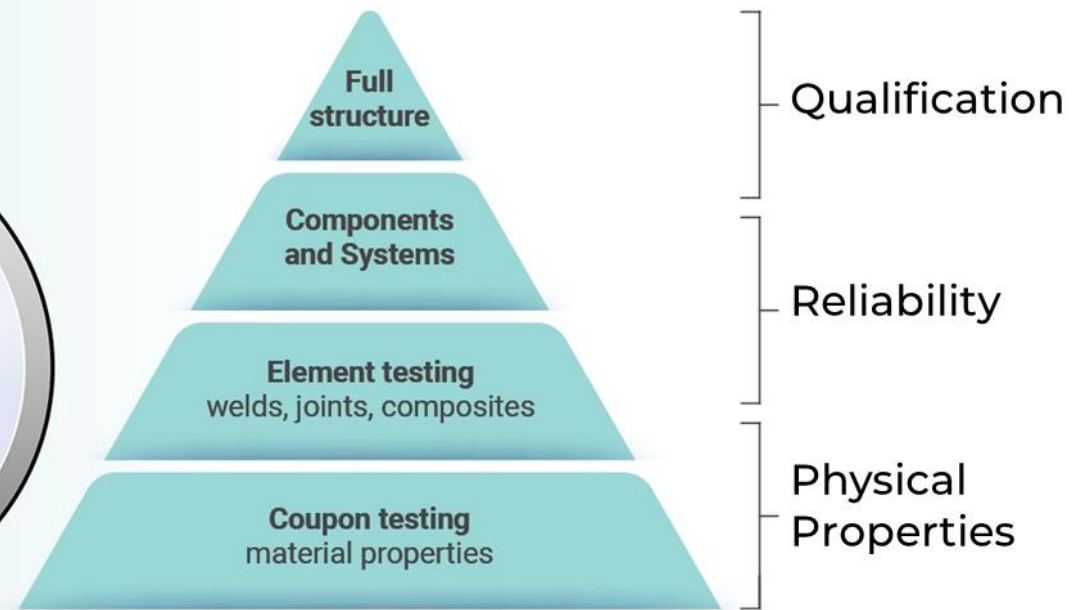
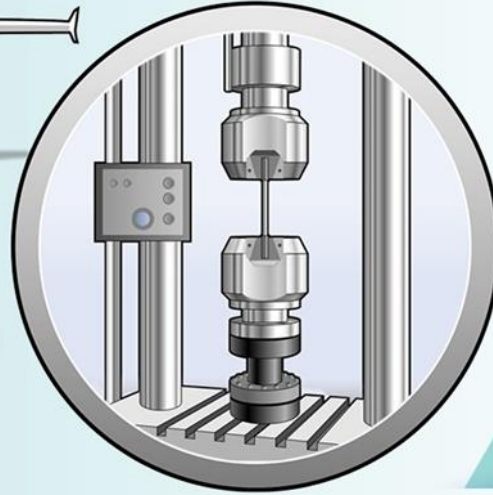
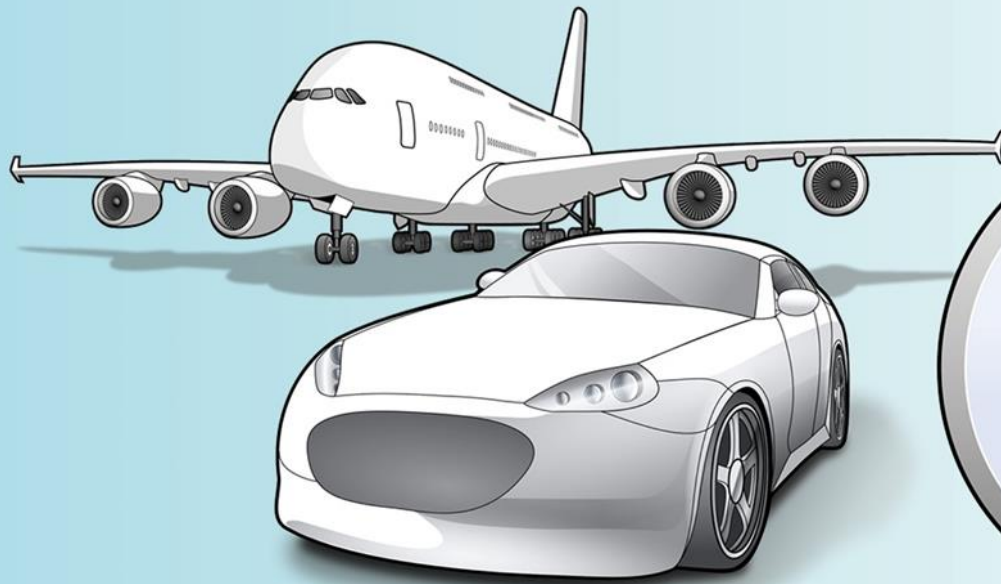
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