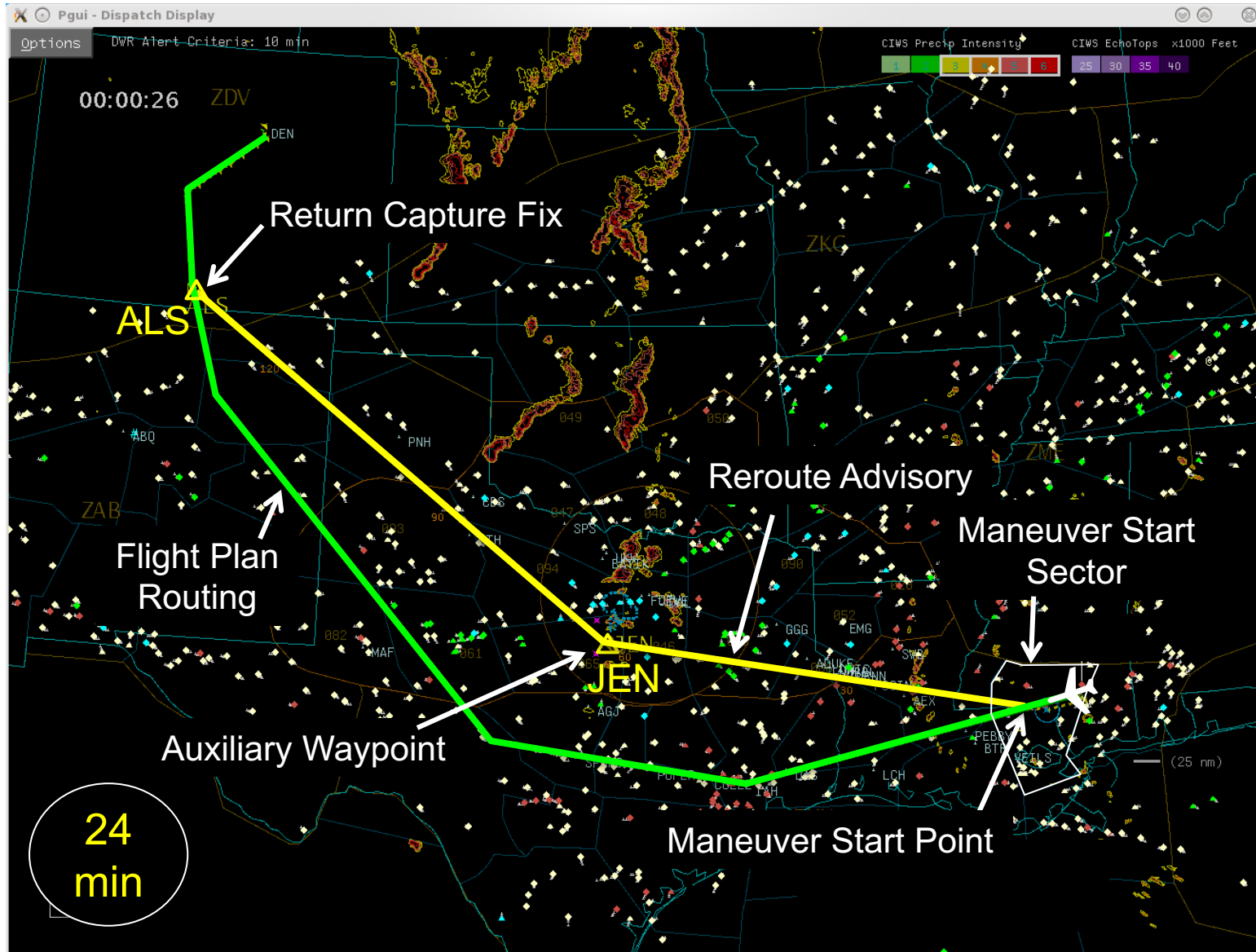# Predicting the Operational Acceptance of Route Advisories
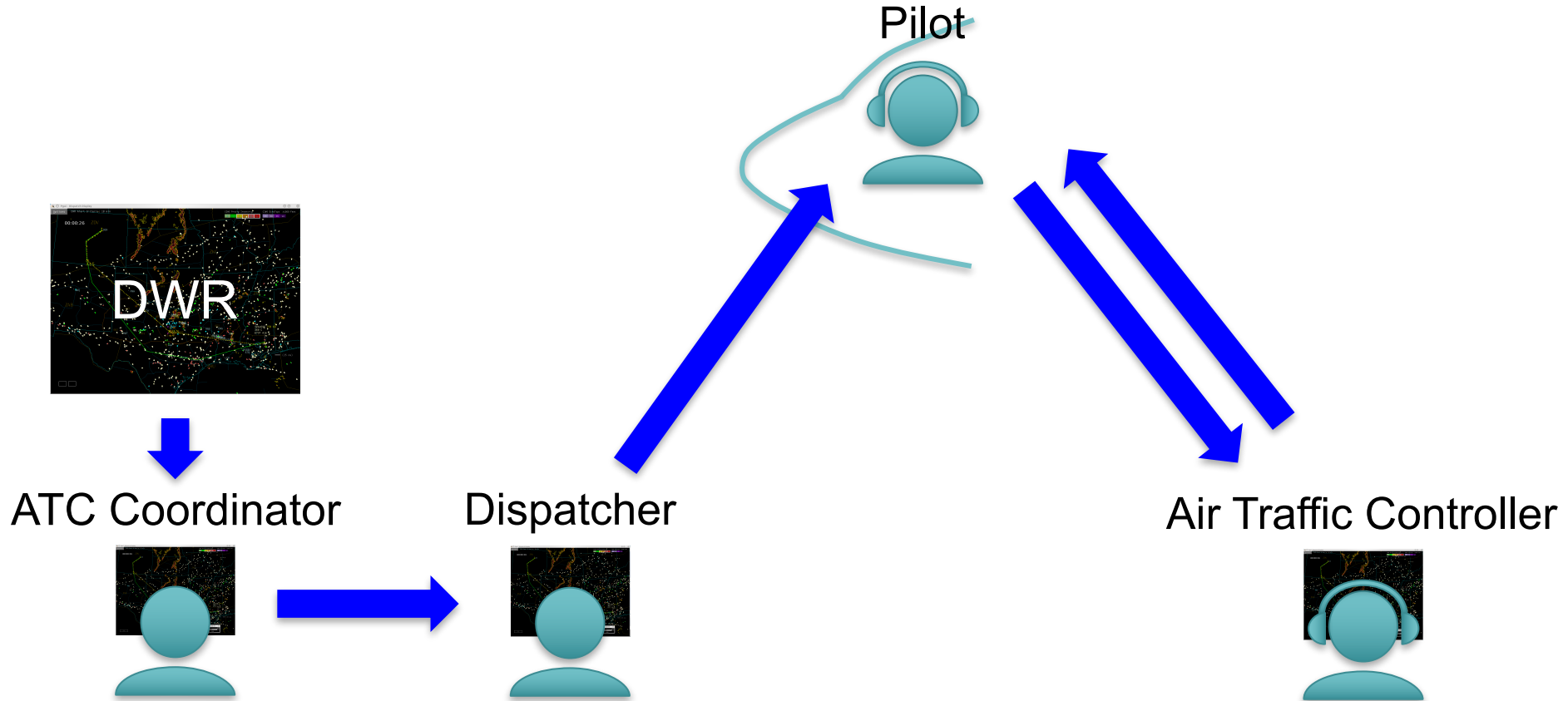
Antony Evans (Crown Consulting, Inc.)

Paul Lee (NASA Ames)

Reroute Advisories

Dynamic Weather Routes (DWR)

DWR

ATC Coordinator

Dispatcher

Pilot

Air Traffic Controller

Motivation

Route Observed in Flight Plan Amendment Data
(Jun-Aug 2015)

		True	False
ATC Response to DWR Route Advisory (DWR trial, 2014)	Accepted	97%	3%
	Rejected	69%	31%

Evans, et al. (2016)

- Historical usage required for ATC route acceptance
- Other factors also contribute to ATC acceptance

- <u>Objective</u>: Develop a predictor of operational acceptability for route advisories

Approach

Identify features	• Literature review • Subject matter experts

⬇

Extract data	• ATC accepted routes • ATC rejected routes

⬇

Data Mining	• Binary classifier

⬇

Validation

Features

- Number sectors over capacity
- Max demand to capacity ratio
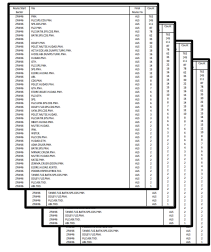
- Historical count (full route)
- Historical count (by segment)
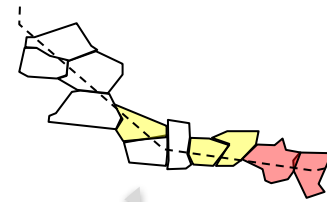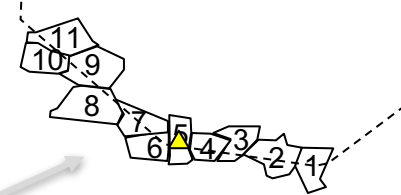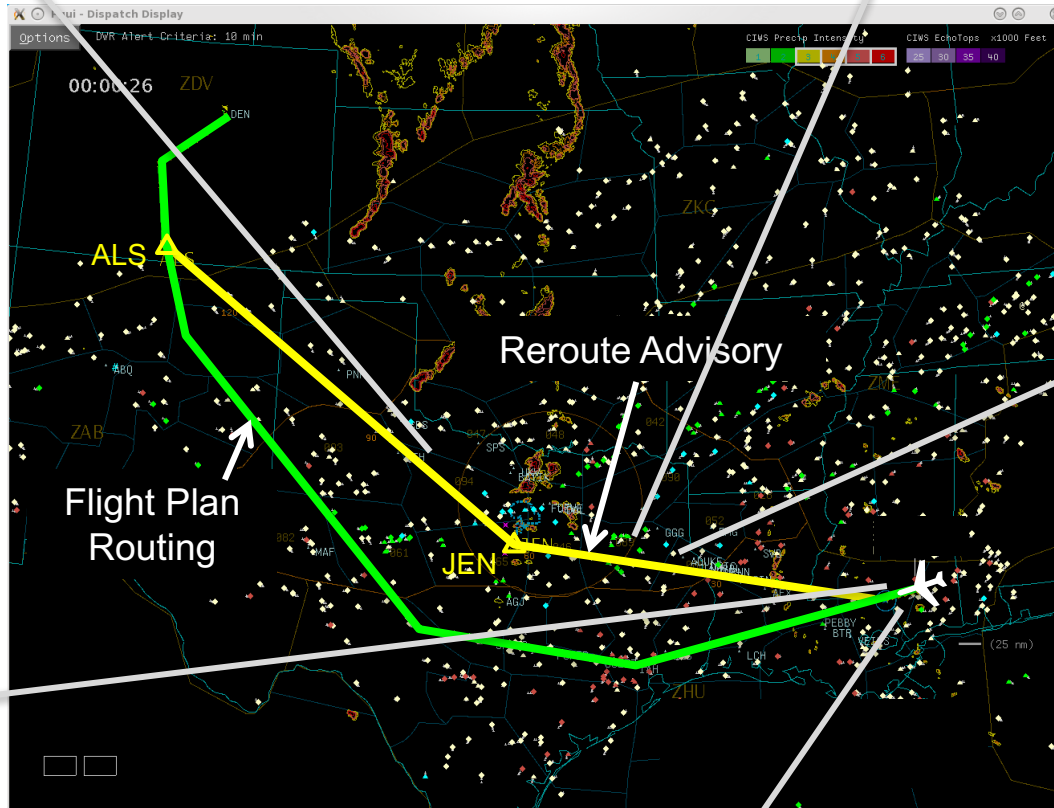
Reroute Advisory

Flight Plan Routing

- Number downstream sectors
- Direct routing or via aux. waypoint
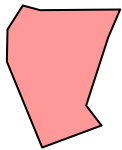
- Maneuver start sector demand/capacity
- Maneuver start sector over capacity
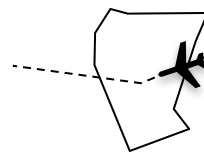
- Time to exit maneuver start sector
- Distance between maneuver start point and sector exit

Data

Usage

ASDI Data

June 2015	July 2015	August 2015

⬇

Flight Plan Amendments

⬇

Common Routing Tables

⮕ Usage

Feature Extraction

DWR Trial Data (ZFW and adjacent Centers)

May 2014	June 2014	July 2014	August 2014	September 2014

⬇

DWR Advisories   Flight Plan Amendments

⬇
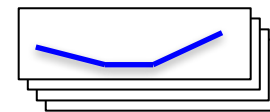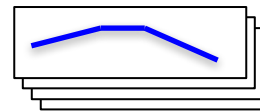
Future ATM Concepts Evaluation Tool (FACET)
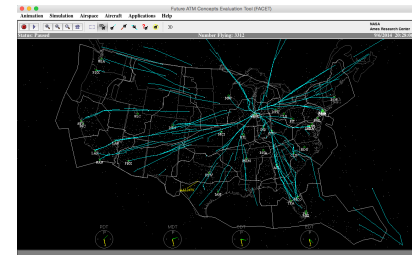
⮕ Sector Counts etc.

Classifying Routings

No flight plan amendment implemented within 30 min

DVC · TXO · ZFW48

Reroute advisory

ZFW48.TXO.DVC — ATC Rejected (9%)

Flight plan amendment

ABQ · ZFW48

Reroute advisory

ZFW48.ABQ — ATC Acceptable (13%)

ALS · PNH · JEN · ACT · ZHU65

Flight plan amendment

Reroute advisory

ZHU65.JEN.ALS — ATC Rejected (31%)

ZHU65.ACT.PNH.ALS — ATC Acceptable (47%)
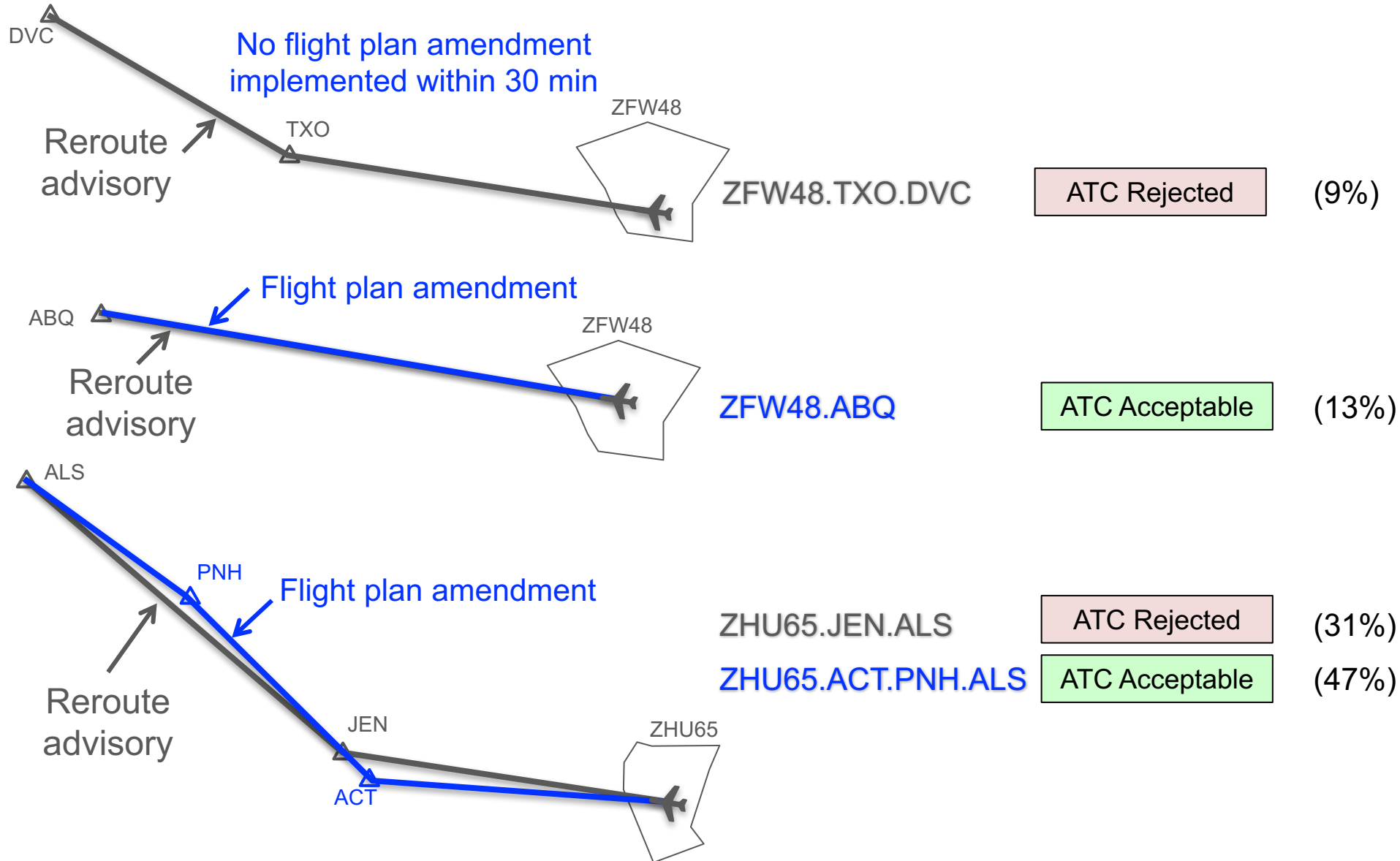
Model Development

Feature Selection	• Forward search through 10 features

⬇

Model Selection	• Logistic regression • Decision tree • Support Vector Machine (SVM) with sigmoid kernel • Random forest • Adaptive Boost (AdaBoost)

⬇

Parameter Selection	• e.g., Number of trees

⬇

Model Validation	• Nested cross-validation

Feature Selection

- Forward Search with Random Forest, 10-fold cross validation
- 317 to 544 observations – 40% to 48% Rejected; 60% to 52% Accepted
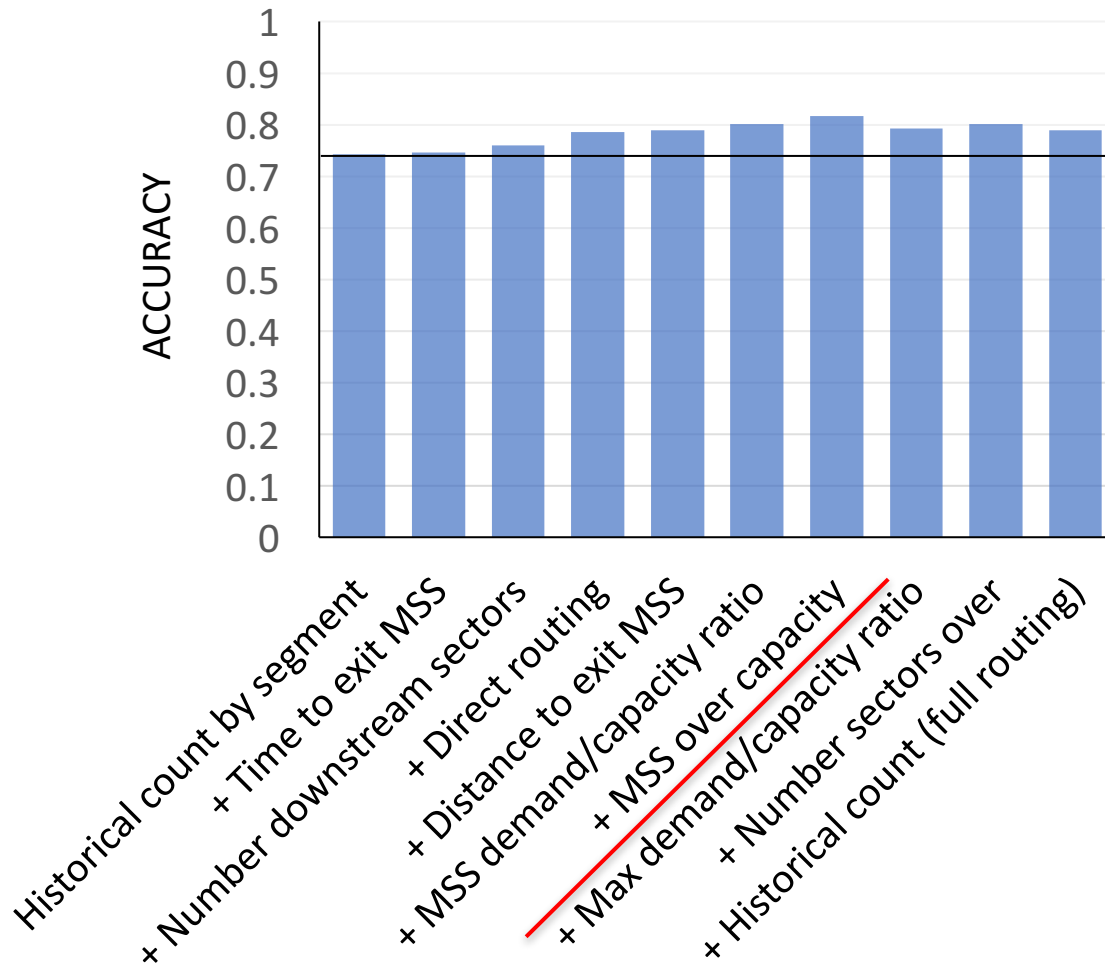
MSS – Maneuver Start Sector

Features
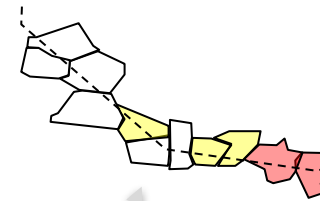
❌ Number sectors over capacity

❌ Max demand to capacity ratio
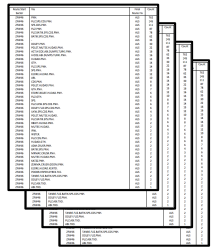
❌ Historical count (full route)

✅ Historical count (route segment)
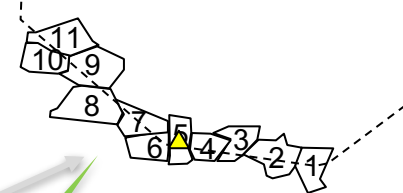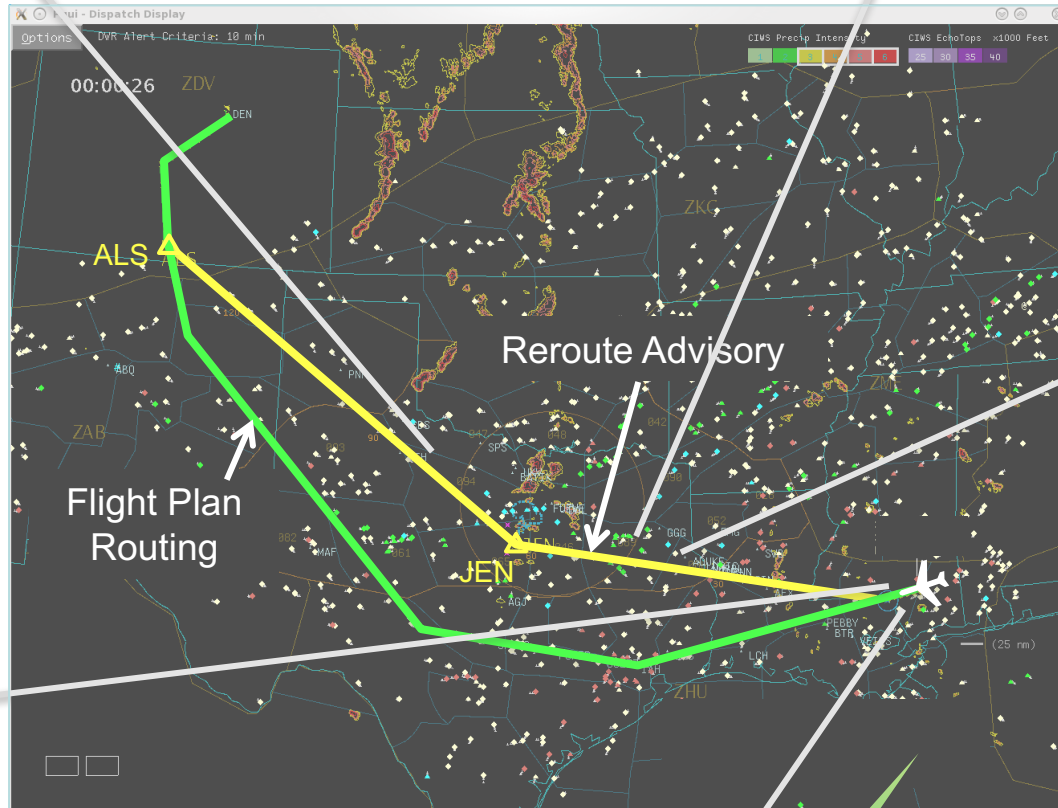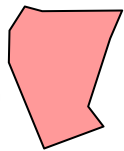
Reroute Advisory

Flight Plan Routing

ALS

JEN

✅ Number downstream sectors

✅ Direct routing or via aux. waypoint

✅ Maneuver start sector demand/capacity

✅ Maneuver start sector over capacity
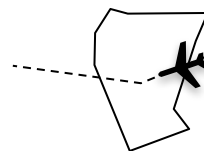
✅ Time to exit maneuver start sector

✅ Distance between maneuver start point and sector exit

Model Selection

- 7 features
- 10-fold cross validation
- 317 observations – 48% Rejected; 52% Accepted

- Parameter Selection: 40 trees

Model Validation

- 7 features, Random Forest, 40 trees
- Nested 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

	Predicted	
	Rejected	Accepted
Observed (Actual) Rejected	61%	39%
Accepted	22%	78%

Model Accuracy: 70%

Receiver Operating Characteristic Curve

Discrimination threshold = 70%
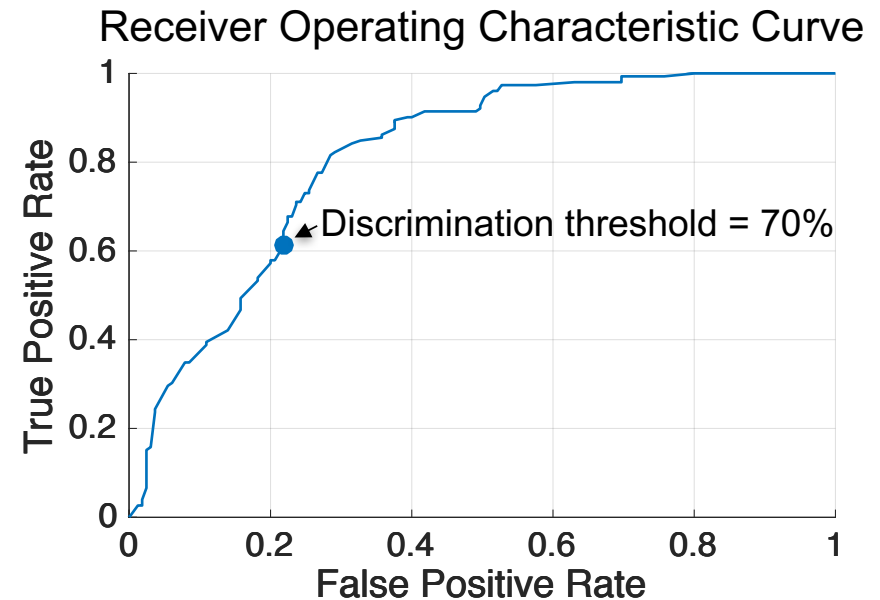
Conclusions

- Developed a predictor of operational acceptability for route advisories:
  - Accuracy of 74%
  - Route rejection predicted at rate of 88%
- Relevant model features:
  - Historical usage
  - Timing/location of request in maneuver start sector
  - Number of downstream sectors
  - Direct routing or via auxiliary waypoints
  - Demand to capacity levels in maneuver start sector
- Best performing model is Random Forest with 40 trees

Future Work

- Extension to other airspace
  - Trial data for NAS Constraint Evaluation and Notification Tool (NASCENT)

- Improve features
  - Include weather impact on maneuver start sector capacity
  - Add other features, e.g., Center information
  - May use voice recordings to identify timing and details of pilot requests to ATC

Questions?

Back-up Slides

DWR Use and Estimated Actual Savings

January 2013 to September 2014
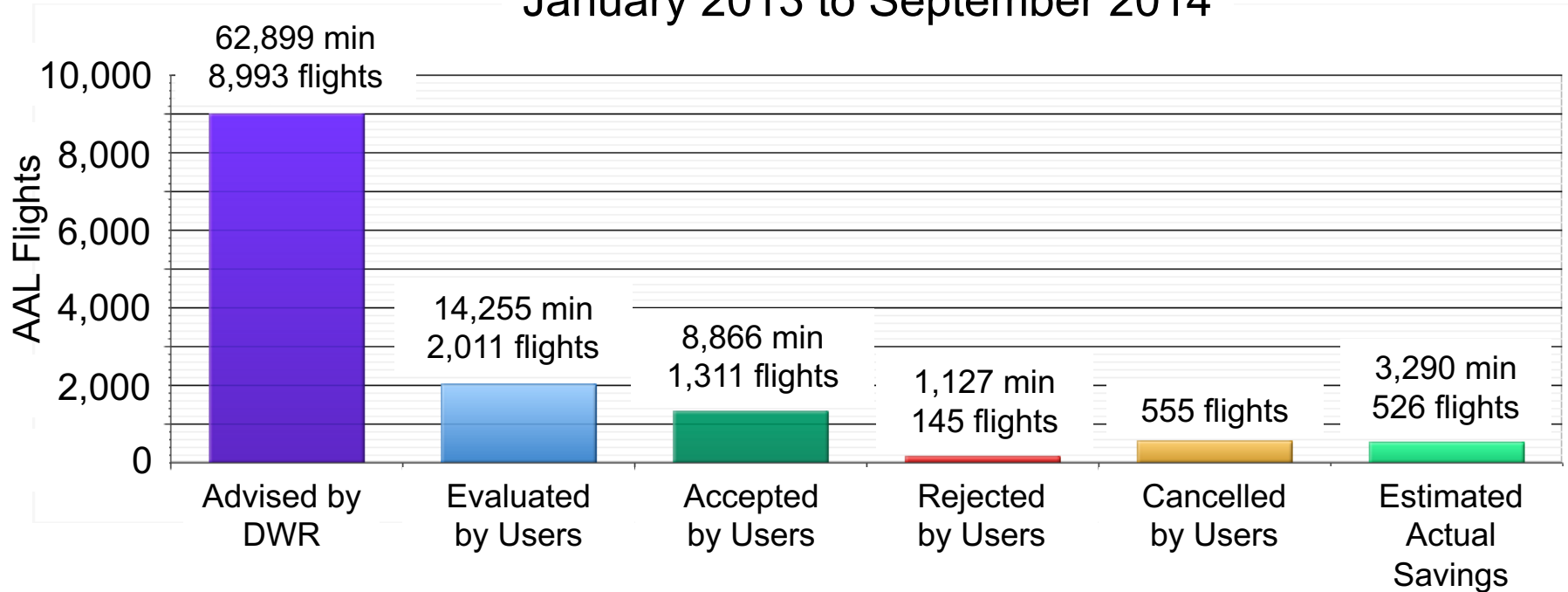
40% of dispatcher accepted routes see actual savings

McNally, D., Sheth, K., Gong, C., Sterenchuk, M., Sahlman, S., Hinton, S., Lee, C., Shih, F-T., "Dynamic Weather Routes: Two Years of Operational Testing at American Airlines," *Air Traffic Control Quarterly*, Vol. 23, No. 1, pp. 55-81, 2015.

Traditional Model Development

Dataset

Development Set

Evaluation Set

Training Set

Test Set

Nested Cross Validation

Dataset

Development Set

Evaluation Set

Training Set

Test Set
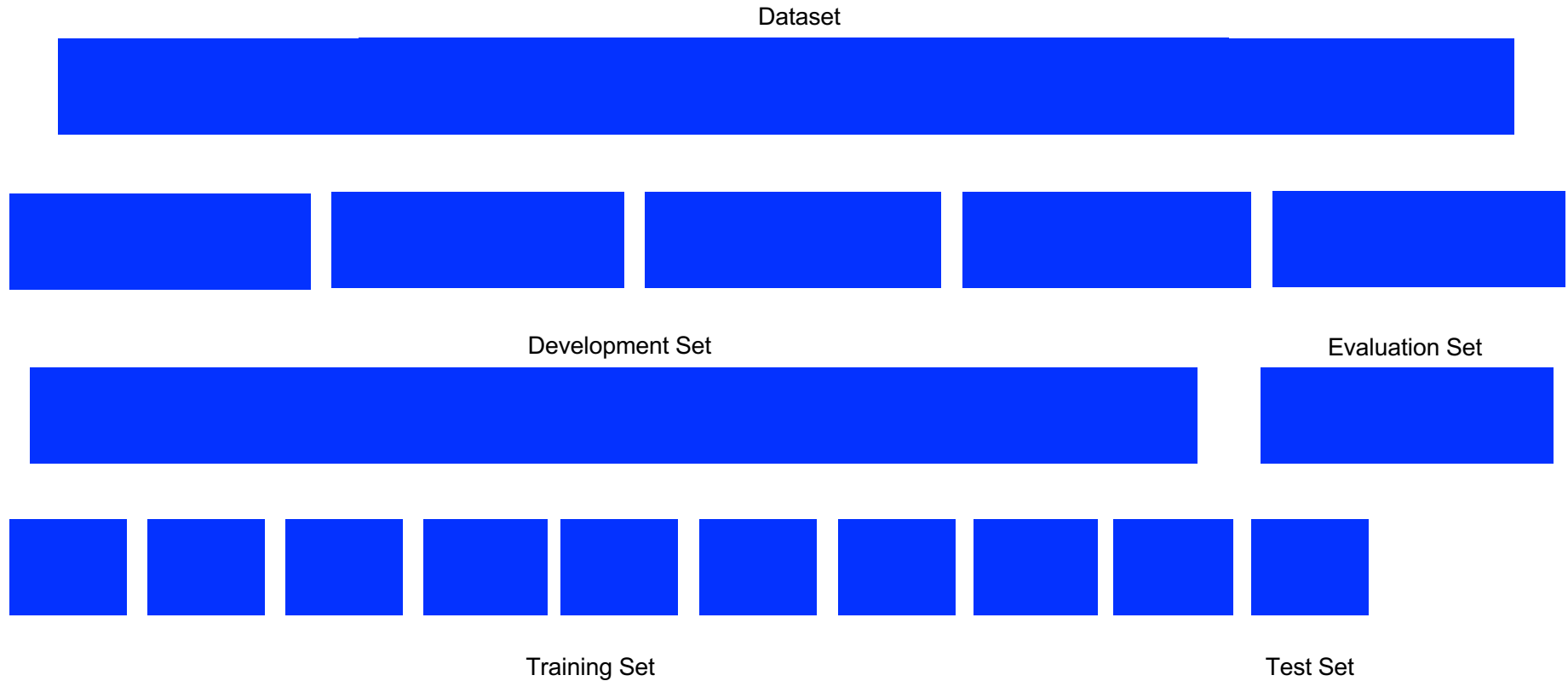
Feature Selection: Forward Search

- Random Forest, 10-fold cross validation
- 317 to 544 observations – 40% to 48% Rejected (positive); 60% to 52% Accepted (negative)

F-Score (50% discrimination threshold)

Receiver Operating Characteristic (ROC) Curve
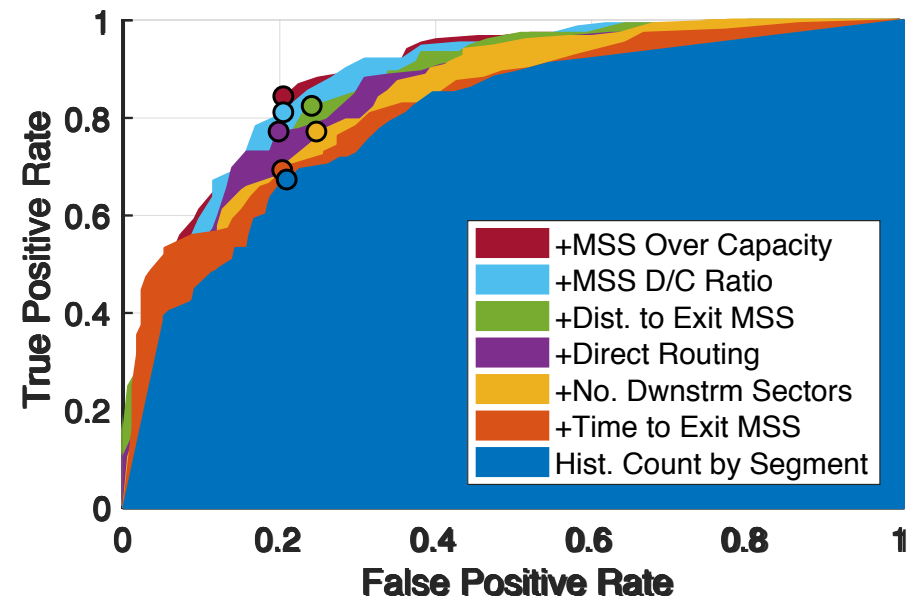
Feature Selection: Forward Search

- Method: Random Forest, 40 trees, 10-fold cross-validation
- Positive (Rejected or Modified) 40%; Negative (Accepted) 60%
- Observations: between 317 and 544, depending on features included

Model F-Score

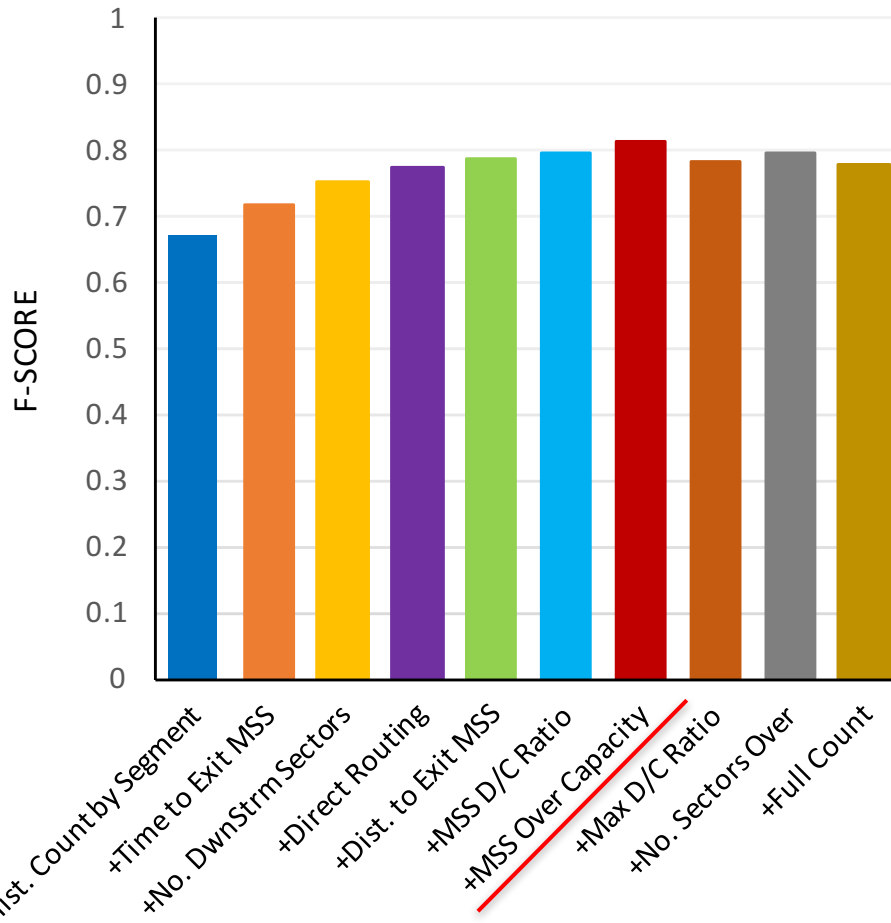|	1 Feature	2 Features*	3 Features*	4 Features*	5 Features*	6 Features*	7 Features*	8 Features*	9 Features*	10 Features*
Full Count	0.648	0.695	0.753	0.771	0.764	0.766	0.801	0.775	0.767	**0.780**
Concat. Count	**0.674**	-	-	-	-	-	-	-	-	-
Direct Routing	0.387	0.597	0.705	**0.775**	-	-	-	-	-	-
No. Sectors Over	NA	0.599	0.693	0.743	0.746	0.766	0.809	0.783	**0.797**	-
Max D/C Ratio	0.255	0.664	0.751	0.773	0.769	0.789	0.772	**0.784**	-	-
MSS Over Capacity	NA	0.583	0.674	0.744	0.758	0.782	0.815	-	-	-
MSS D/C Ratio	0.381	0.660	0.749	0.758	0.773	**0.796**	-	-	-	-
No. Dwnstrm. Sectors	0.484	0.667	**0.755**	-	-	-	-	-	-	-
Time to Exit MSS	0.497	**0.719**	-	-	-	-	-	-	-	-
Dist. to Exit MSS	0.467	0.665	0.719	0.761	**0.789**	-	-	-	-	-

* Includes feature set with highest F-Score from previous column

- Feature Set with highest F-Score:
  - Concatenation Count,
  - Number of Downstream Sectors,
  - Distance to Exit MSS,
  - MSS Over Capacity
  - Time to Exit MSS,
  - Direct Routing
  - MSS Demand/Capacity Ratio

Feature Selection

- Forward Search, using a Random Forest and 10-fold cross-validation
- Feature Set with highest F-Score:
  - Hist. Count by Segment,
  - Number of Downstream Sectors,
  - Distance to Exit Maneuver Start Sector,
  - Maneuver Start Sector Over Capacity.
  - Time to Exit Maneuver Start Sector,
  - Direct Routing,
  - Maneuver Start Sector Demand/Capacity Ratio,
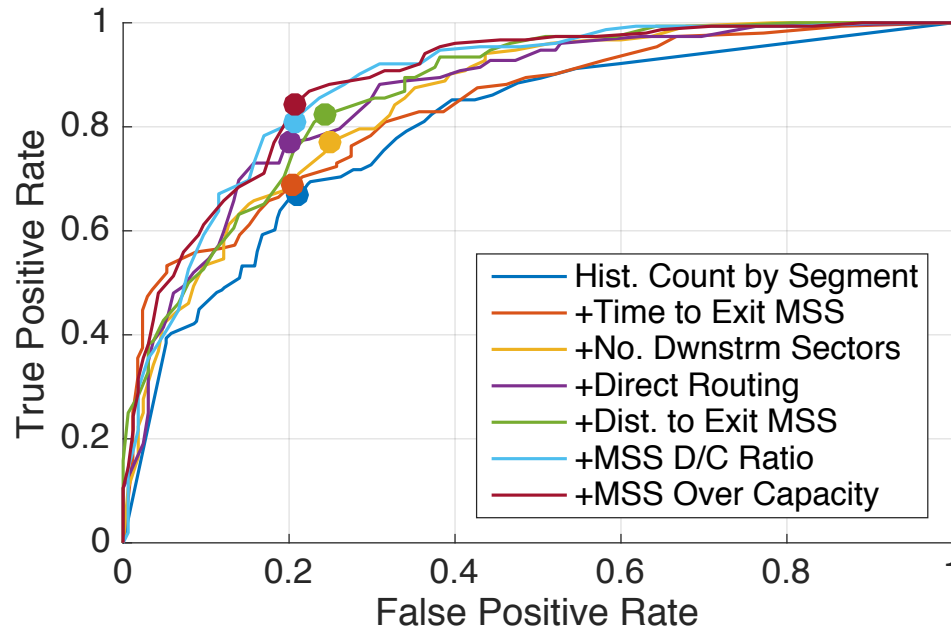
Receiver Operating Characteristic Curve

Model Selection

- 7 features
- 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

Accuracy (50% discrimination threshold)
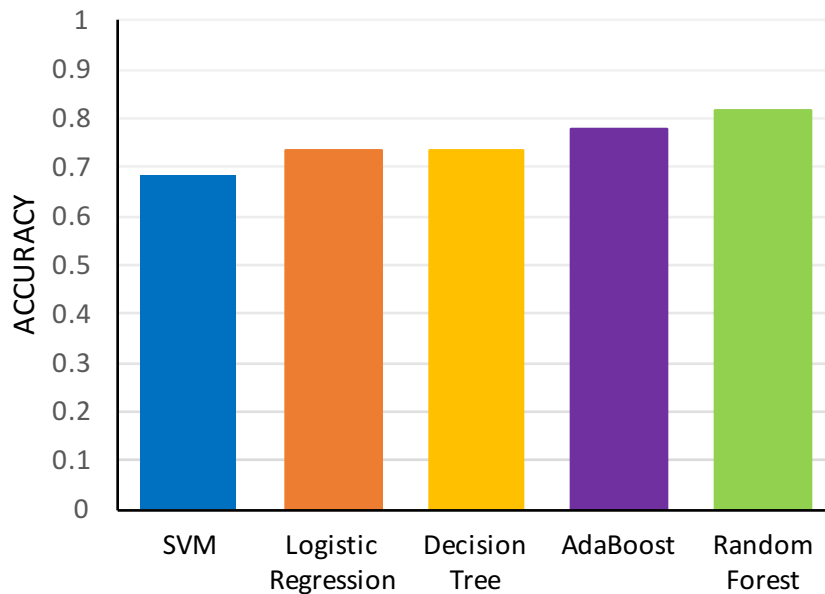
Receiver Operating Characteristic (ROC) Curve
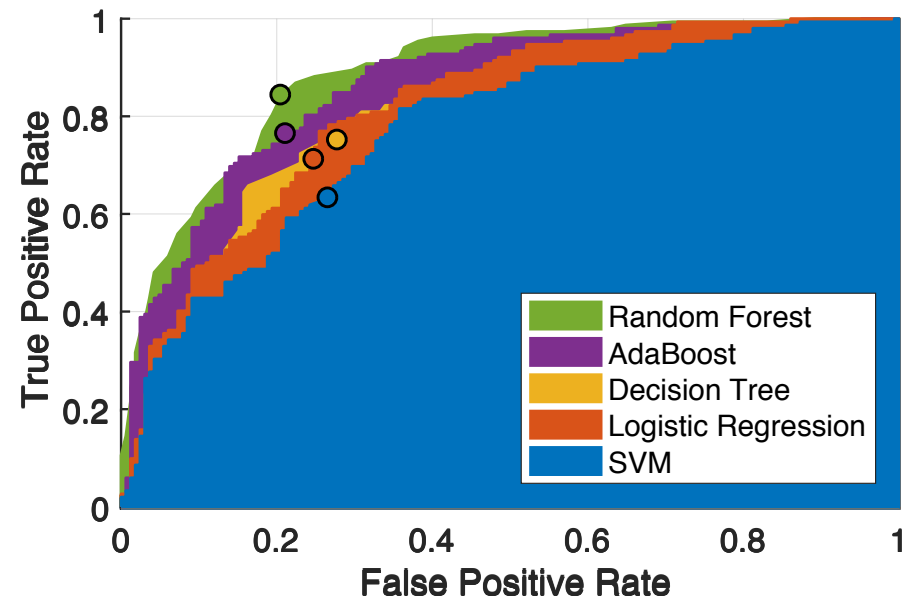
- Parameter Selection: 40 trees

Model Selection

- 10-fold cross-validation
- 317 observations – 48% Positive (Rejected or Modified); 52% Negative (Accepted)

	Logistic Regression	Decision Tree	SVM	Random Forest	AdaBoost
Accuracy	0.73	0.74	0.69	0.82	0.78
Misclassification Error	0.27	0.26	0.31	0.18	0.22
True Positive Rate/Recall	0.71	0.75	0.63	0.84	0.76
True Negative Rate	0.75	0.72	0.73	0.79	0.79
Precision	0.73	0.71	0.69	0.79	0.77
F-score	**0.72**	**0.73**	**0.66**	**0.82**	**0.77**

Receiver Operating Characteristic Curve
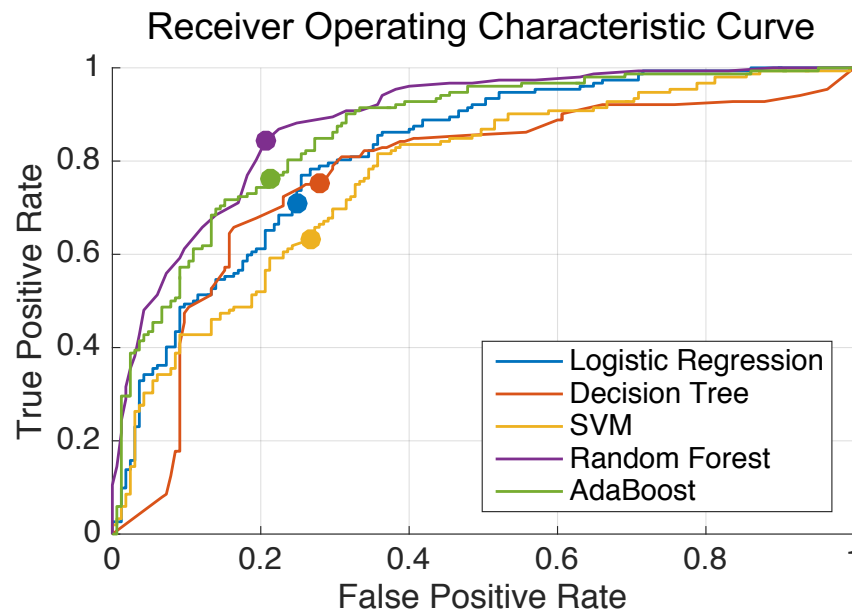
Parameter Selection: Number of Weak Learners

- Random Forest, with 10-fold cross validation
- 317 observations – 48% Positive (Rejected or Modified); 52% Negative (Accepted)
- Parameter value with highest F-Score: 40 trees
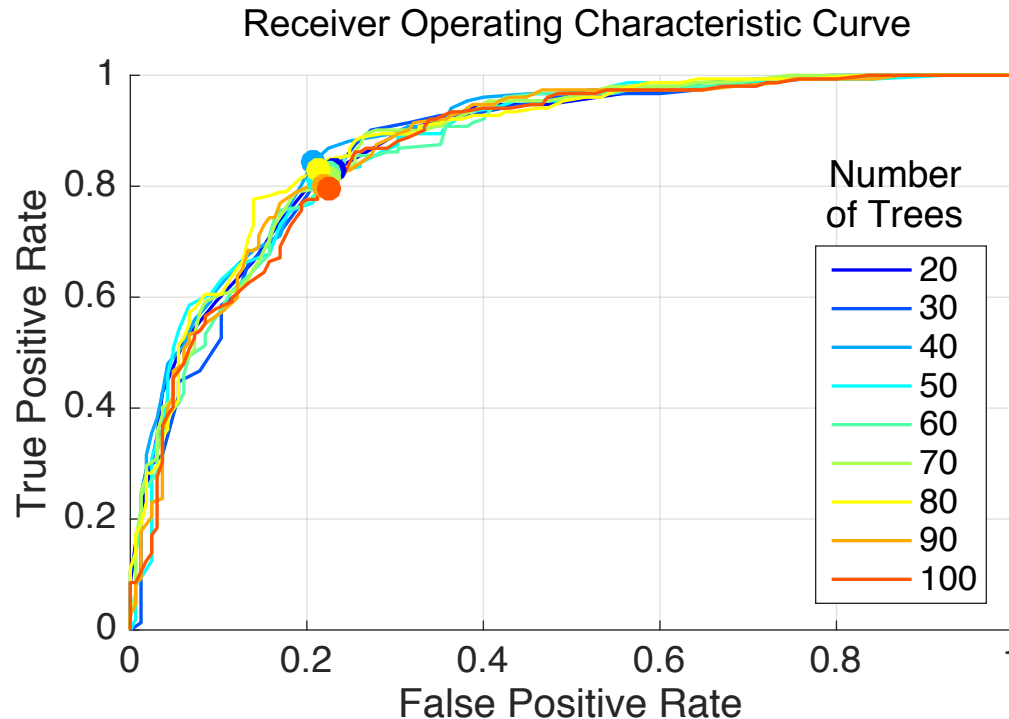
Feature Selection

- <u>Method</u>: Forward Search, training a Random Forest with 40 trees, using 10-fold cross-validation
- <u>Metric</u>: F-Score
- <u>Observations</u>: between 317 and 544, depending on features included
- <u>Data Balancing</u>: Positive (Rejected or Modified) 40%; Negative (Accepted) 60%

- Feature Set with highest F-Score (0.815):
  - Hist. Count by Segment,
  - Number of Downstream Sectors,
  - Distance to Exit MSS,
  - MSS Over Capacity
  - Time to Exit MSS,
  - Direct Routing
  - MSS Demand/Capacity Ratio

Receiver Operating Characteristic Curve
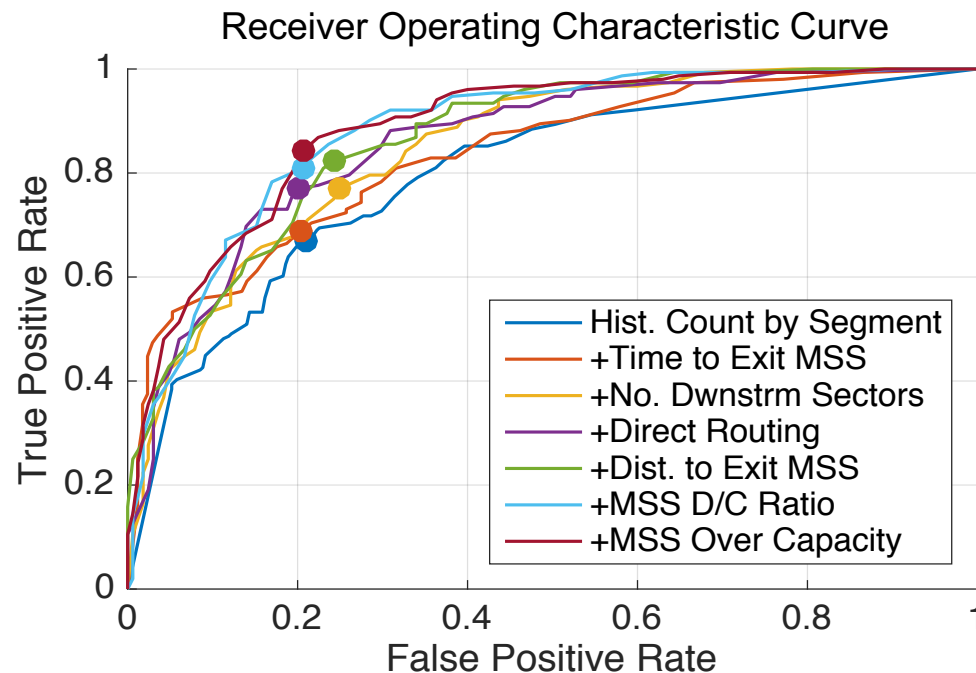
Model Selection

- <u>Method</u>: 10-fold cross-validation
- <u>Observations</u>: 317
- <u>Data Balancing</u>: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%
- <u>Features</u>: Hist. Count by Segment, Time to Exit MSS, No. Downstream. Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.

	Logistic Regression	Decision Tree	SVM	Random Forest	AdaBoost
Accuracy	0.732	0.735	0.685	0.817	0.776
Misclassification Error	0.268	0.265	0.315	0.183	0.224
True Positive Rate	0.711	0.750	0.632	0.842	0.763
True Negative Rate	0.752	0.721	0.733	0.794	0.788
Precision	0.725	0.713	0.686	0.790	0.768
F-score	**0.718**	**0.731**	**0.658**	**0.815**	**0.766**
Area Under ROC	0.818	0.767	0.770	0.886	0.864
Average Precision	0.776	0.687	0.735	0.870	0.826
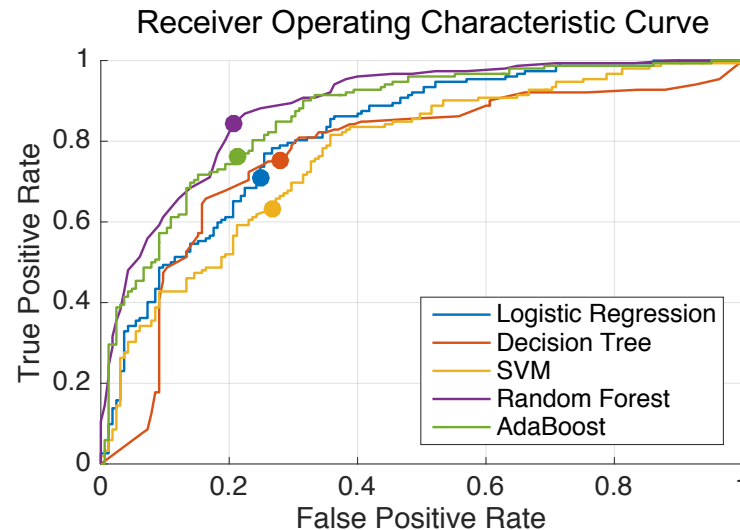
Receiver Operating Characteristic Curve

Parameter Selection: Number of Weak Learners

- <u>Method</u>: Random Forest, with 10-fold cross validation   <u>Metric</u>: F-Score
- <u>Data</u> Balancing: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%   <u>Observations</u>: 317
- <u>Features</u>: Hist. Count By Segment, Time to Exit MSS, No. Dwnstrm. Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.

Number of Trees:	20	30	40	50	60	70	80	90	100
Accuracy	0.798	0.801	0.817	0.798	0.798	0.795	0.808	0.792	0.785
Misclassification Error	0.202	0.199	0.183	0.202	0.202	0.205	0.192	0.208	0.215
True Positive Rate	0.829	0.816	0.842	0.809	0.822	0.816	0.829	0.803	0.796
True Negative Rate	0.770	0.788	0.794	0.788	0.776	0.776	0.788	0.782	0.776
Precision	0.768	0.780	0.790	0.778	0.772	0.770	0.783	0.772	0.766
F-score	**0.797**	**0.797**	**0.815**	**0.794**	**0.796**	**0.792**	**0.805**	**0.787**	**0.781**
Area Under ROC	0.877	0.871	0.886	0.875	0.870	0.878	0.883	0.874	0.867
Average Precision	0.860	0.820	0.870	0.833	0.844	0.854	0.863	0.840	0.835

Receiver Operating Characteristic Curve

Parameter Selection: Number of Weak Learners

- <u>Method</u>: Random Forest, with 10-fold cross validation

- <u>Metric</u>: F-Score

- <u>Observations</u>: 317

- <u>Data Balancing</u>: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%

- <u>Features</u>: Hist. Count by Segment, Time to Exit MSS, No. Downstream Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Cap.
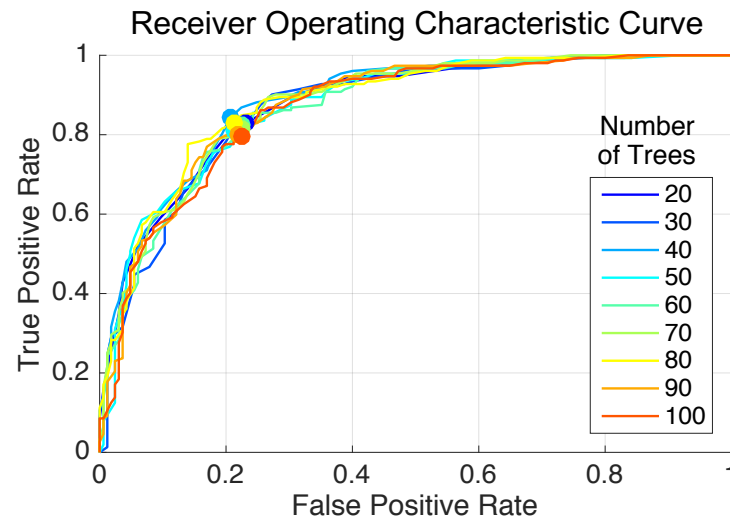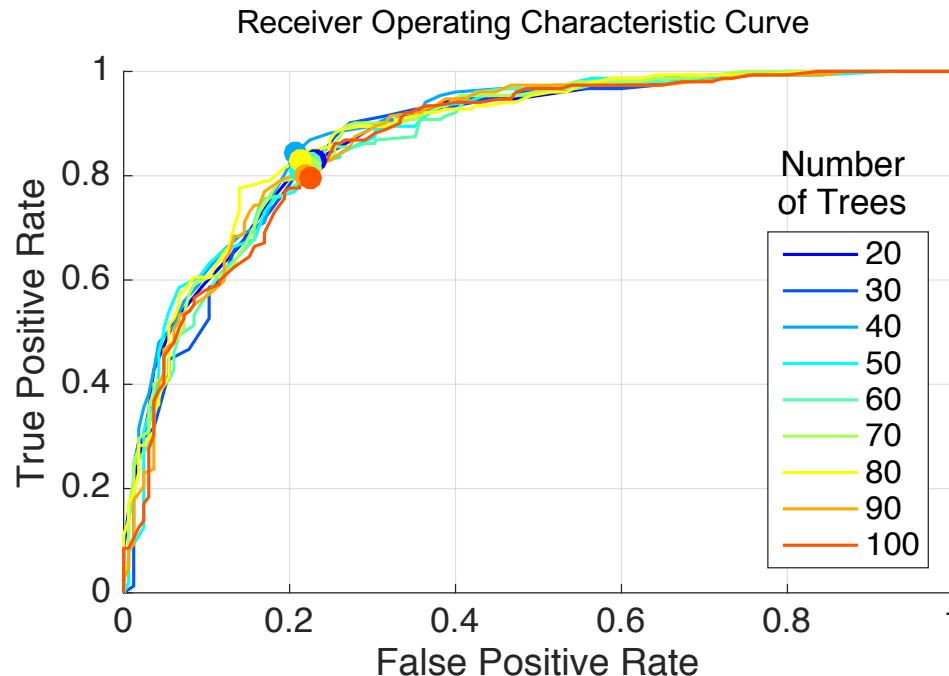
- Parameter value with highest F-Score (0.815):
  - 40 trees

Receiver Operating Characteristic Curve

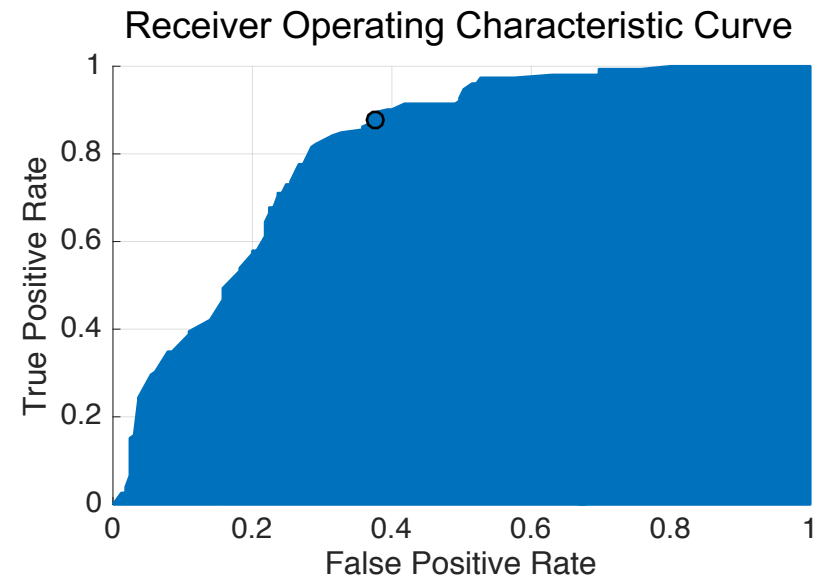# Model Validation

- Random Forest, 7 features, 40 trees
- Nested 10-fold cross validation
- 317 observations – 48% Rejected (positive); 52% Accepted (negative)

	Predicted	
	Rejected	Accepted
Observed (Actual) Rejected	88%	12%
Accepted	38%	62%

Model Accuracy: 74%

Receiver Operating Characteristic Curve

True Positive Rate vs. False Positive Rate
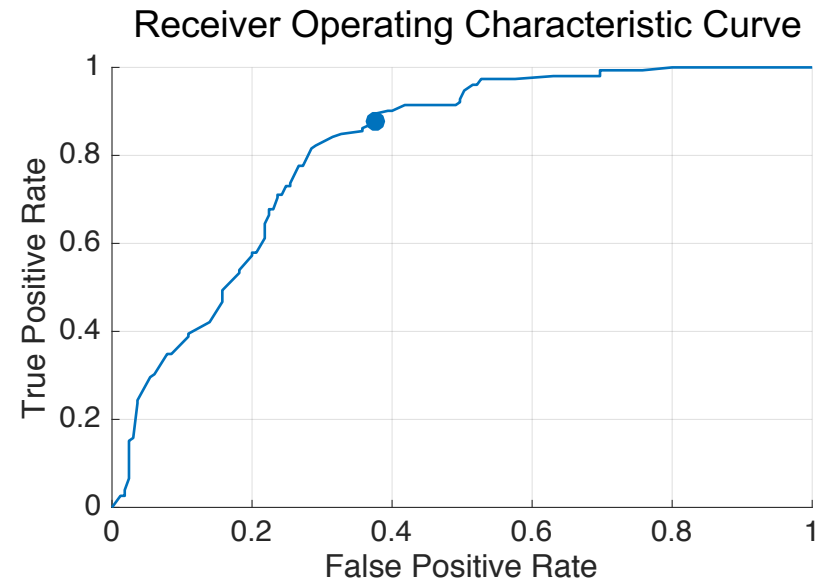
Model Validation

- <u>Method</u>: Random Forest, with 10-fold nested cross validation
- <u>Observations</u>: 317
- <u>Data Balancing</u>: Positive (Rejected or Modified) 40%; Negative (Accepted) 60%

	Nested Cross-Validation
Accuracy	0.744
Misclassification Error	0.256
True Positive Rate/Recall	0.875
True Negative Rate	0.624
Precision	0.682
FScore	**0.767**
Area Under ROC	0.814
Average Precision	0.742

Receiver Operating Characteristic Curve

Comparison to One-Class Classification

- <u>Method</u>: 10-fold cross-validation
- <u>Observations</u>: 317
- <u>Data balancing</u>: Positive (Rejected or Modified) 48%; Negative (Accepted) 52%
- <u>Features</u>: Hist. Count by Segment, Time to Exit MSS, No. Downstream Sectors, Direct Routing, Dist. to Exit MSS, MSS D/C Ratio, MSS Over Capacity

	Random Forest	Two-Class SVM	One-Class SVM
Accuracy	0.817	0.685	0.558
Misclassification Error	0.183	0.315	0.442
True Positive Rate/Recall	0.842	0.632	0.211
True Negative Rate	0.794	0.733	0.879
Precision	0.790	0.686	0.615
FScore	**0.815**	**0.658**	**0.314**