AVT-373 Research Specialist Meeting on Emerging Technologies for Proactive Corrosion Maintenance

Maintenance Oriented Corrosion Severity for Aircraft Predictive Maintenance Tool 'CorroVision'

Nabil Humphrey & Darren Roles - Australia

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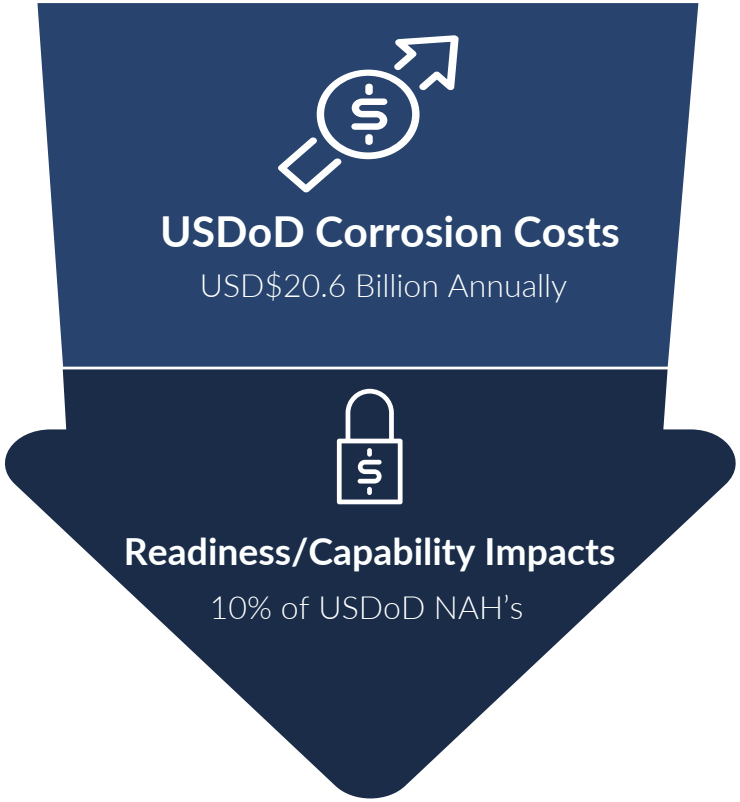
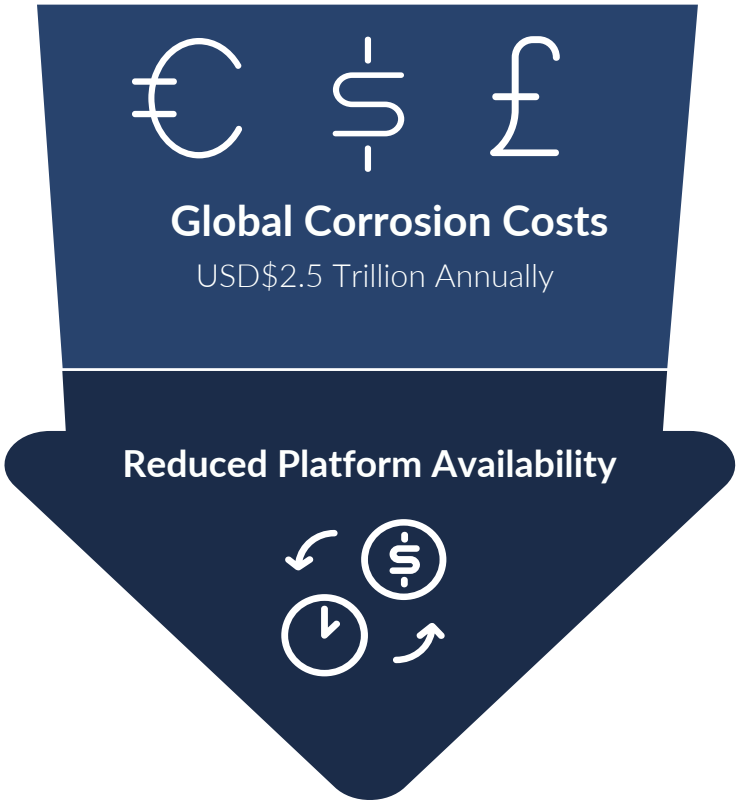
The Corrosion Problem





Decreased Readiness/Availability

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Operational Readiness & Availability Impacts

Impacts to sustainment costs

- 60% of platform life-cycle costs are sustainment related
- Platform impacts
  - Critical assets are unavailable for operational use.
  - Decreased mission success.
  - Expedited resources come at a premium cost.
  - Unplanned maintenance disrupts planned budgets and allocations.
  - Reputational decline.
  - Competitors with proactive strategies gain a competitive edge

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A little bit of history…

- RAAF Orion Fleet
  - ➢ Corrosion servicing
    - 2 day schedule @ 6mths
    - 4 week actual
  - ➢ Wide area CIC application
    - Maintenance involvement
    - Optimised implementation
    - Improved data fidelity
    - Interval extended to 12mths
    - Manual trending & data analysis

Platform availability **>10%**

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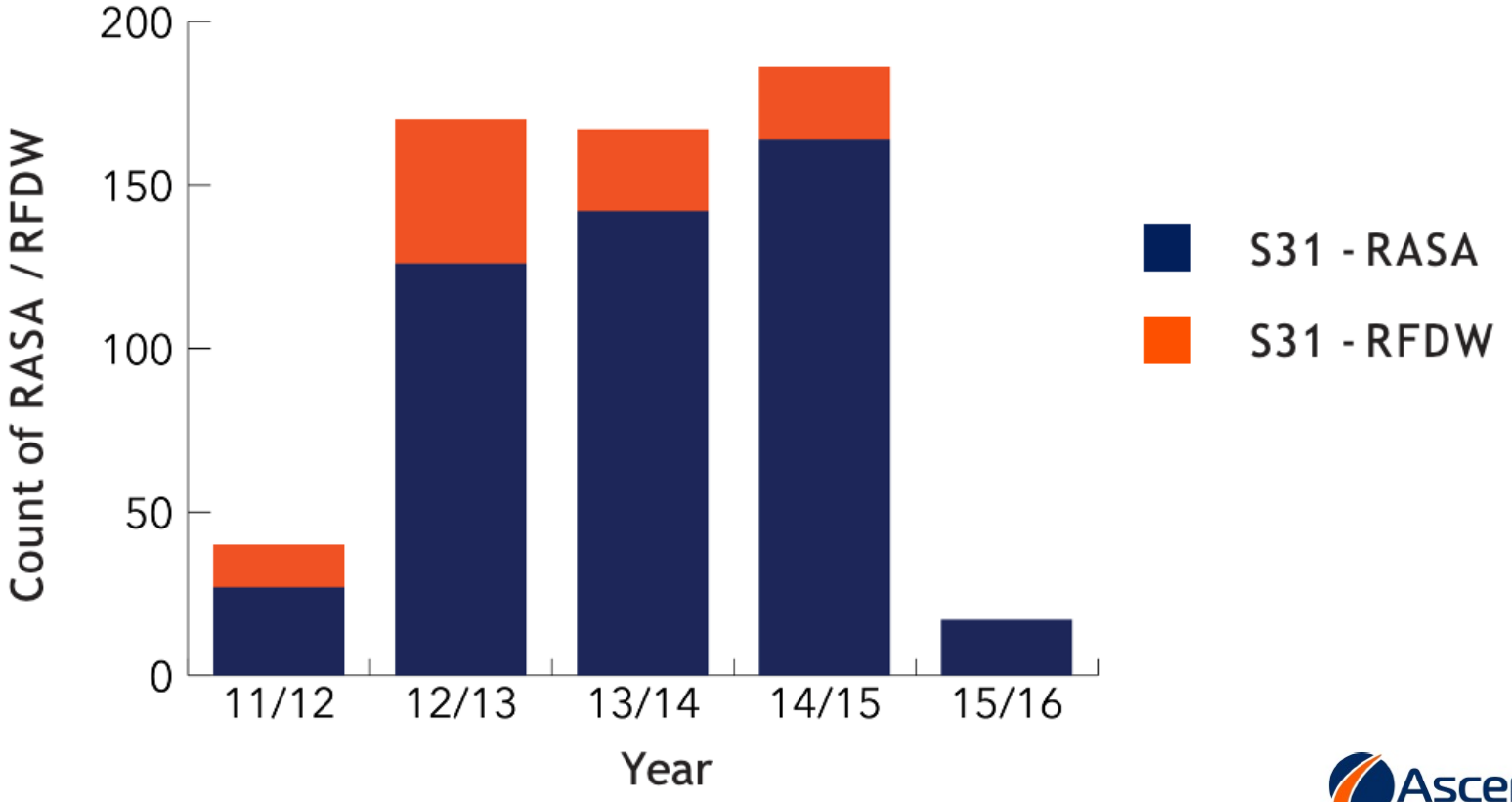

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AI - A Transformative Approach

Revolutionise corrosion management with AI/ML

- **Big Data Utilisation:** Platform Agnostic Predictive Insights
- **Collaboration:** AI/ML Experts and Industry Professionals
- **Predicting Trends:** Historical Data Analysis
- **Identifying Hotspots:** Targeted Prevention
- **Authoritative Decisions:** Data-Driven Insights
- **Real-world Case Studies:** Successful Implementation

But how?

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CorroVision

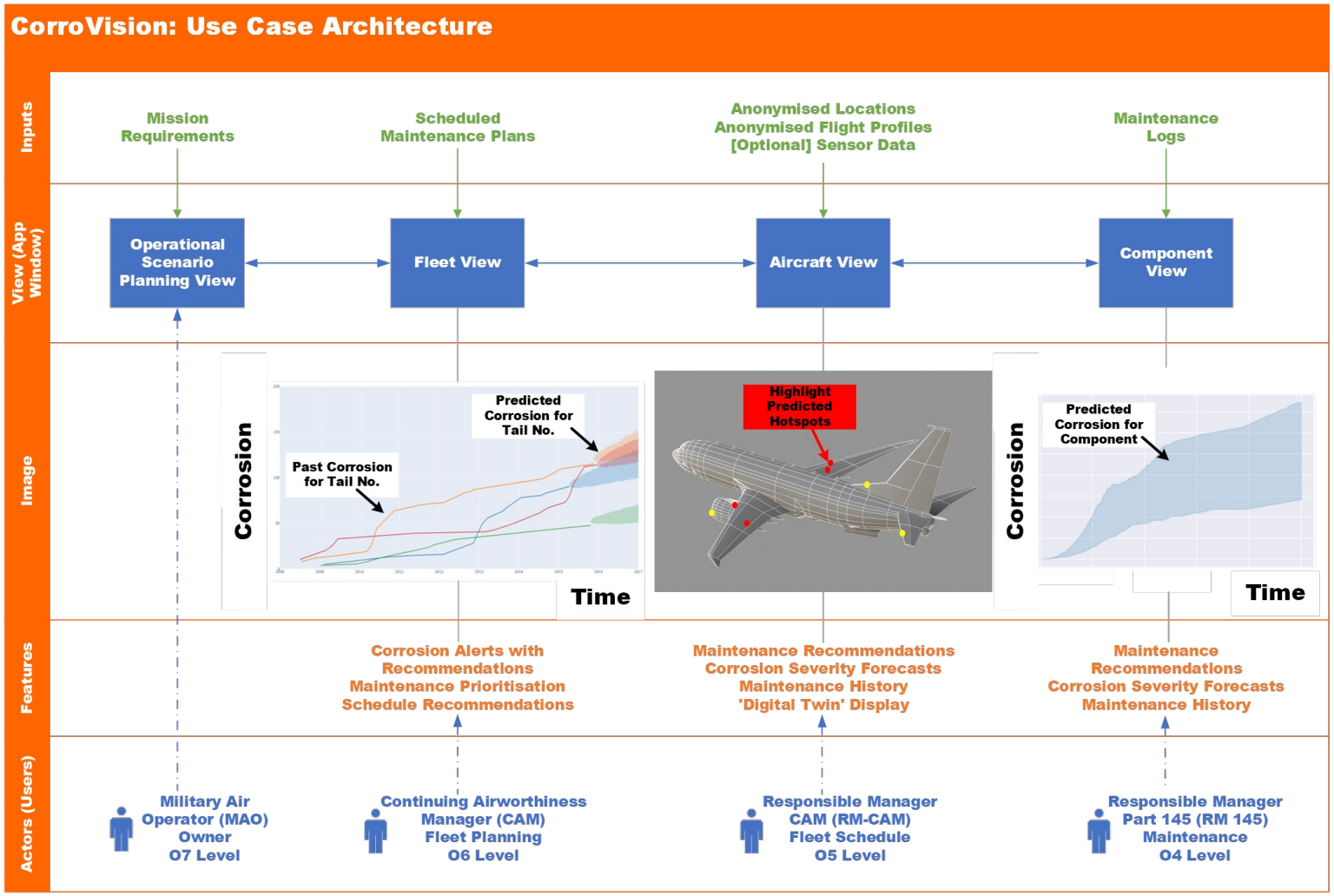
eXplainable Artificial Intelligence (XAI)

- Auditable whitebox system
- Can interrogate each subsystem against an objective standard
- As a result, the output is 'credible data'

Predictive Analytics

- Provides quantified, probabilistic predictions of future operational conditions & requirements
- Empower decision-makers rather than replace them

Use-Case Architecture



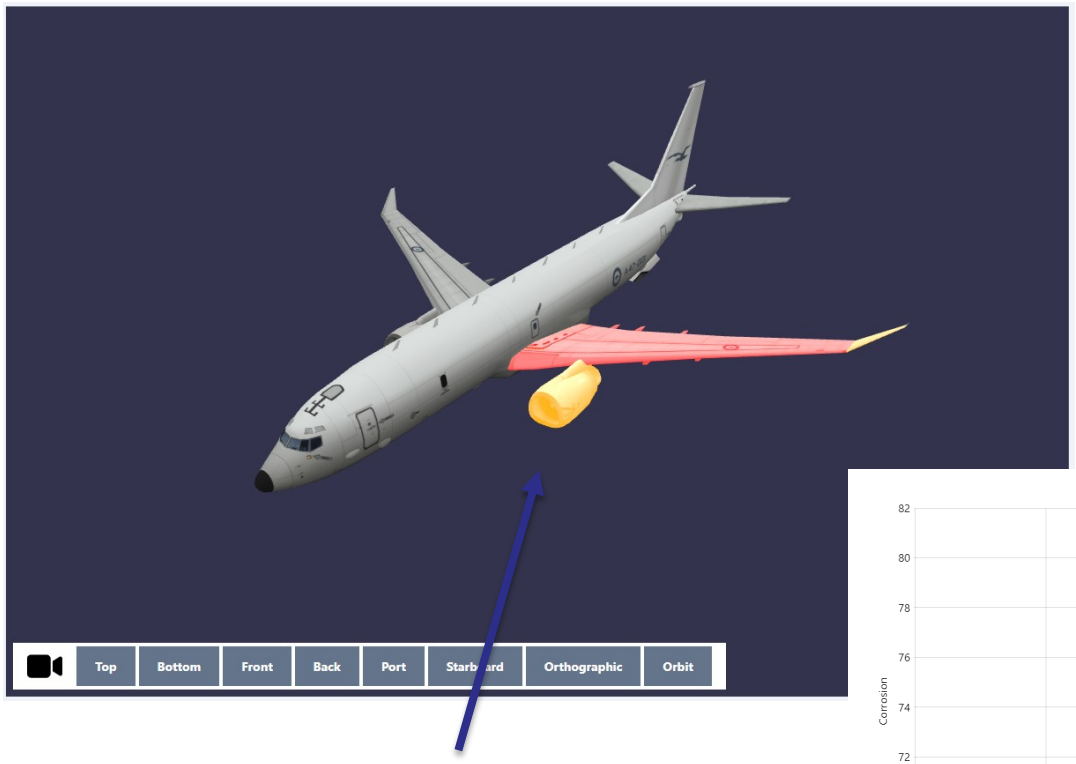
Data Inputs

- **Corrosion Maintenance Logs:** History of scheduled and unscheduled corrosion inspections indexed by a detailed assembly parts hierarchy.
- **Base Location Logs:** Anonymised with flight profile logs to form an overall usage severity index.
- **Flight Profile Logs:** Coarse-level profiles anonymised with base locations.
- **[Optional] Sensor Data (e.g. RH, SIE)**
- **Treatment Logs (e.g. bird-baths)**
- **Scheduled Maintenance Plans**
- **Mission Requirements**

Users and Roles

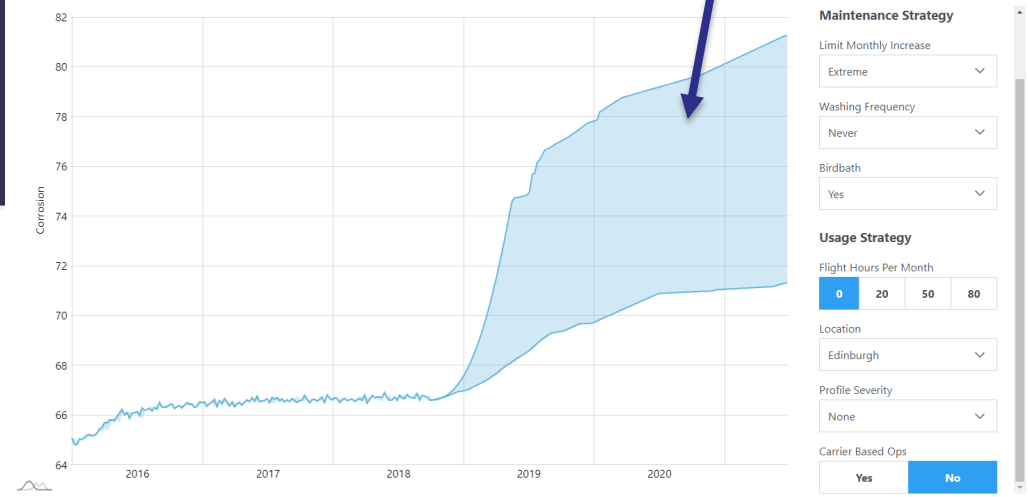
- **Information and controls are exposed to stakeholders depending on the decision-making level.**
- **Maintenance Role (O-4 Level):** Component-level maintenance recommendations & corrosion forecasts.
- **Fleet Schedule Role (O-5 Level):** Aircraft-level maintenance recommendations & corrosion forecasts.
- **Fleet Planning Role (O-6 Level):** Fleet-level corrosion alerts/recommendations, maintenance prioritisation and optimisation.
- **Owner / Mission Planning Role (O-7+ Level):** Operational scenario planning, platform-level sustainment cost optimisation, acquisition optimisation.

Software Implementation



Interactive 3D model with highlighted corrosion issues

Component-level interactive corrosion forecasts

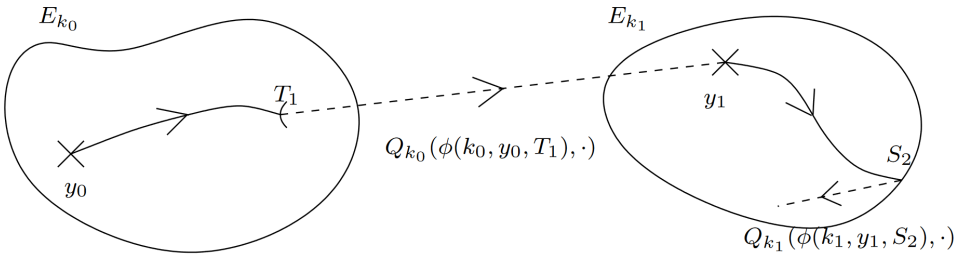


The Model

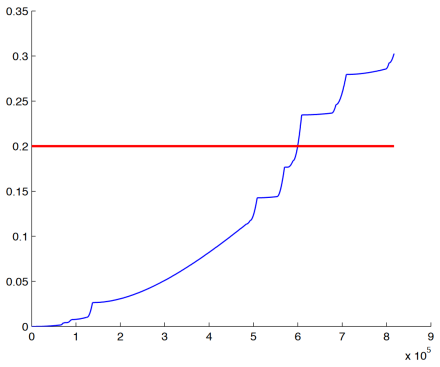
- Research Background
- Combating Temporal Clustering
- Model Anchor Points
- Orion Results: Temporal Cross-Validation
- Orion Results: Fleet Optimisation

Research Background

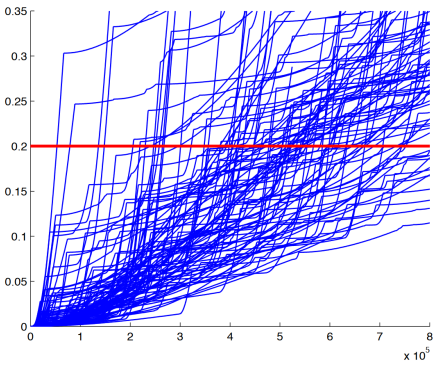
Using a single-component Piecewise-Deterministic Markov Model (PDMM),



To probabilistically generate thickness loss trajectories:



(a) One trajectory



(b) 100 trajectories

Optimal stopping for the predictive maintenance of a structure subject to corrosion

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Abstract

We present a numerical method to compute the optimal maintenance time for a complex dynamic system applied to an example of maintenance of a metallic structure subject to corrosion. An arbitrarily early intervention may be uselessly costly, but a late one may lead to a partial/complete failure of the system, which has to be avoided. One must therefore find a balance between these too simple maintenance policies. To achieve this aim, we model the system by a stochastic hybrid process. The maintenance problem thus corresponds to an optimal stopping problem. We propose a numerical method to solve the optimal stopping problem and optimize the maintenance time for this kind of processes.

Index Terms

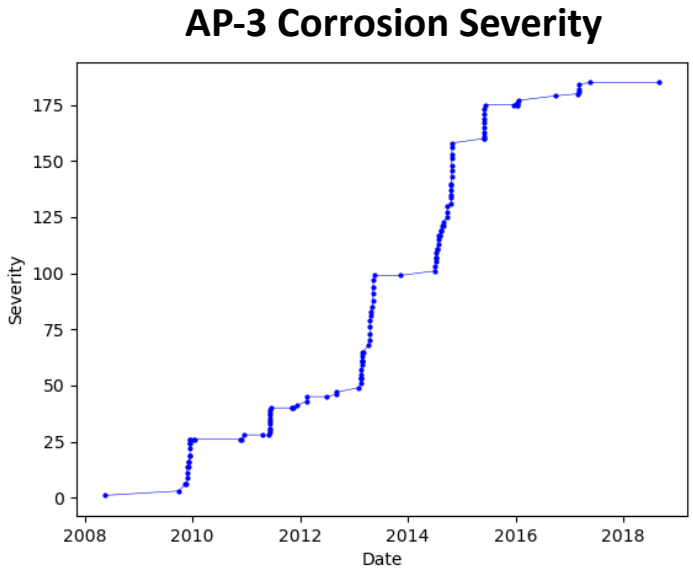
Dynamic reliability, predictive maintenance, Piece-wise-deterministic Markov processes, optimal stopping times, optimization of maintenance.

Combating Temporal Clustering

Problem: any metric constructed over inspection log data is liable to severely violate Lipschitz continuity assumptions required by the PDMM due to temporal clustering.

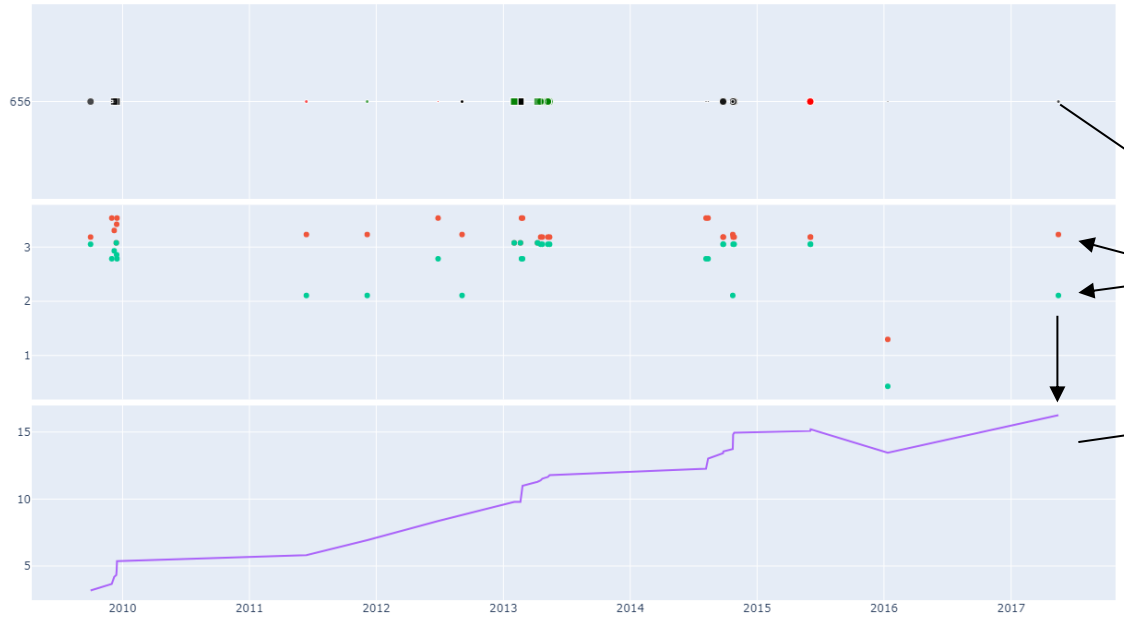
Solution:

1. Explicitly temporally cluster inspection log data and use a hindcasting dispersion model to temporally 'distribute' corrosion
2. Model Anchor Points



Model Anchor Points

- **Model anchor points $a_-(x_i)$ and $a_+(x_i)$ are calculated from each corrosion maintenance log entry x_i.**
- **a_- is the pre-maintenance state, a_+ is the post-maintenance state.**



Anchor Model

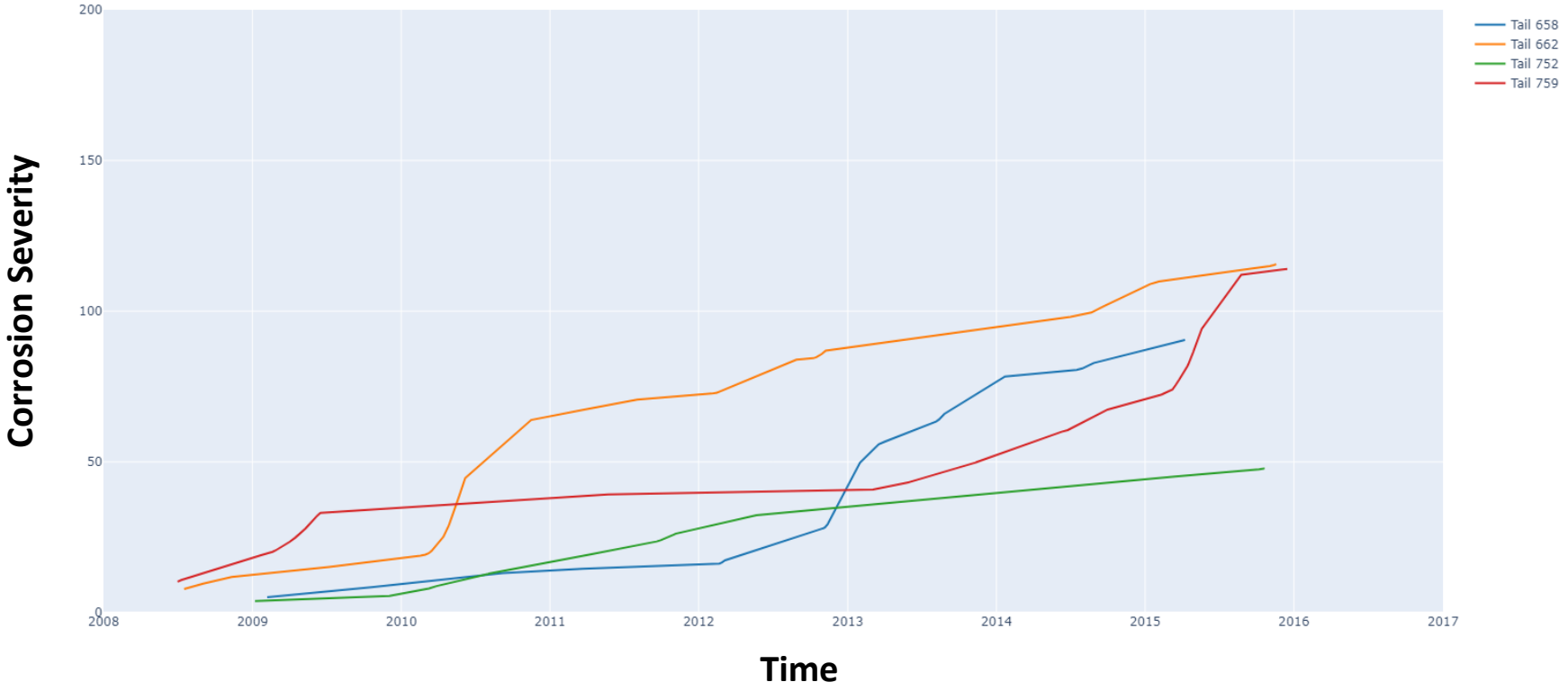
Metric Space Learning

Intervention-independent quantity:

$$c_k = \sum_{i<k} a_-(x_i) - a_+(x_{i-1})$$

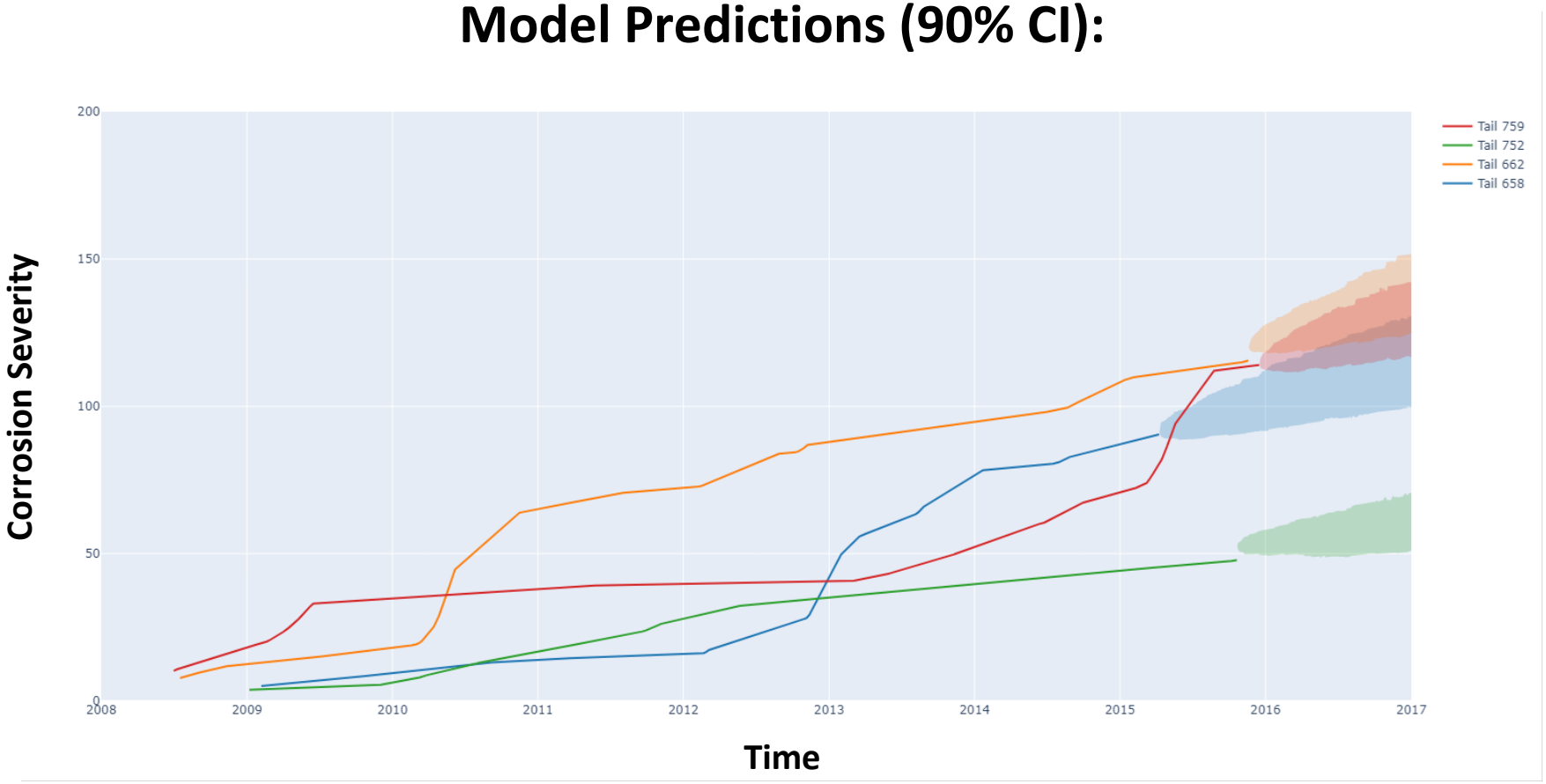
Orion Results: Temporal Cross-Validation

Historical Data is Amputated:



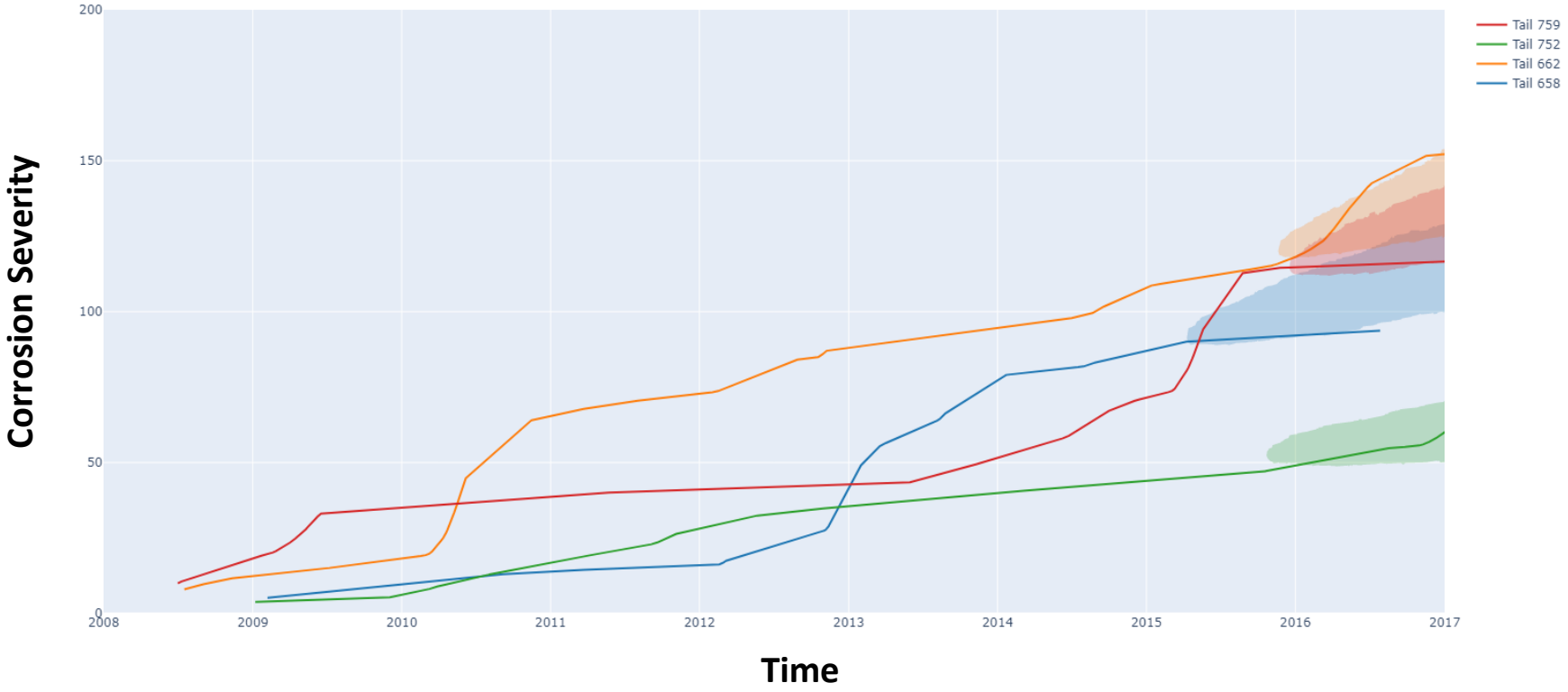
Orion Results: Temporal Cross-Validation

Model Predictions (90% CI):

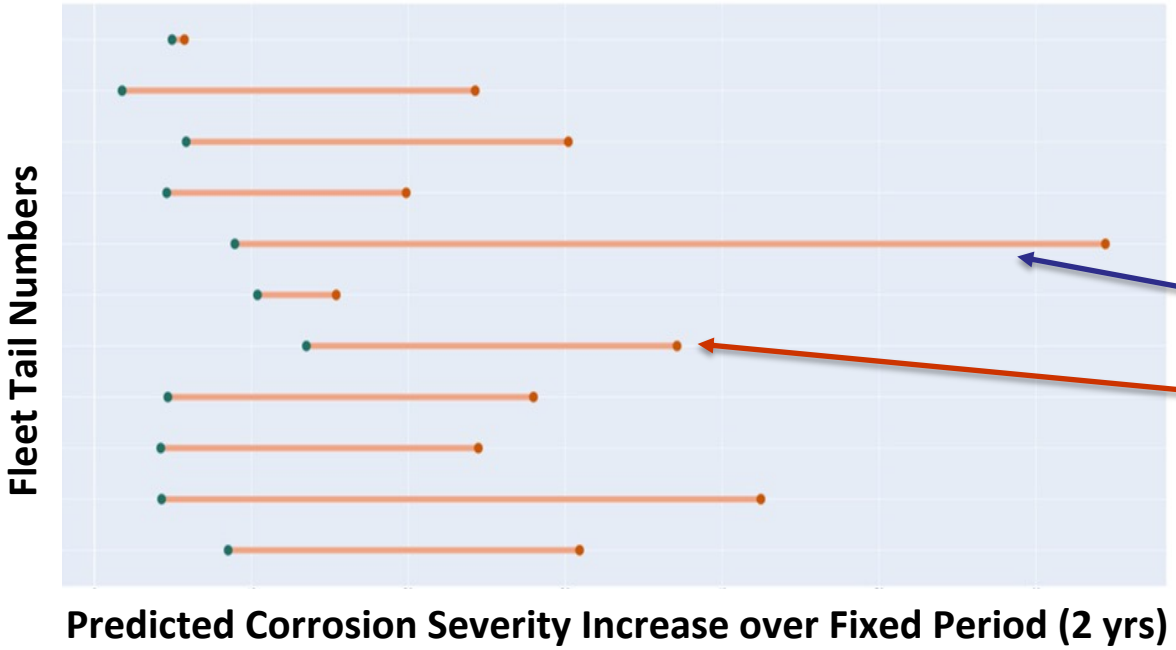


Orion Results: Temporal Cross-Validation

Overlaid Observed Corrosion:



Orion Results: Fleet Optimisation



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Summary and Future Work

- **CorroVision integrates physical analytical models with usage history, inspections, repairs, and treatment application effectiveness to predict corrosion.**
- **CorroVision is able to predict and optimise fleet-level maintenance requirements to largely eliminate unscheduled corrosion maintenance.**
- **The future path is gaining access to more datasets to optimise data fusion mechanics, and to further engage with stakeholders to drive technology maturation.**

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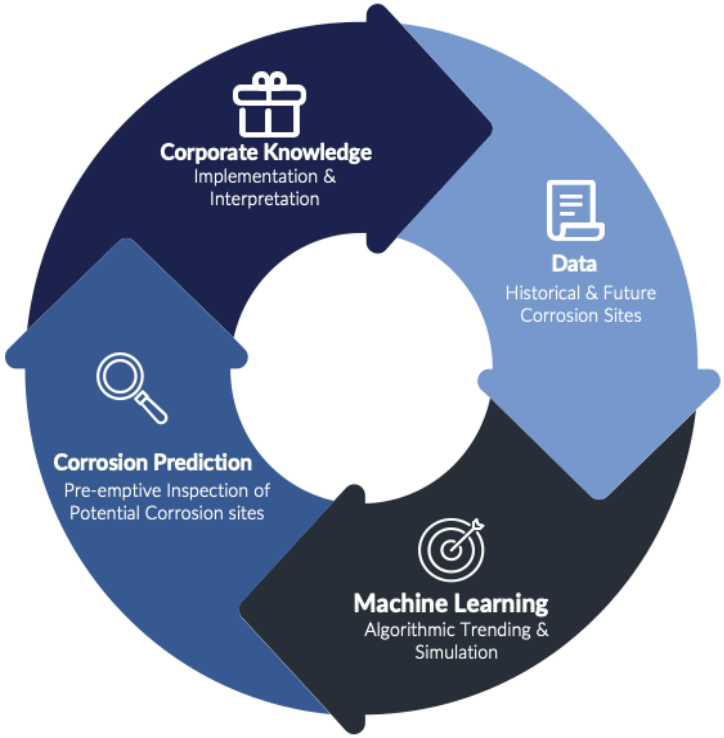
CorroVision

An Innovative Heuristic Software Solution



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