Digital Twins for Aviation Fleets: Introduction

- Perceived value of Digital Twins in Aviation
- Lessons learnt from recent applications
  - And maybe why not so simple…
- Aviation Interfaces to DAFNI
  - Airspace / airport infrastructure modelling / prediction
  - Understanding and optimising technical-social impacts of future disruptive technologies in aviation
    - Urban air mobility scenario modelling
    - Grid interface for electric storage
    - …

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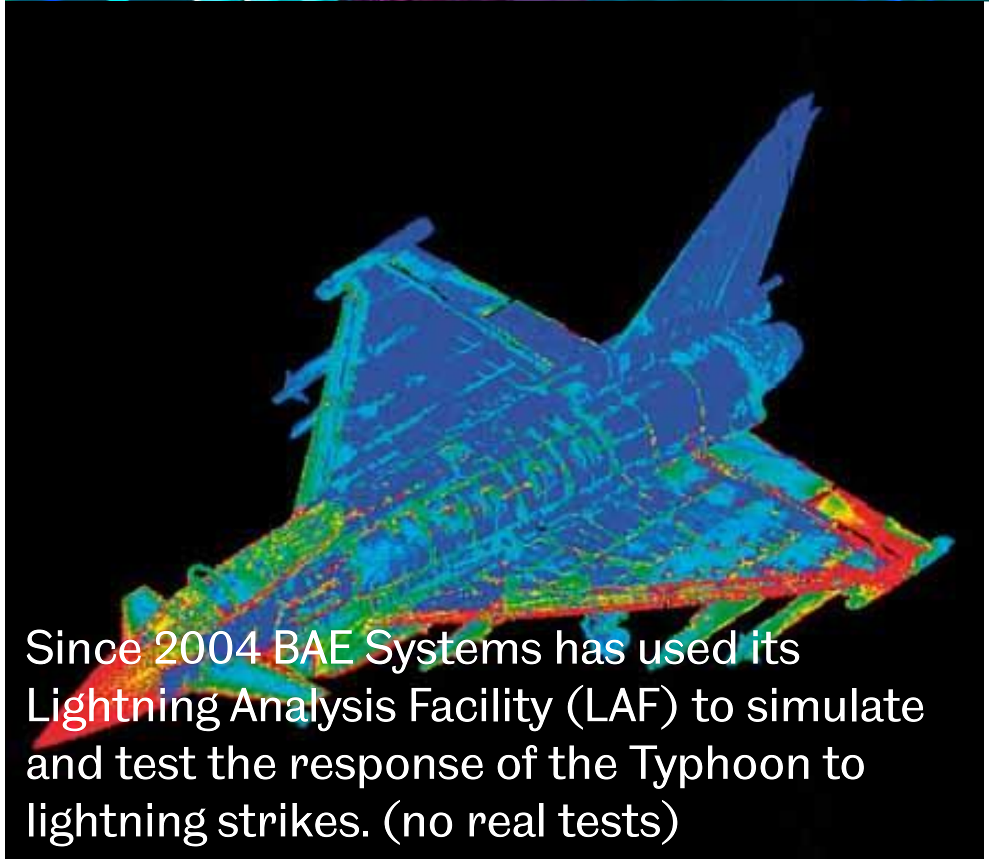
Rolls-Royce | Pioneering the IntelligentEngine with R2 Data Labs, https://www.youtube.com/watch?v=ikq2VyzWoX0

Aviation Digital Twins

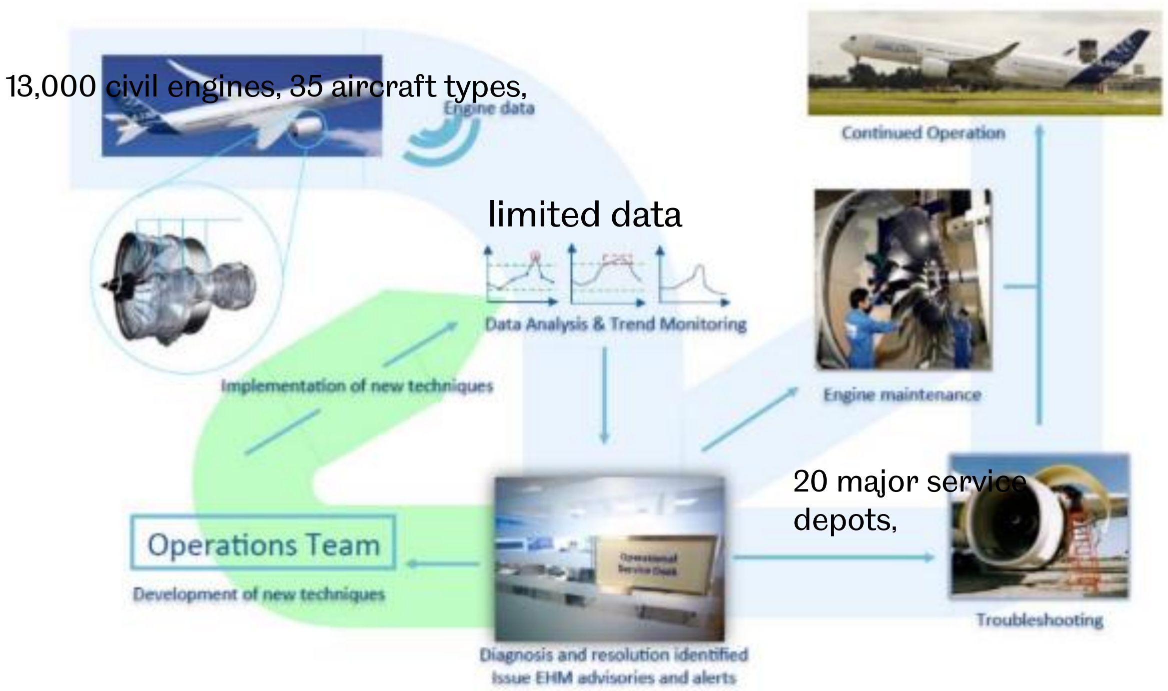
- Rebranding 'modelling' isn't going to bring development time / costs down!
- However trusted models + data is powerful
  - 'As built' models
    - Manufactured components tolerance→ virtual optimised integrations, individual deterioration mechanisms, …
  - 'As operated' models
    - Actual usage → optimised design mods, better predictions, …
    - Actual performance → anomaly detection, 'biological age', …
    - Actual operations → asset maintenance decisions, airspace management

https://www.rolls-royce.com/media/our-stories/discover/2019/how-digital-twin-technology-can-enhance-aviation.aspx

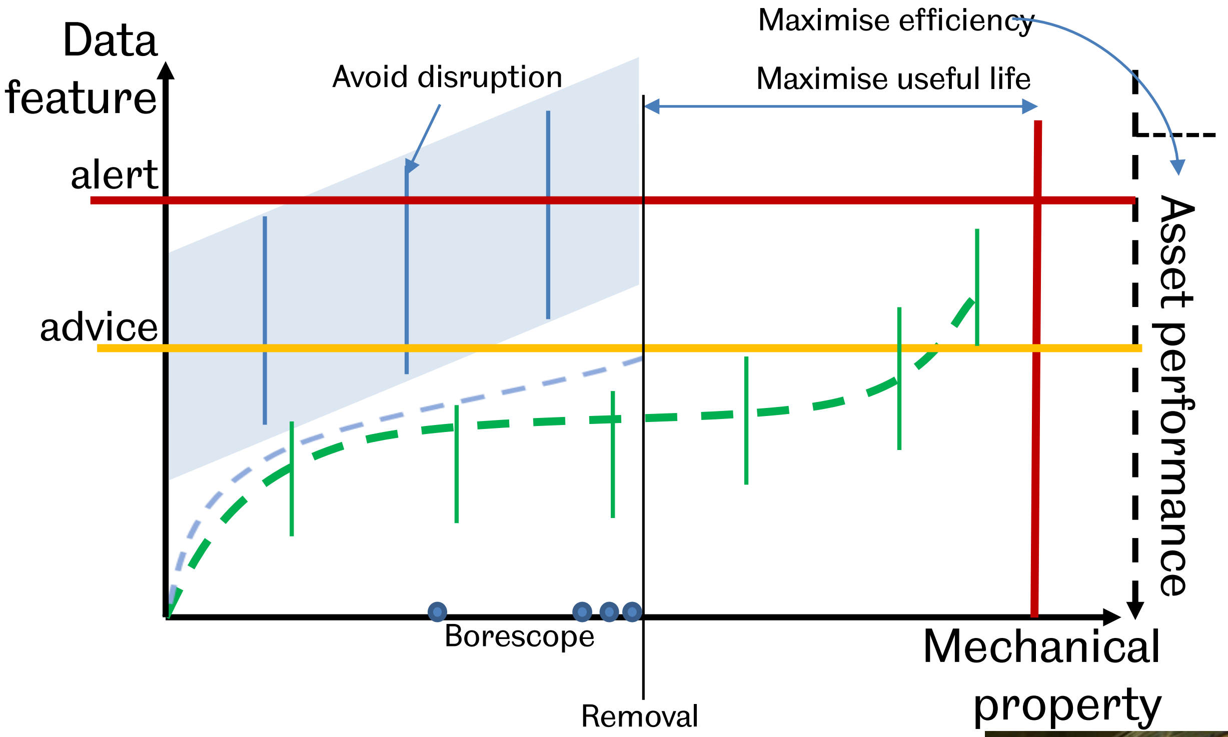


Since 2004 BAE Systems has used its Lightning Analysis Facility (LAF) to simulate and test the response of the Typhoon to lightning strikes. (no real tests)

Remote Asset Management



Source: Palmer, T. (2015), Rolls-Royce plc



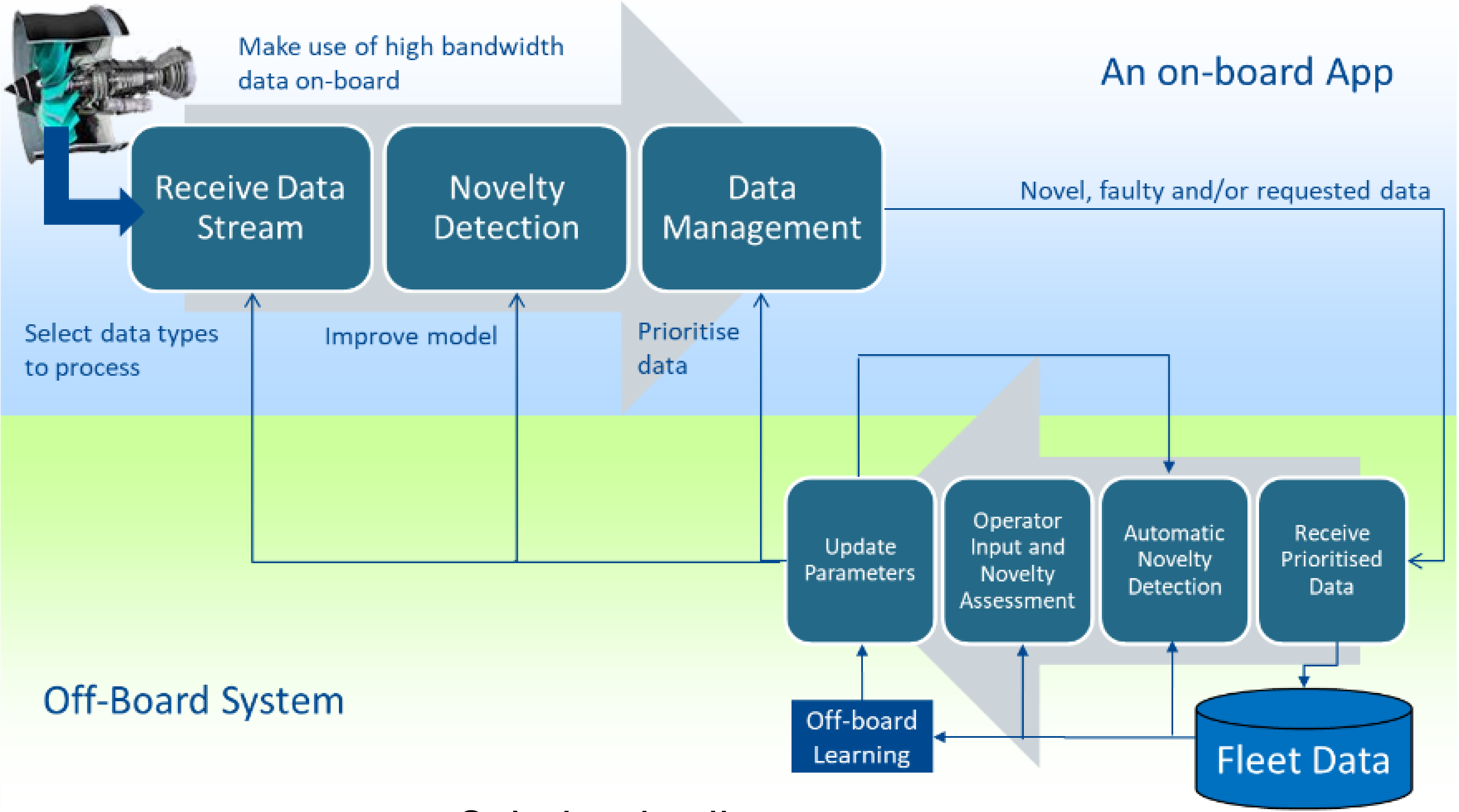
Today:
Data features (for faults, performance, etc) based on nominal relationships, thresholds set on fleet behaviour, asset performance measures inaccurate, large data sets are a burden

Future systems will:
Calculate true asset performance
Model mechanical properties for as built system
Incorporate all measurements and asset management
Allow control and operational adjustments to be modelled

Solution Concept – Adaptive data acquisition

Challenges

- Accuracy in simulation at all times (target ~1%)
- Plant complexity, variability, noise
- Constraints – bandwidth, compute, on-board memory
- Separations of degradation and faults
- Data completeness – non-connectivity, 'dirty data',
- Security and regulations (e.g. Export Control)
- Trust, transparency, translation of solution (verifiable with available data)

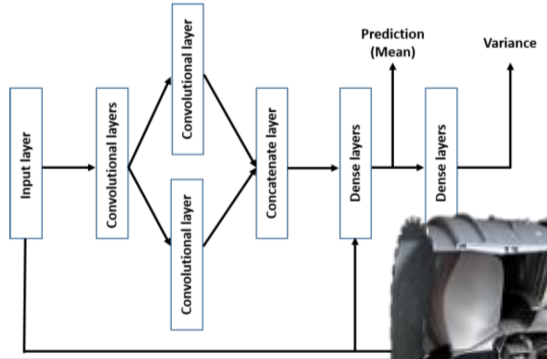


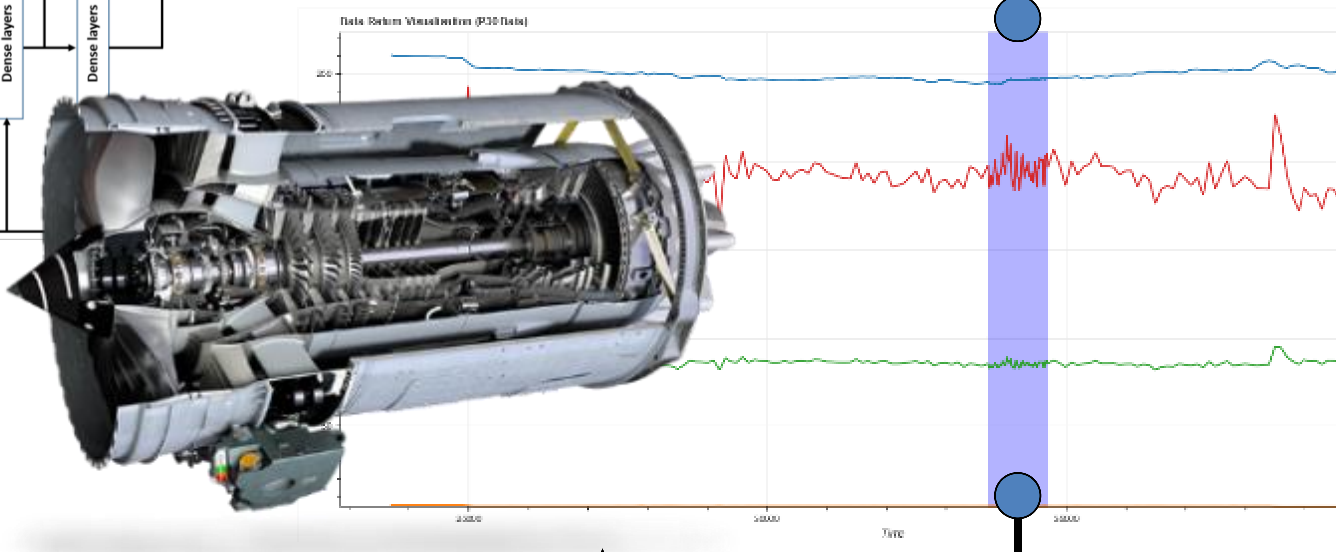
Solution Attributes

- Embedded / edge deep models using TensorFlow Lite
- Fleet and multi-scale aspects → transfer learning
- Data selection → Active learning

Implementation Overview

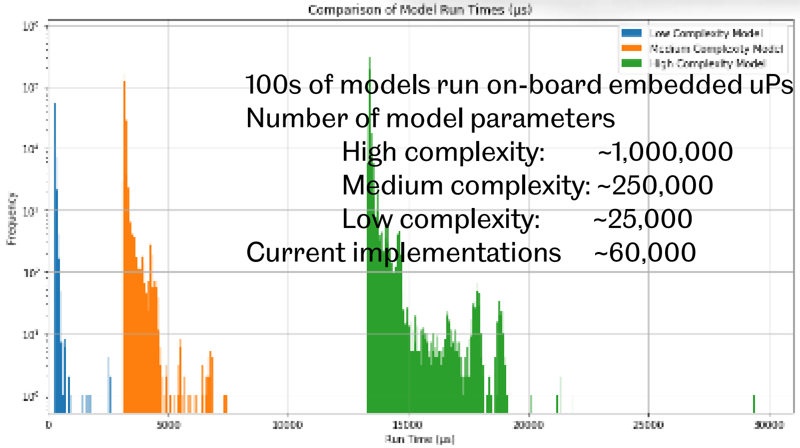
Control System Comms



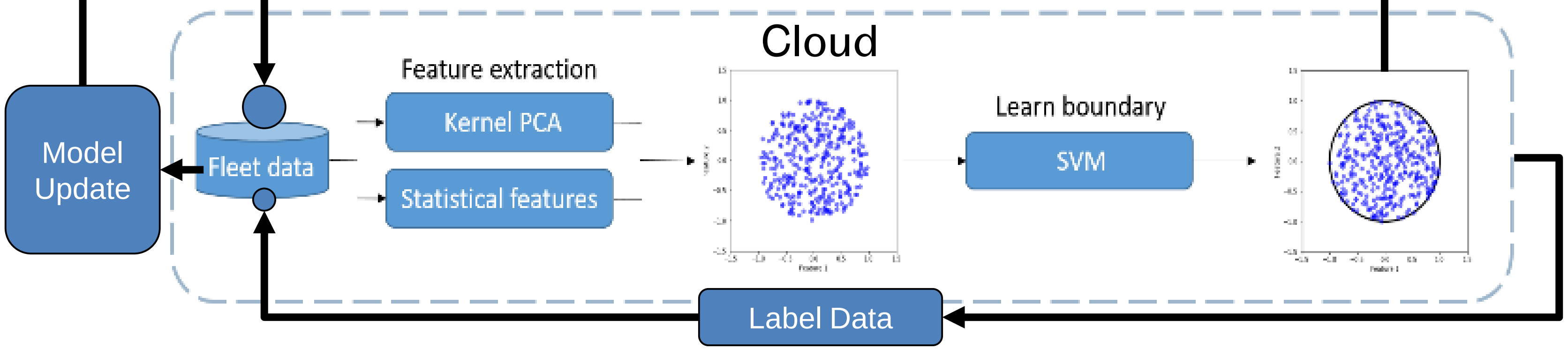


- Novel and uncertain data identified
- Returned to ground in higher volumes than conventional data streams.
- May be visualised, automatically processed or stored as labelled archive

Aircraft Comms



100s of models run on-board embedded uPs
Number of model parameters
High complexity: ~1,000,000
Medium complexity: ~250,000
Low complexity: ~25,000
Current implementations ~60,000



Summary

- Digital twins should be 'as-built' or 'as-operated' simulation models.
- Digital twins require data assimilation often under constraints
  - ‘Closed-loop’ data acquisition demonstrated to TRL-4
  - Currently scheduled for flight trial → TRL-6
- Models will be used for what-if assessments and optimisation
- Acknowledgements
  - Adam Hartwell (on-board deep learning)
  - Felipe Montana (off-board triage of data)
  - Will Jacobs (system design)
- Papers

  - Montana F., Hartwell A., Jacobs W., Mills A. (2021). Through-life Learning with Digital Twins in Resource-constrained Systems and Fleets. Unpublished.
  - Hartwell A., Montana F., Jacobs W., Mills A. (2021). Data-Driven, Real-time, Embedded Anomaly Detection for Time Series Gas Turbine Data Using Convolutional Neural Networks. Unpublished.