April 11, 2019

CNA
ANALYSIS & SOLUTIONS

Time Machine Learning: Getting Navy maintenance durations right

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Executive Summary

Problem:

- Delays in the completion of ship maintenance at ship yards stem from two primary factors
  - 1) Estimates of maintenance duration
  - 2) Planning and execution of ship maintenance

Solution:

- CNA developed machine learning models to forecast future availability durations and to identify the drivers of delays

Implementation:

- Reduced errors schedule forecasting from **48% to 13%**
- Include forecasts in to POM process & fleet scheduling

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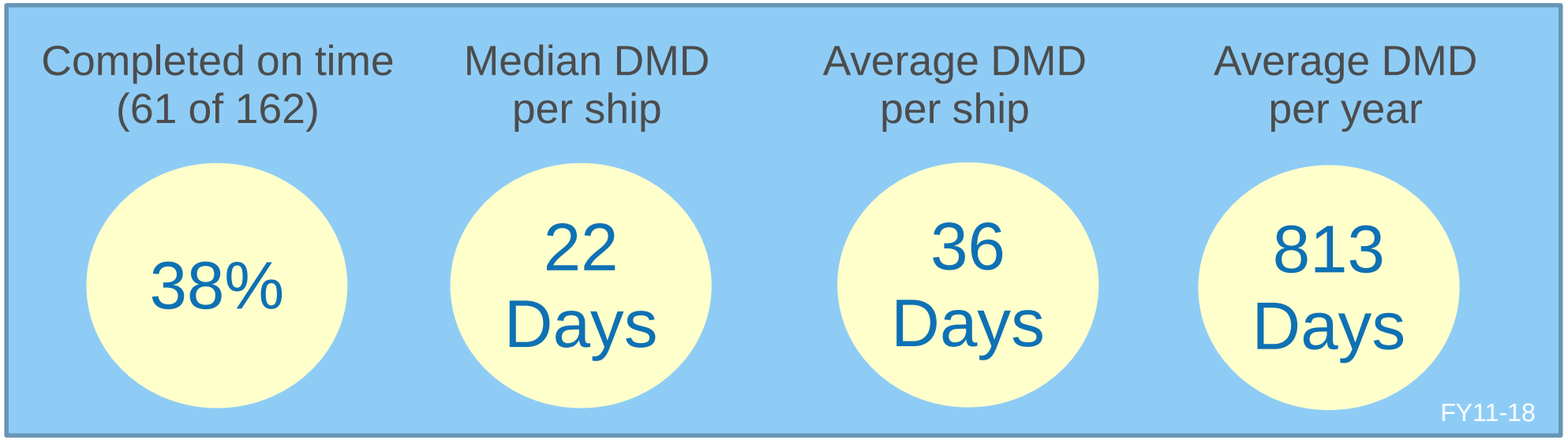
Days of Maintenance Delay (DMD)



- Extended delays in shipyard maintenance lead to churn in scheduling process for Navy ships which potentially can lead to delayed deployments, reduced training time, loss of operational availability, etc.

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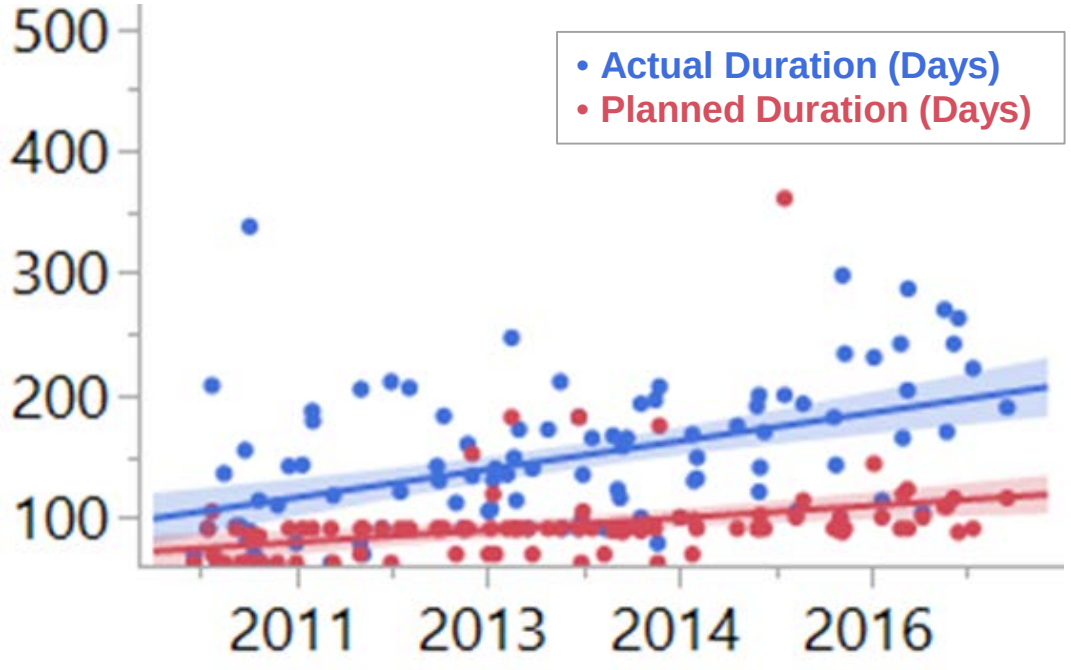
Improving Maintenance Duration Estimates

- Objective is to deliver ships to the fleet when they are required by completing maintenance *on-time*

Estimated and Actual Durations



On-time availabilities can be reached by a combination of:

1. Accurate planning (raising the red line)
2. Faster execution (lower the blue line)

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P2P-S Approach 1: Improve Planning Accuracy

- Problem statement: use predictive analytics to improve forecasted availability durations

Data Collection

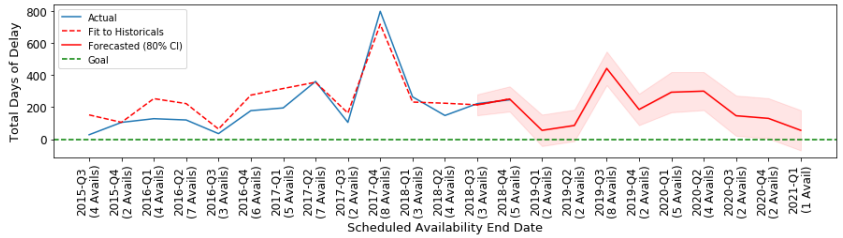
Operations

Material Condition

Maintenance Planning

Historical MX Performance

Improved Availability Forecasts



Model Development

Engineering for data availability at W, W', X, and Y

Neural Network

Random Forest

ElasticNet Regression

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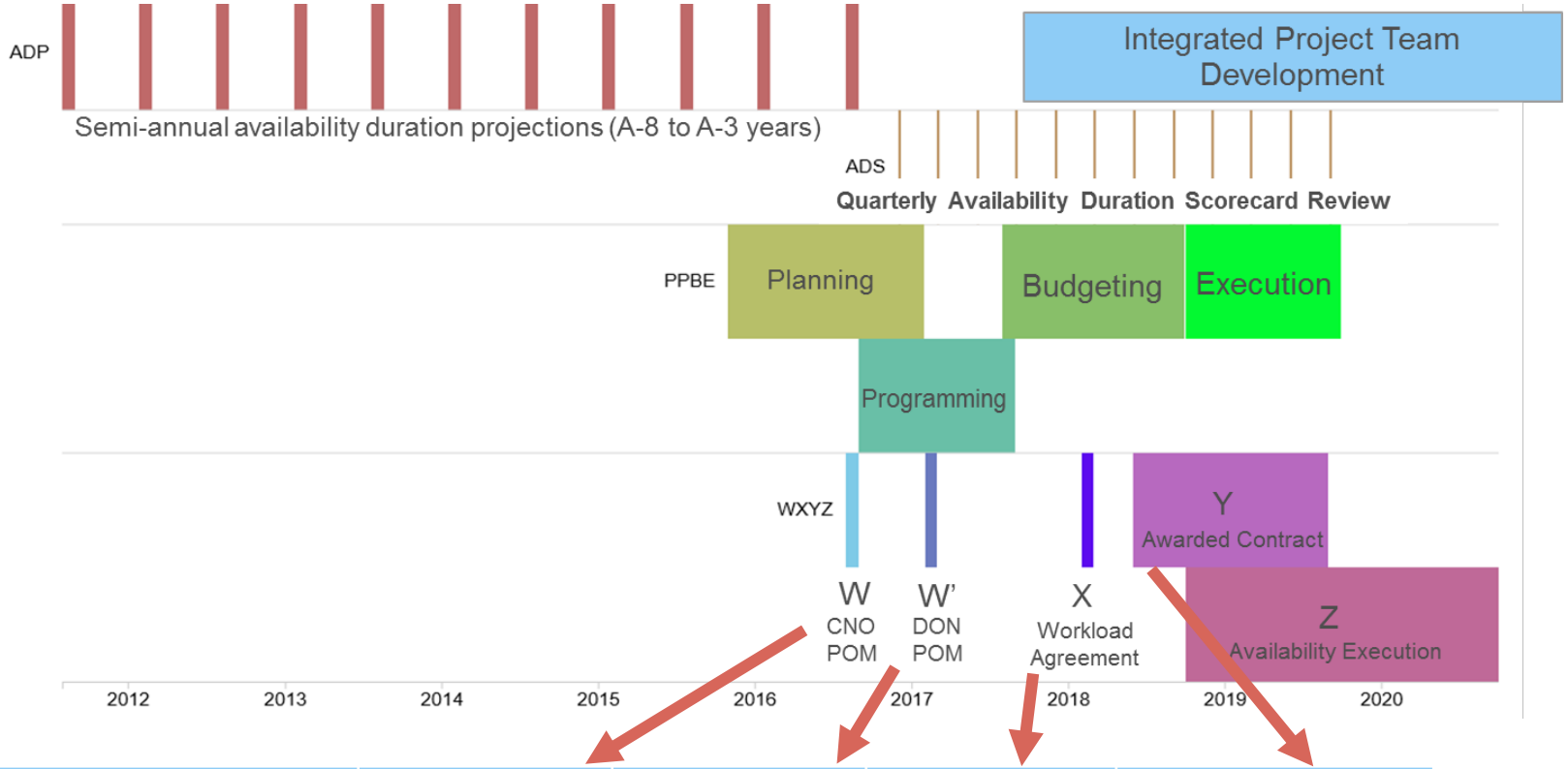
The Availability Scheduling Process and the Schedule Adherence Problem



Avg. % Growth from Plan	POM / W	DON / W'	WLA / X	Award / Y
Delay	87 Days	80 Days	63 Days	39 Days
Delay / Est. Duration	81%	69%	51%	26%

10% Target

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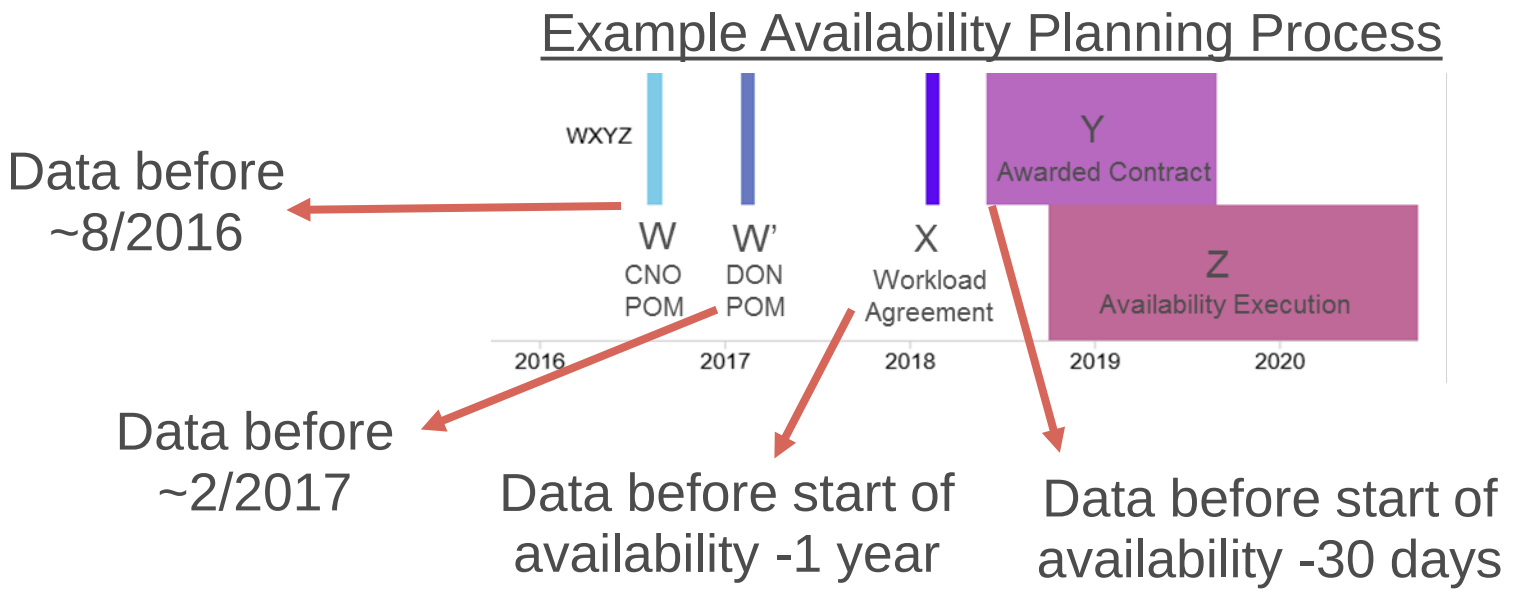
Feature Engineering for Data Availability



- Different data is available for modeling at the W, W', X, and Y points of estimate
- Training data is trimmed to reflect the data that would have been usable at the W, W', X, and Y points of estimate for each maintenance availability

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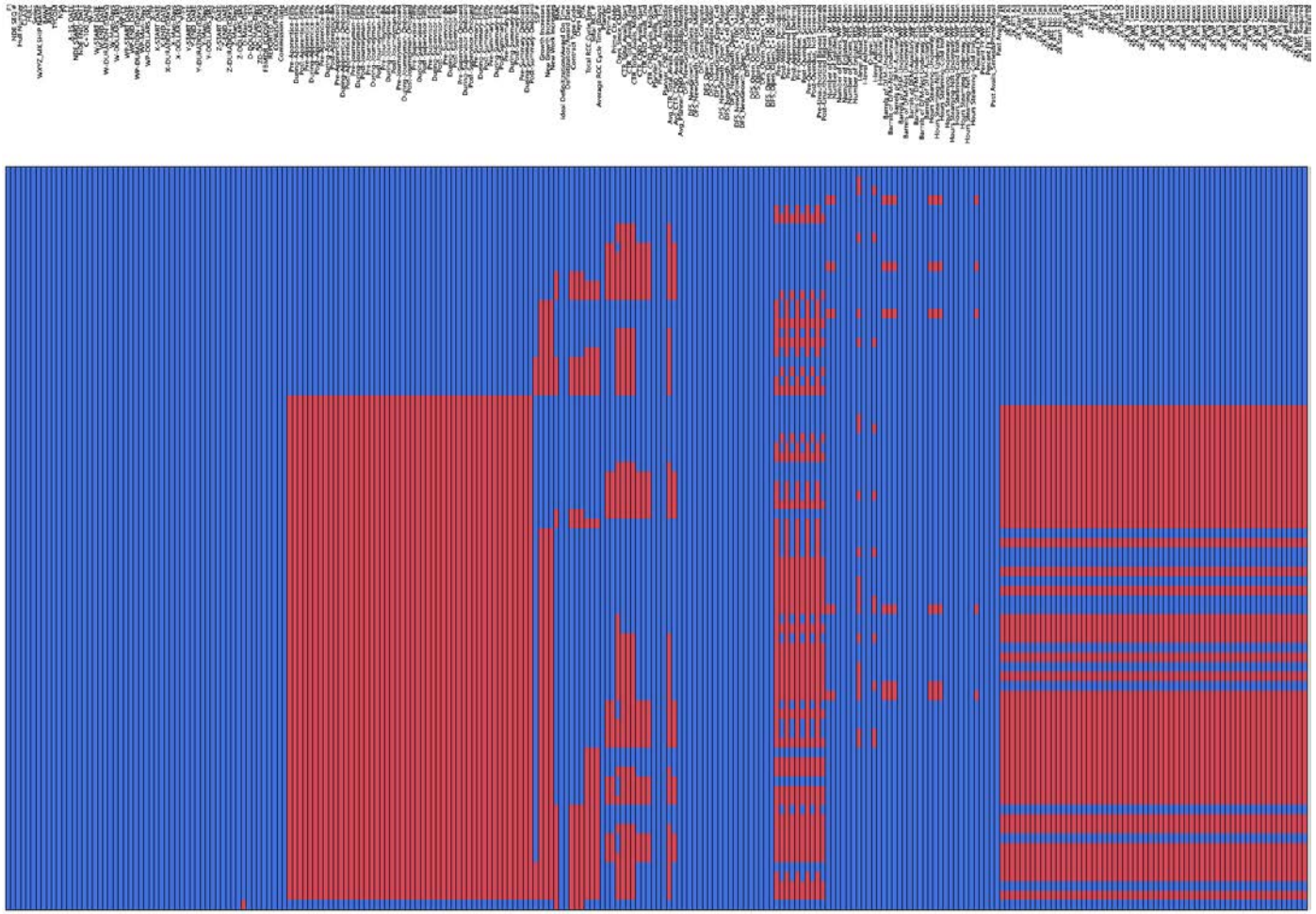
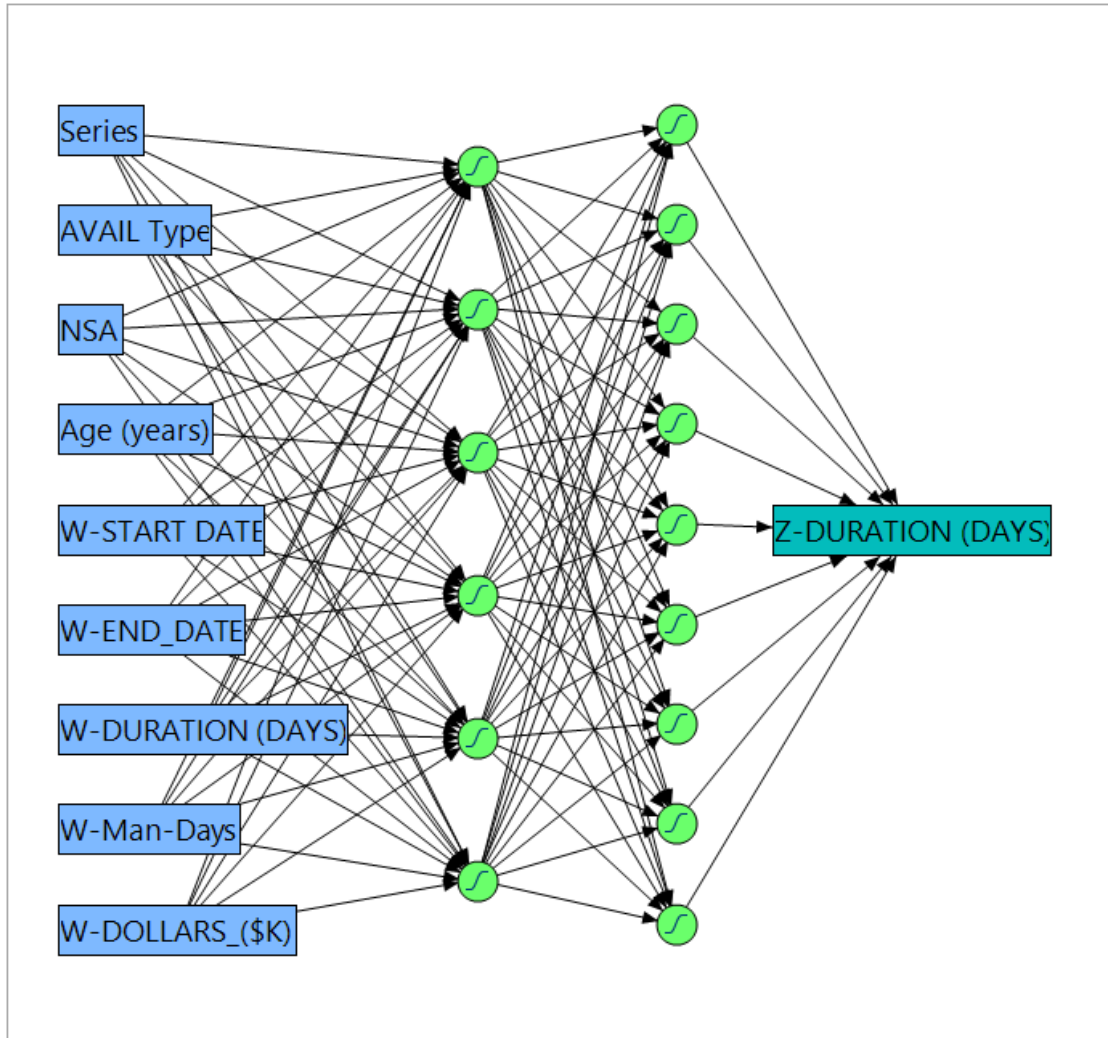
Data & Modeling





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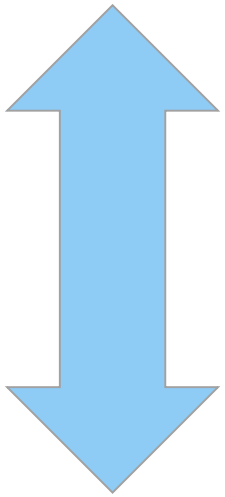
Prediction Model development

- Different types of machine learning models were developed to predict availability durations
  - Models have different strengths and weaknesses

Accuracy & Complexity



Robustness & Interpretability

- **Neural Networks:** uses interconnected artificial neurons to learn trends and interactions between input variables
- **Random Forest:** trains many decision trees and combines their outputs to make predictions
- **ElasticNet Regression:** linear model that selects variables to create a model with good predictive accuracy

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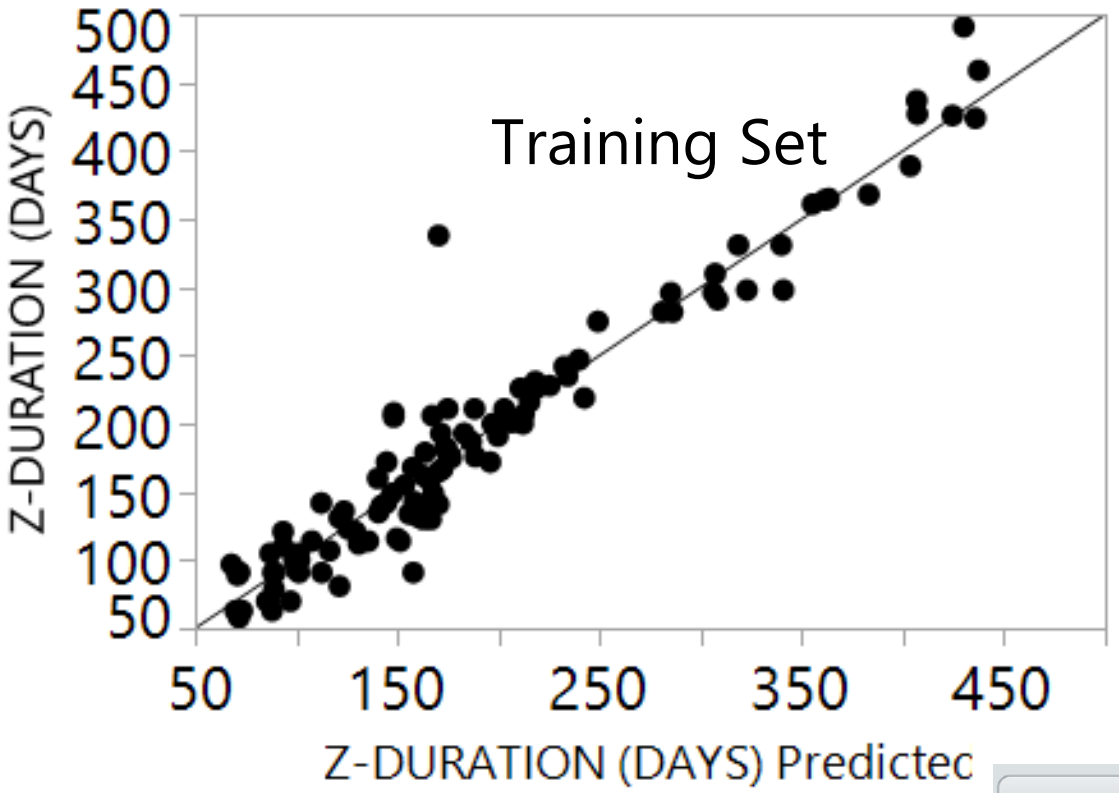
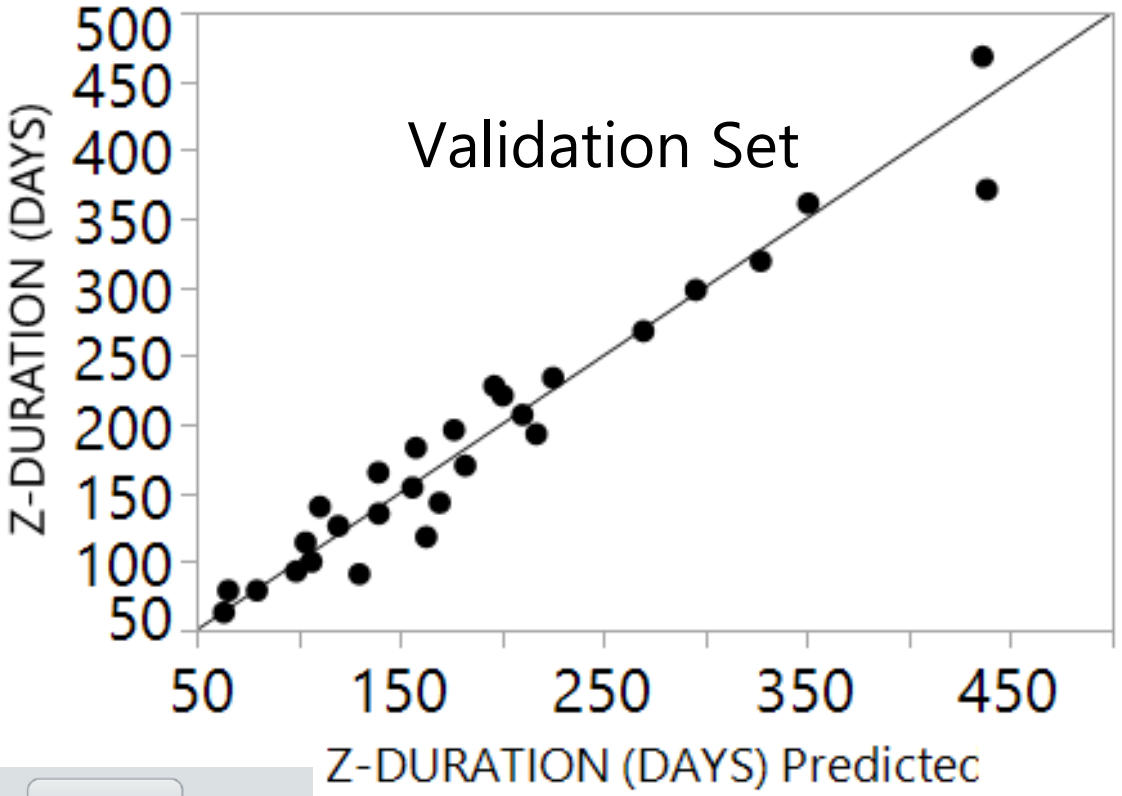
Training and Validation





Training

Z-DURATION (DAYS)

Measures	Value
RSquare	0.9311206
RMSE	26.115773
Mean Abs Dev	17.026698
-LogLikelihood	519.64406
SSE	75705.732
Sum Freq	111

Validation

Z-DURATION (DAYS)

Measures	Value
RSquare	0.9441808
RMSE	23.268597
Mean Abs Dev	17.236762
-LogLikelihood	127.84921
SSE	15159.974
Sum Freq	28

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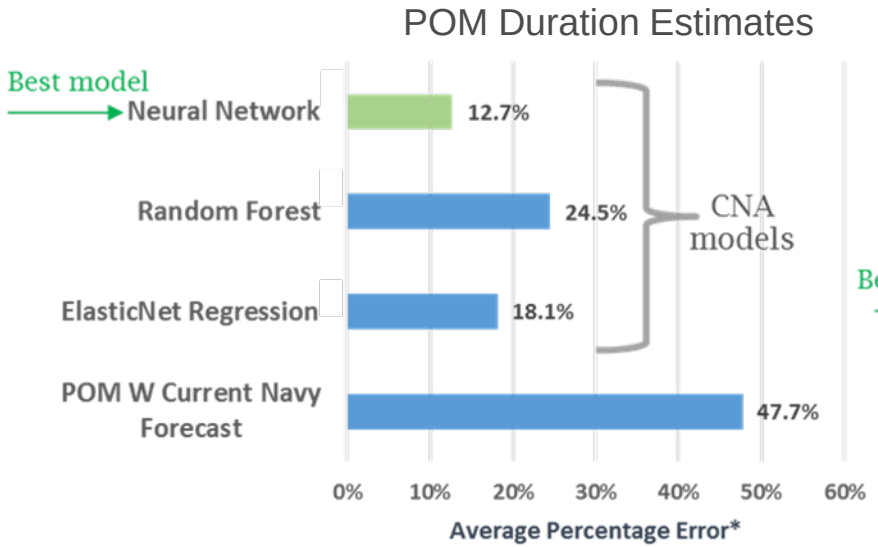
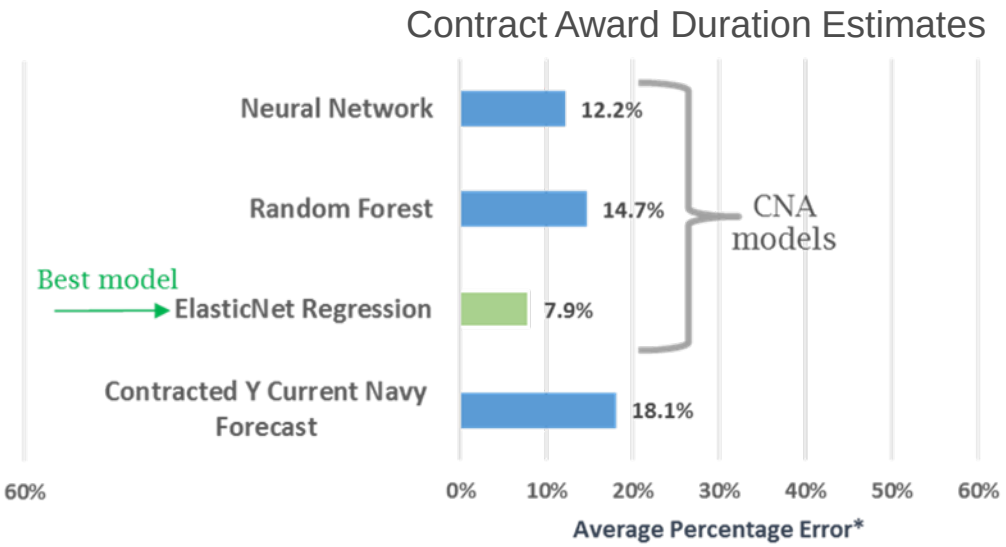
Model Testing and Validation

- Recommend use for fleet scheduling to reduce churn and improve programming and budgeting processes





POM	Navy W	CNA W
Avg. Error in Days	128 Days	31 Days
Avg. Error in %	47.7%	12.7%

Contract	Navy Y	CNA Y
Avg. Error in Days	49 Days	17 Days
Avg. Error in %	18.1%	7.9%

All tested models outperformed current Navy estimating processes

*Average percentage error is the Mean Absolute Percentage Error (MAPE)

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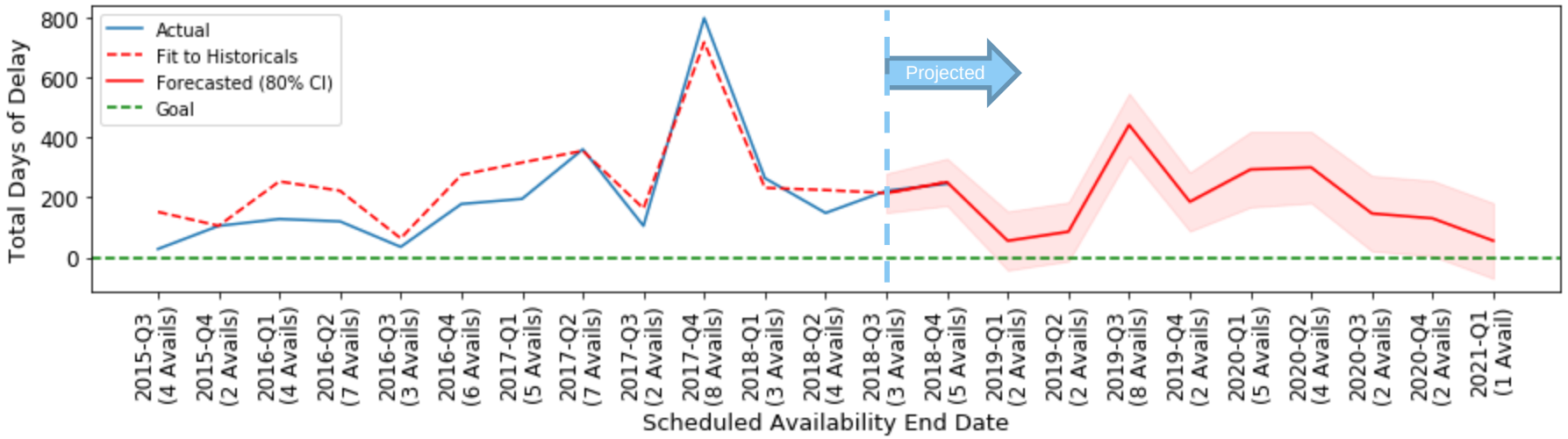
Jan 2019 P2P-S: Predicting Maintenance Delays for Near-Term Availabilities (X and Y)



Current trends in maintenance delays are forecasted to continue without improvements

- Leverage predictive models for planning
  - Improved planning could substantially reduce delays
  - Avoid consistent underestimates of duration

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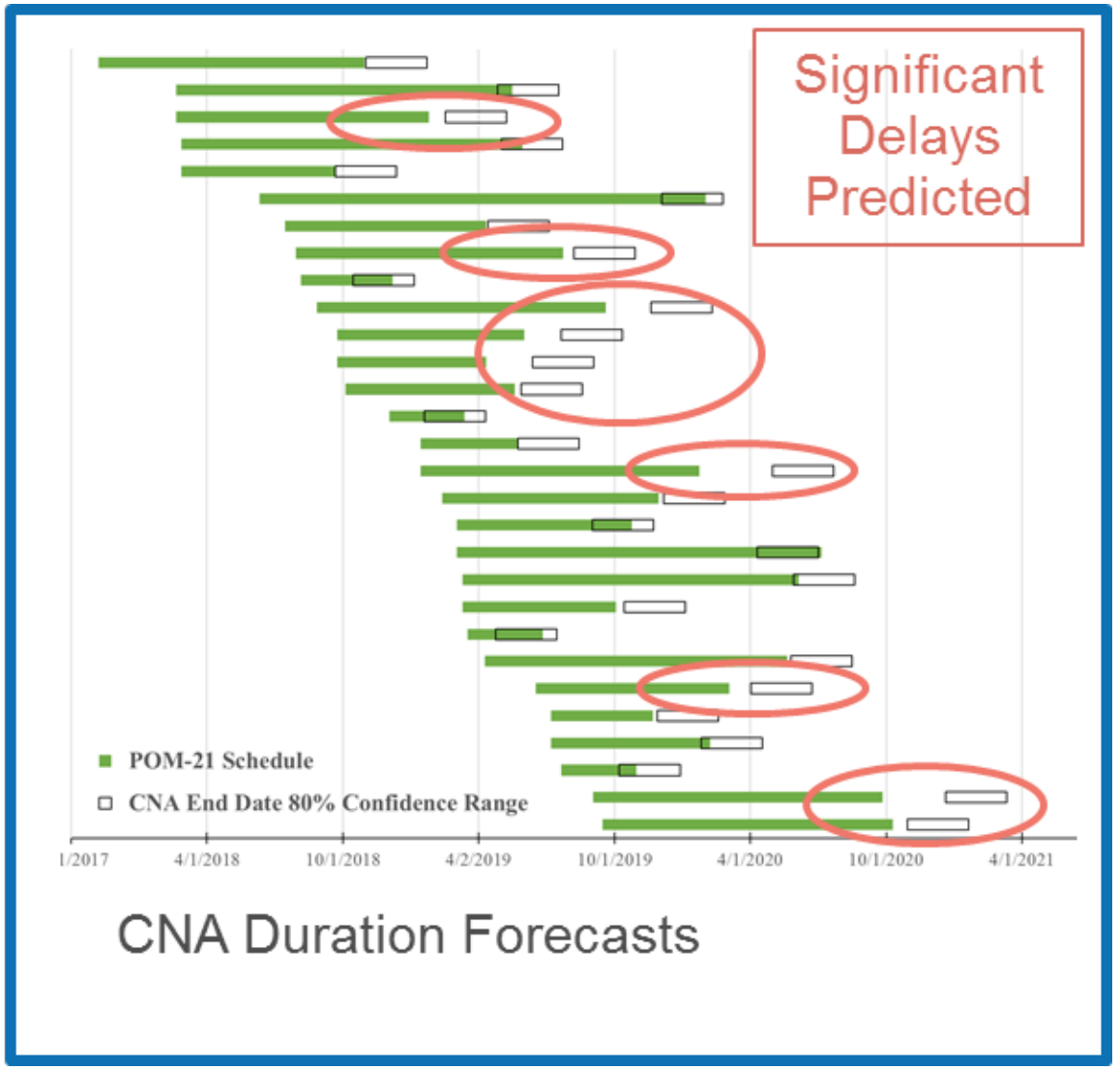
Using forecasts to identify which ships may be late

- Estimates allow for a focused approach for identifying potential delays
- Enables levers to be adjusted to prevent predictions from coming true
- Forecasts updated with new data each quarter



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