Using Historical Data to Automatically Identify Air-Traffic Controller Behavior

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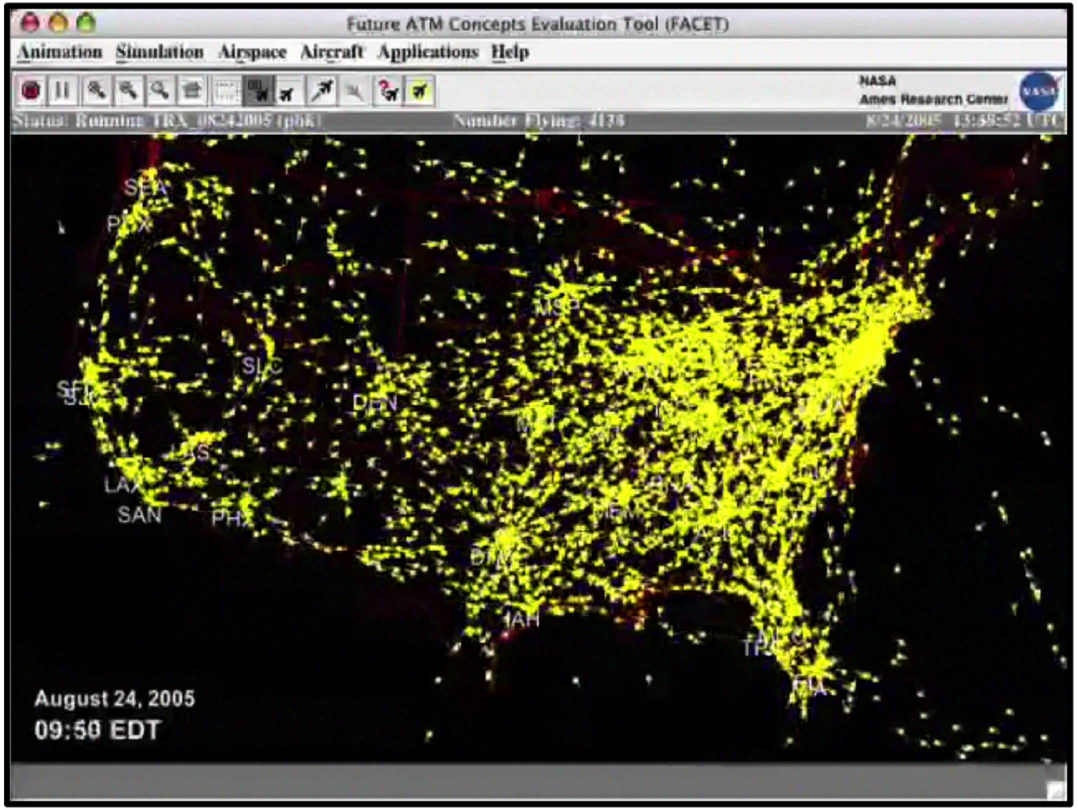
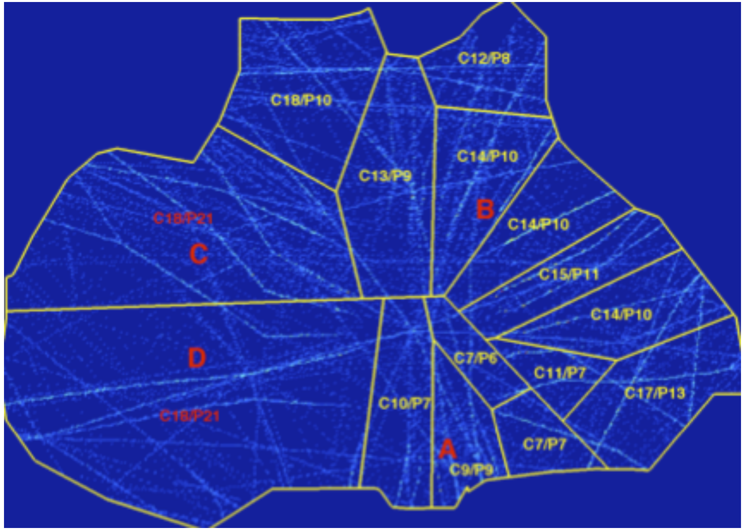
Air Transportation System



Air Traffic Control Sector



Objective

To identify and label instances where air-traffic controllers maneuvered aircraft in historical data

Why Label Data

1. Improve future automation systems by understanding the way different controllers provide air-traffic control services
2. Allows historical data to serve as a baseline for evaluation of future automation systems

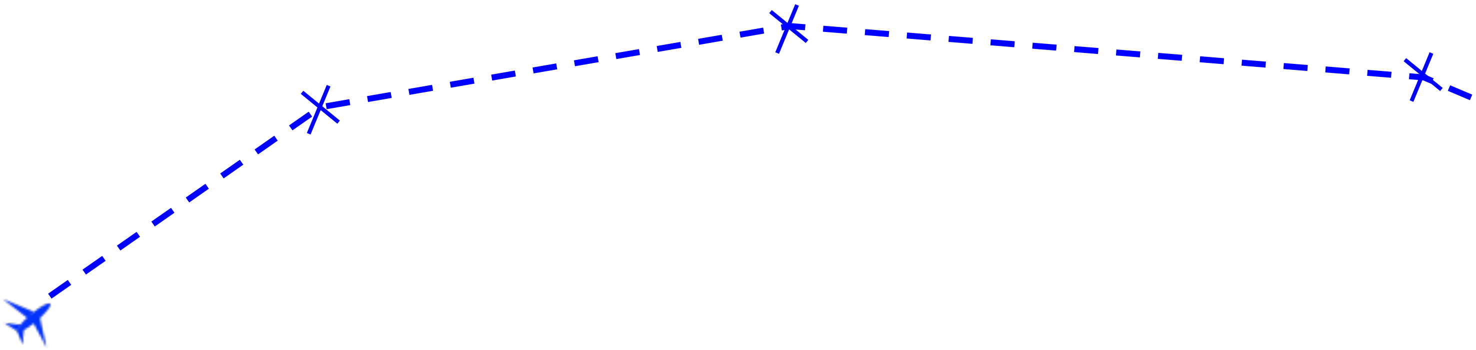
Outline

- Trajectory prediction
- Data source
- Labeling controller interventions
  - Using outliers
  - Comparing time-series
- Understanding trajectory prediction errors
- Future Work

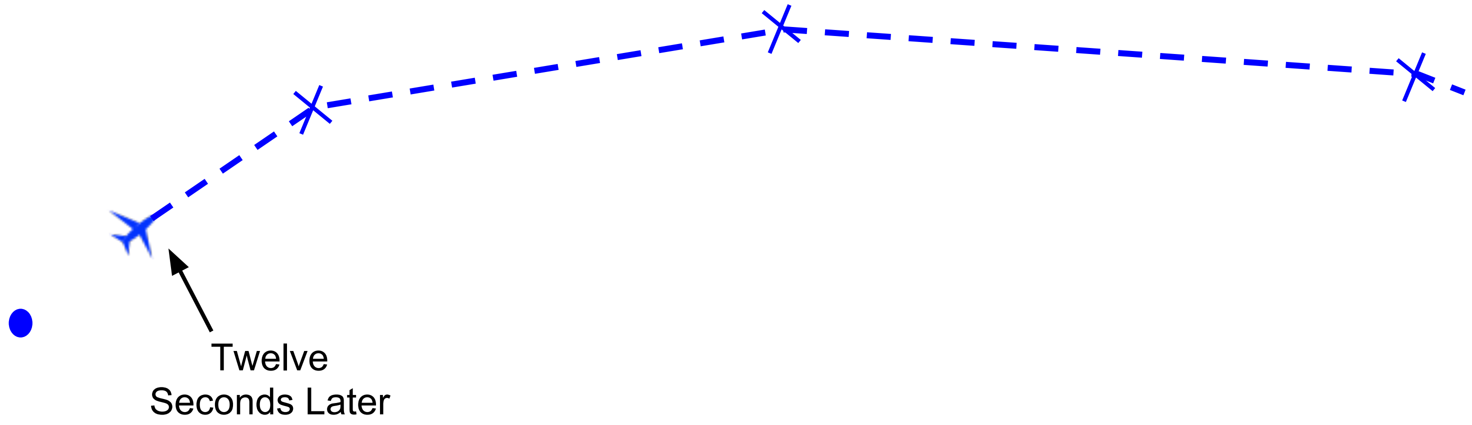
Trajectory Prediction Systems

- A predicted trajectory is a set of 4D points predicting where an aircraft will be in the future
- Currently these predictions are used to:
  - Generate runway schedules for efficient arrivals
  - Help controllers identify aircraft-to-aircraft issues
- Will serve as the foundation for future automation systems

Trajectory Predictions



Trajectory Predictions



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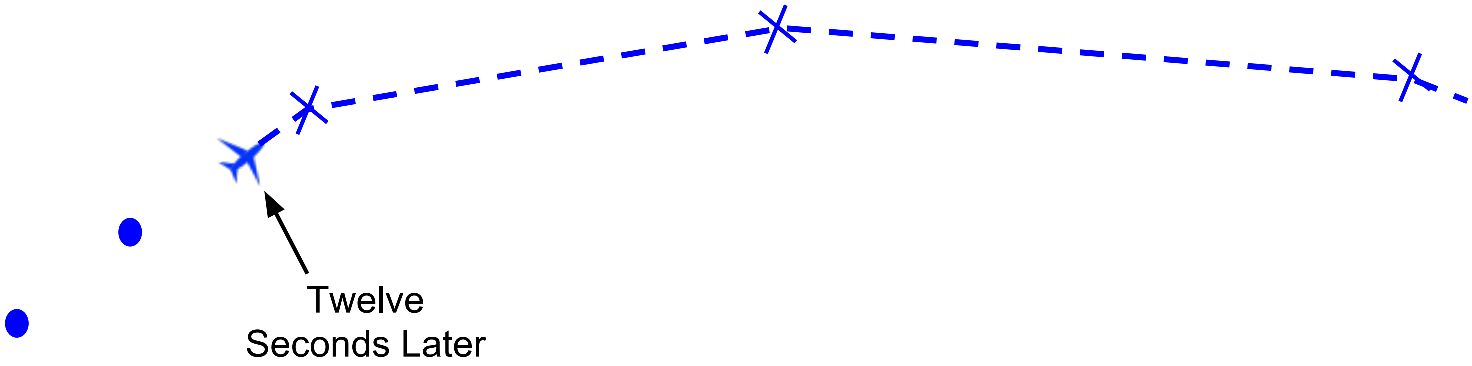
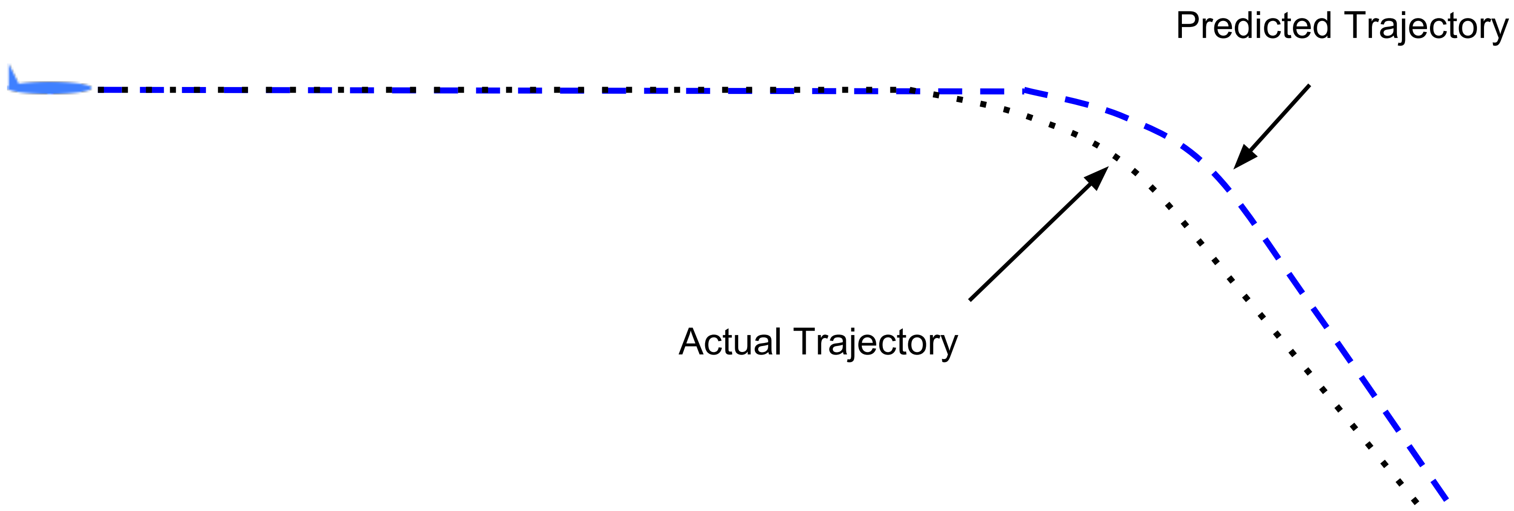


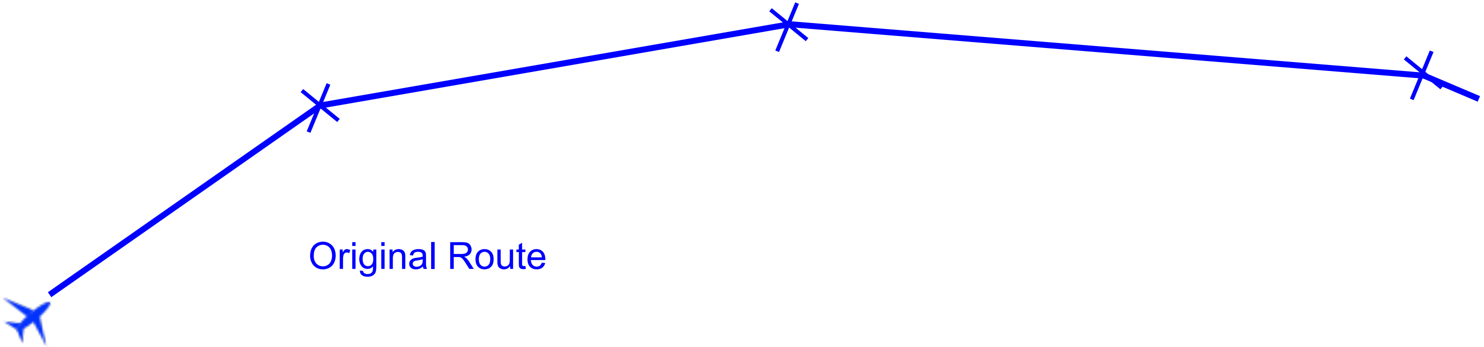
Nobody is Perfect



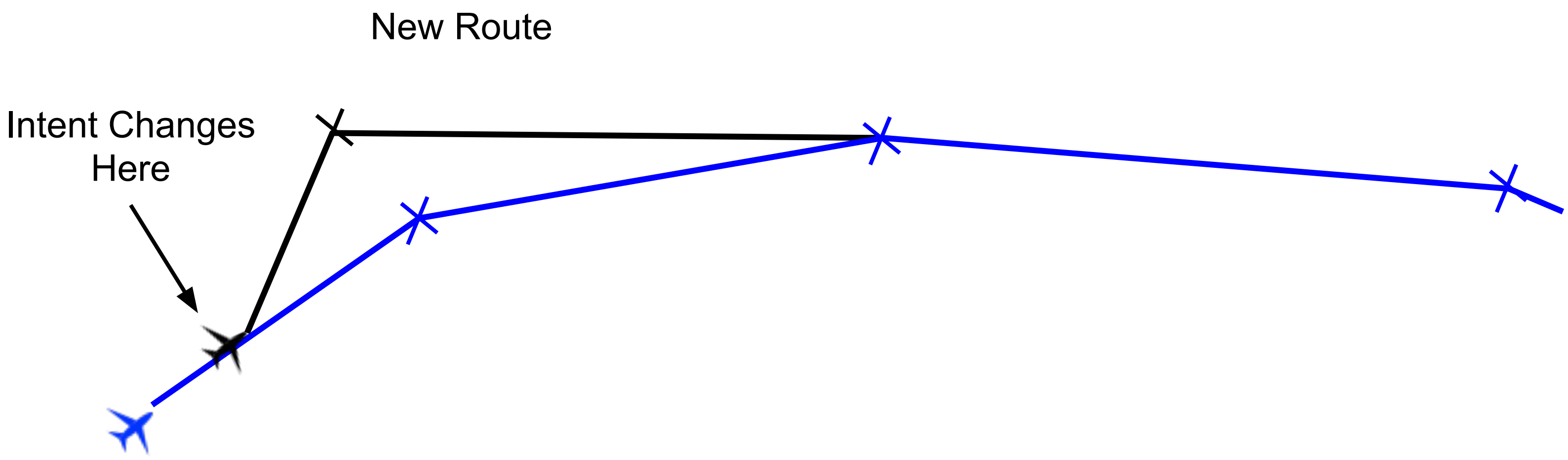
Some Causes of Prediction Errors

- Unknown wind speed
- Unknown aircraft weight
- Communication delays
- Incorrect aircraft dynamic models
- Unknown intent

Change of Intent

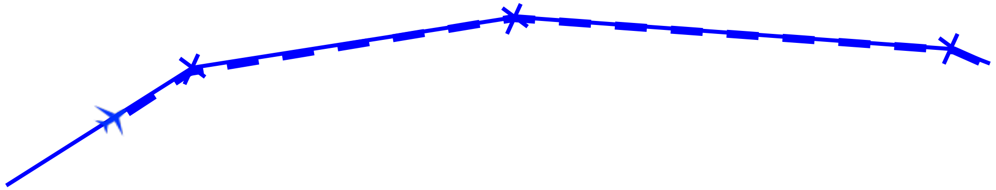


Change of Intent

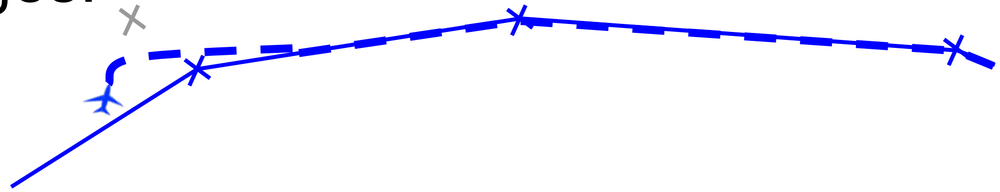


Trajectory Prediction Behavior

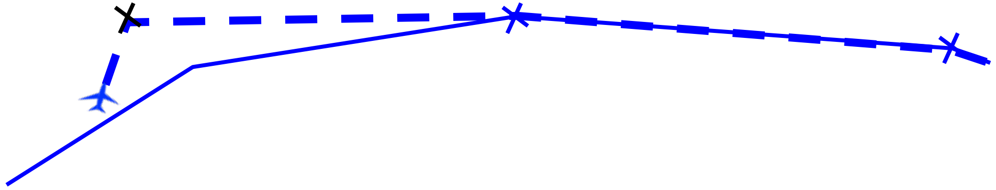
- No intent change:



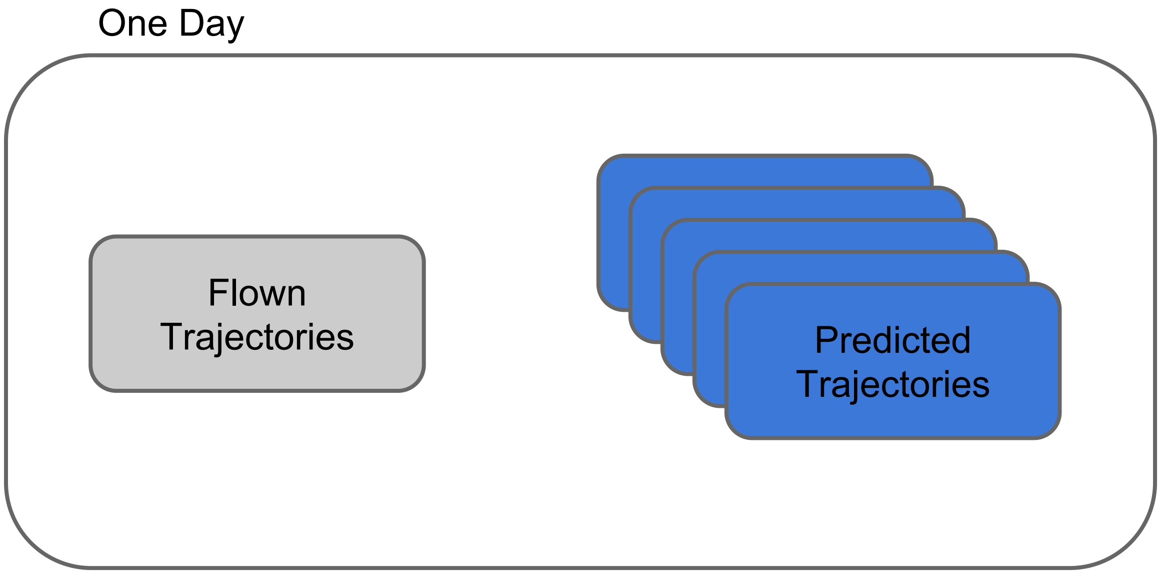
- Hidden intent changes:



- Known intent changes:

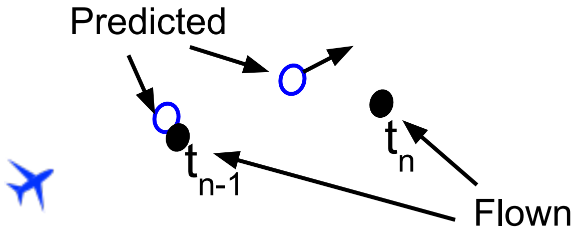


Two Types of Data

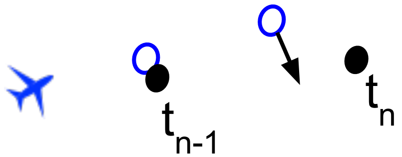


Error Components

Along-track error:



Cross-track error:



Altitude errors:

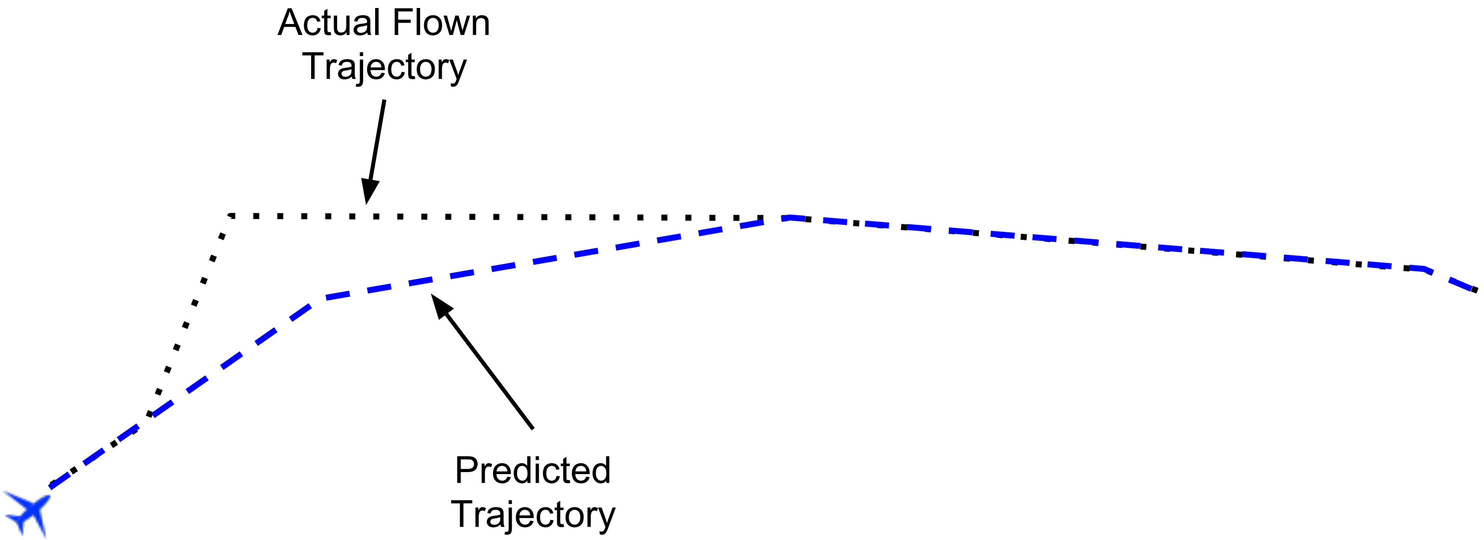
Data Sources

- Aircraft radar tracks and filed routes are available through the FAA Aircraft Situation Display to Industry (ASDI) data
- NASA can process track and route information using the Center TRACON Automation System (CTAS) to create predicted trajectories

Simulated Data

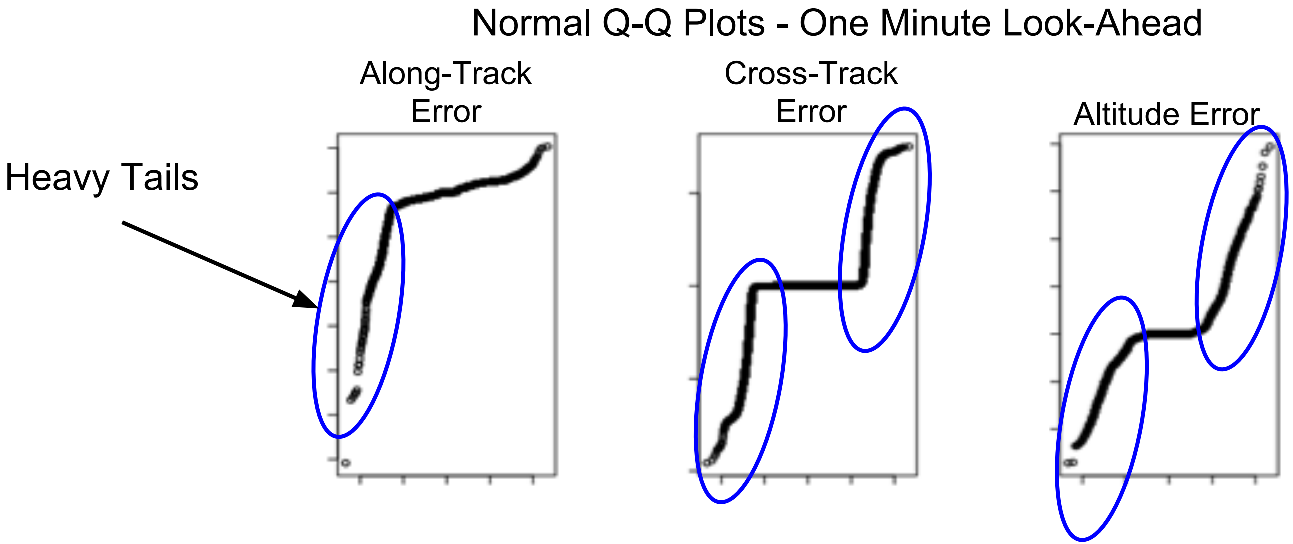
- For our analyses we used entirely simulated data
- The Airspace Concept Evaluation System (ACES) was used to create both flown trajectories and predicted trajectories
- The Advanced Airspace Concept (AAC) Autoresolver was used to emulate air-traffic controller behavior
- Realistic errors were added to trajectory predictions

Using Outliers



Looking at the Distributions

Heavy tails indicative of times when errors are beyond standard levels



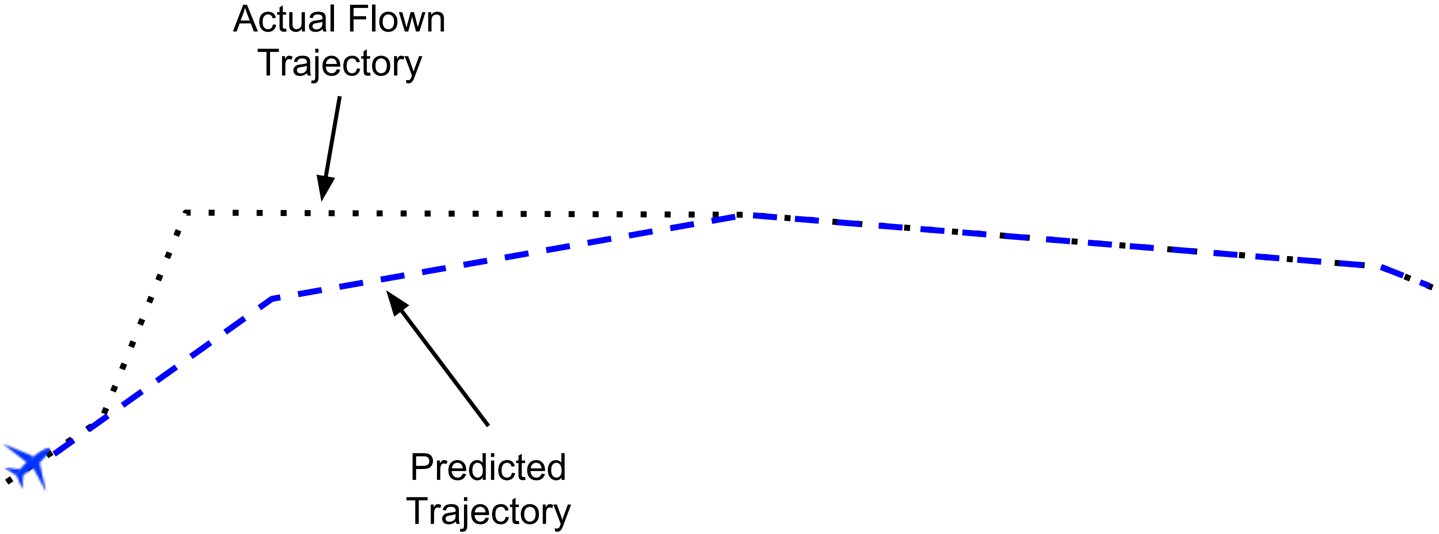
Results Using Outlier Approach

- Success of this approach relies on two assumptions:
    - Predicted trajectories are close to actual trajectory when no maneuvers are present
    - Maneuvers change trajectories significantly
- Since these do not hold in all cases this method was only able to detect 70% of maneuvers without unreasonably high false-detection rates

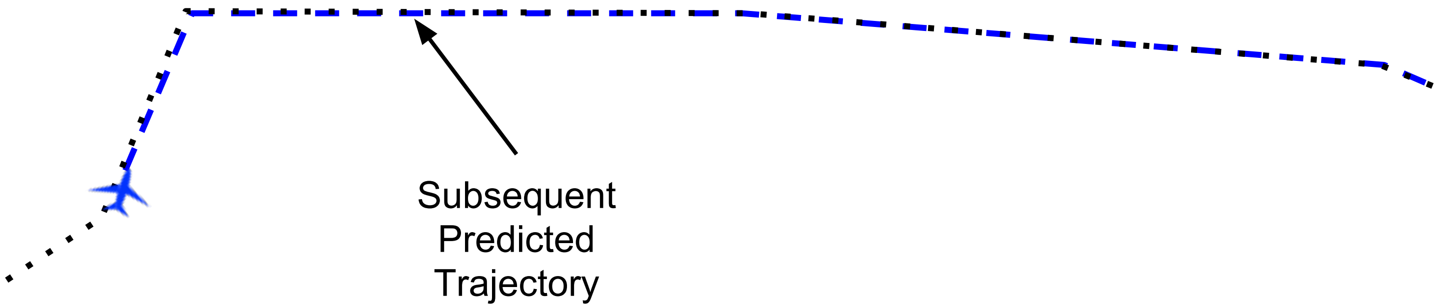
Identifying Intent Changes

- Just looking at the error between predicted and actual points did not provide enough power to identify maneuvers
- Instead we will look for differences between adjacent trajectory predictions

Prediction at Time t_n



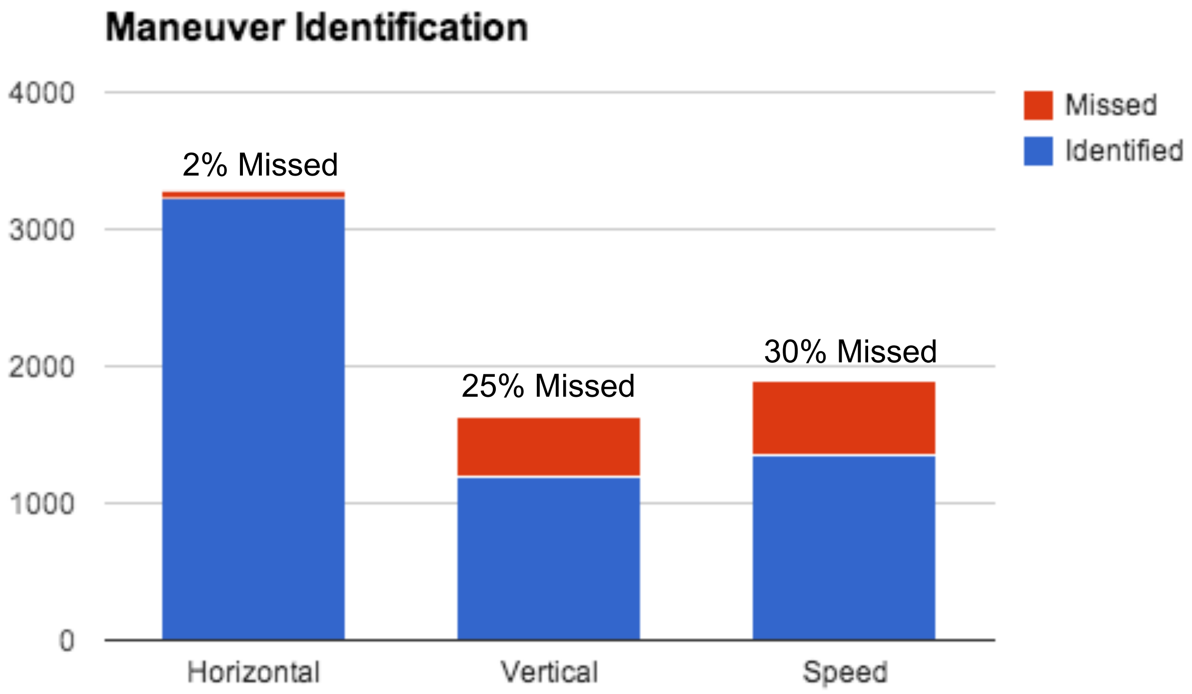
Prediction at Time t_{n+1}



Time-Series Model

- Fit a time-series model to a trajectory created at time t_n and predict what the data should look like at $t=t_n + 3$ minutes
- Do this for all points in all trajectories
- If the data at that point is greater than 2 standard deviations away from the forecasted point then this point is labeled a “singular point”
- Remove singular points due to obvious geometric conditions like top-of-climb

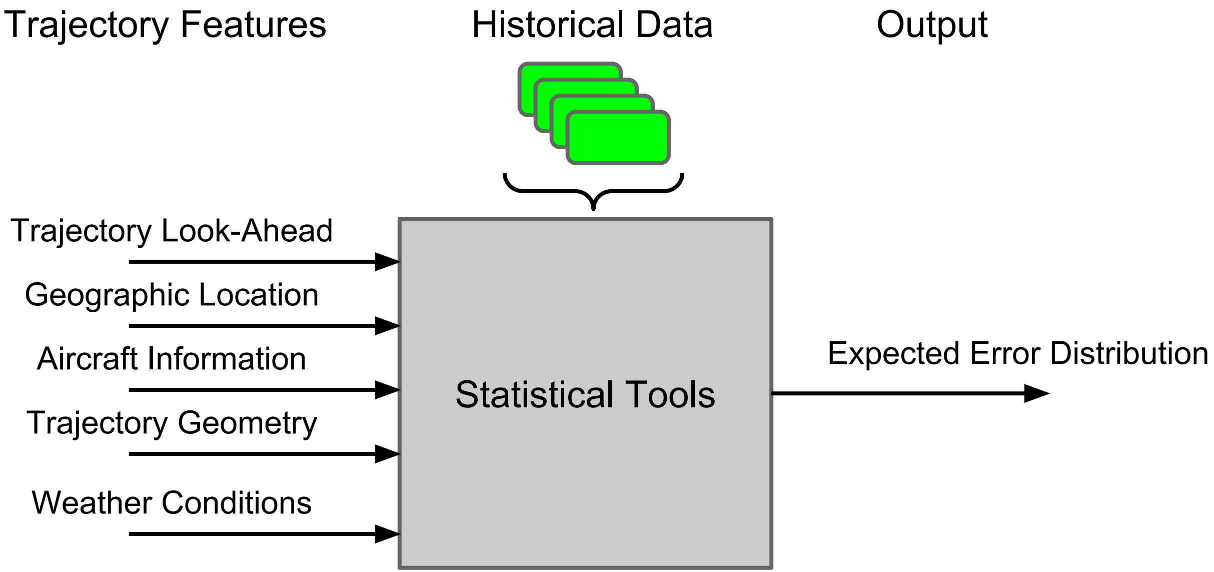
Identification Success Rate



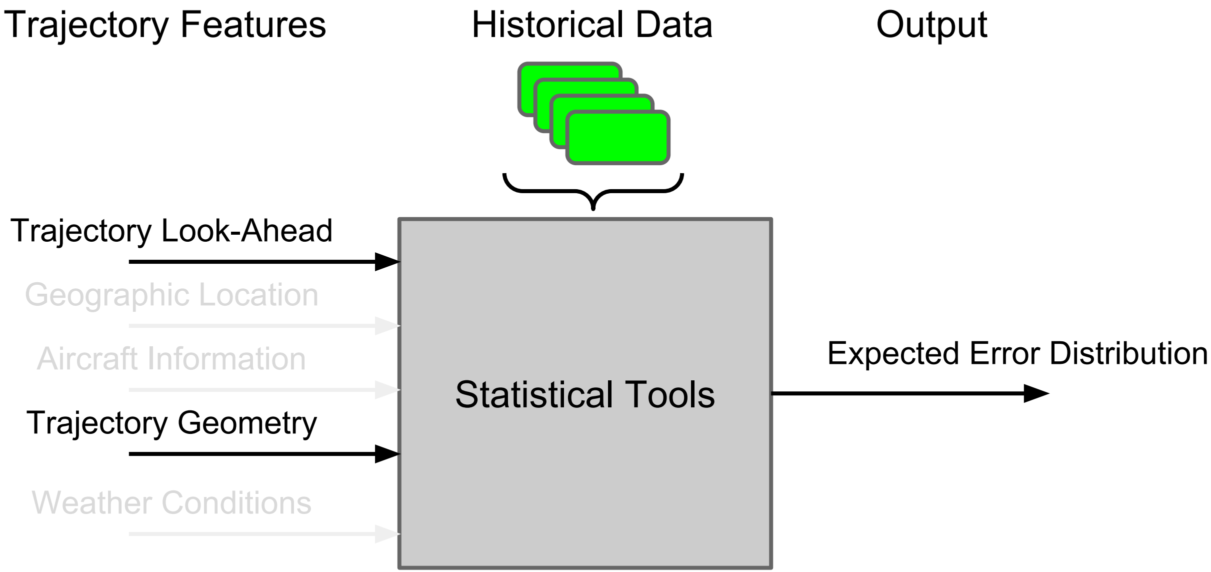
Discussion of Results

- Horizontal maneuvers are relatively easy to identify
- Speed maneuvers were difficult to identify because prediction errors in speed overshadow these types of maneuvers
- Vertical maneuvers may be missed due to coincidence with top-of-climb or top-of-descent points

Understanding Error Distributions



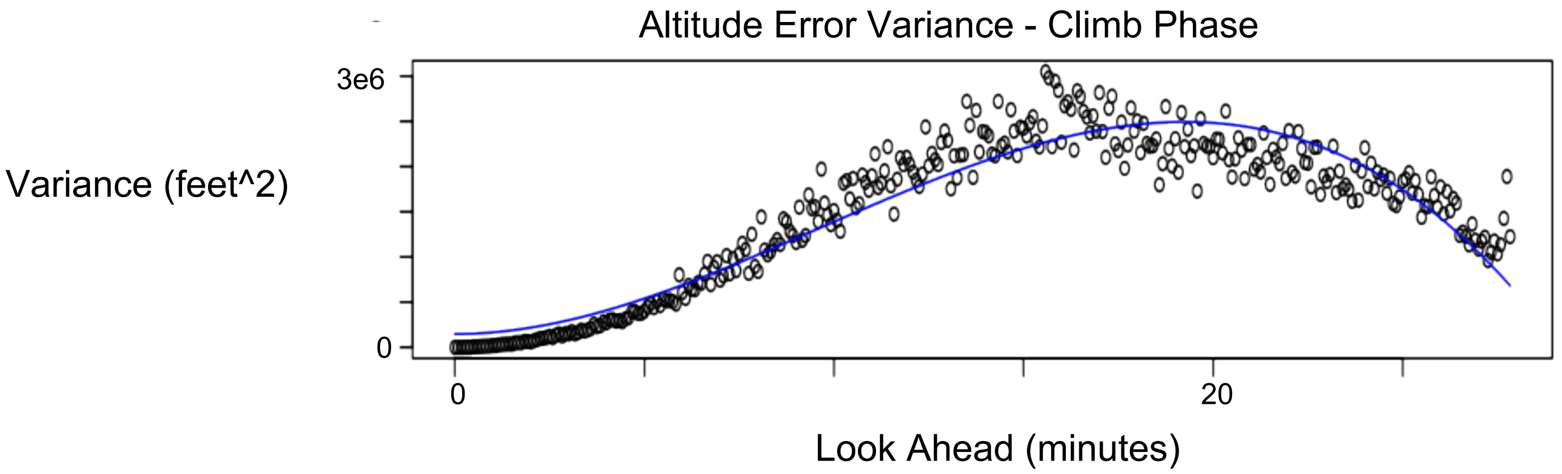
Initial Attempt



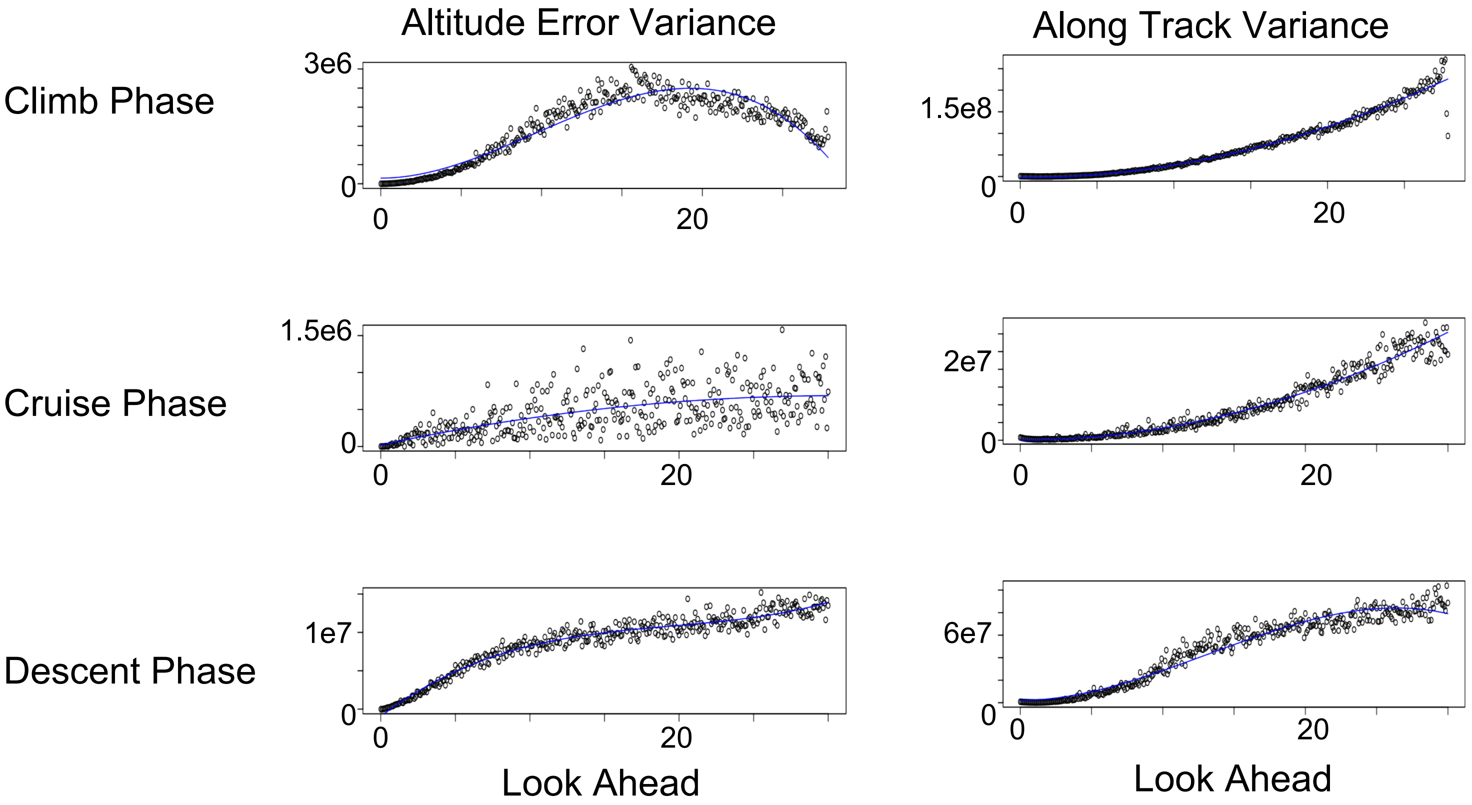
Initial Distribution Analysis

- Break trajectories down by flight phase
  - Before top of climb
  - Between top of climb and top of descent
  - After top of descent
- Analyze the effect of look-ahead time
- Determine the error variance for these factors

Example Variance Calculation



Preliminary Results



Phase II Work

- Improve the time-series method to improve sensitivity to altitude resolutions
- Test identification algorithm on data from the real system
- Identify causes of aircraft maneuvers and what type of maneuver is used in different situations
- Add features to error analysis to more fully understand trajectory prediction errors