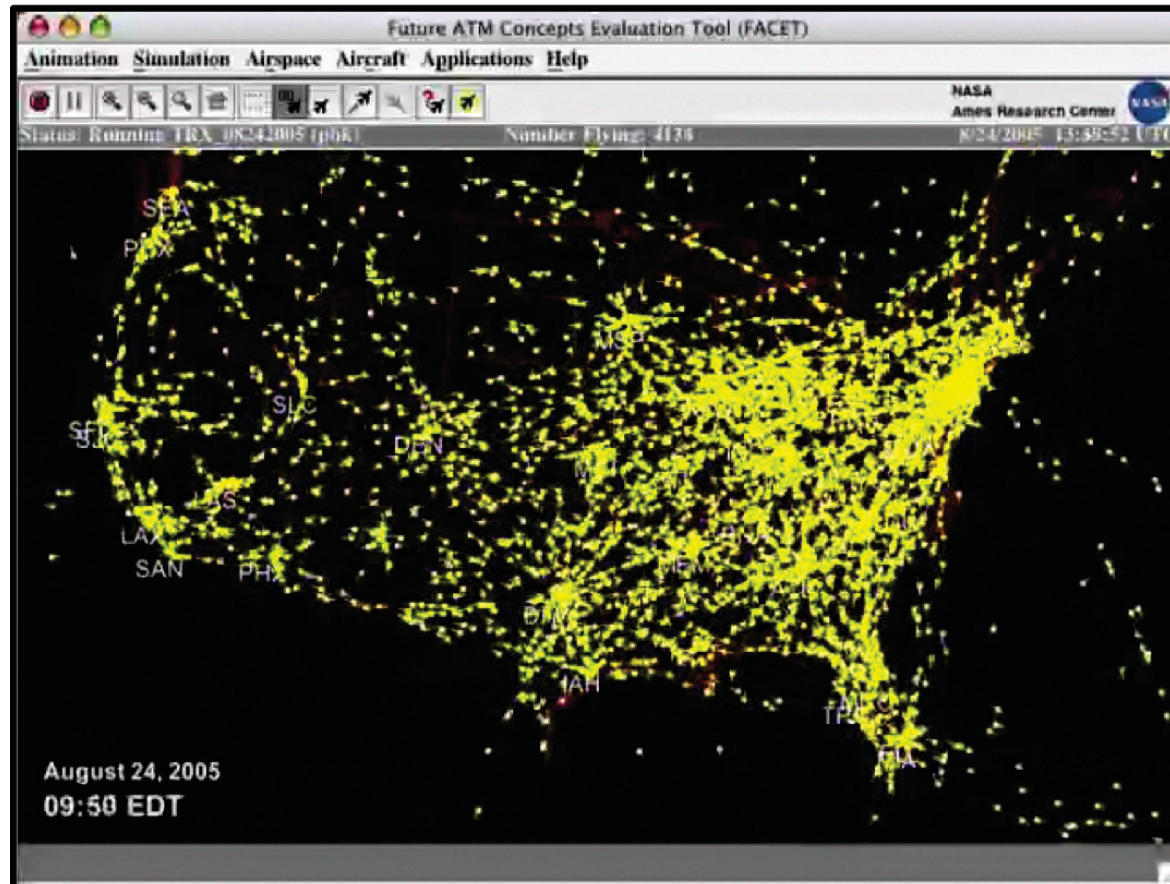# Using Historical Data to Automatically Identify Air-Traffic Controller Behavior

Todd Lauderdale
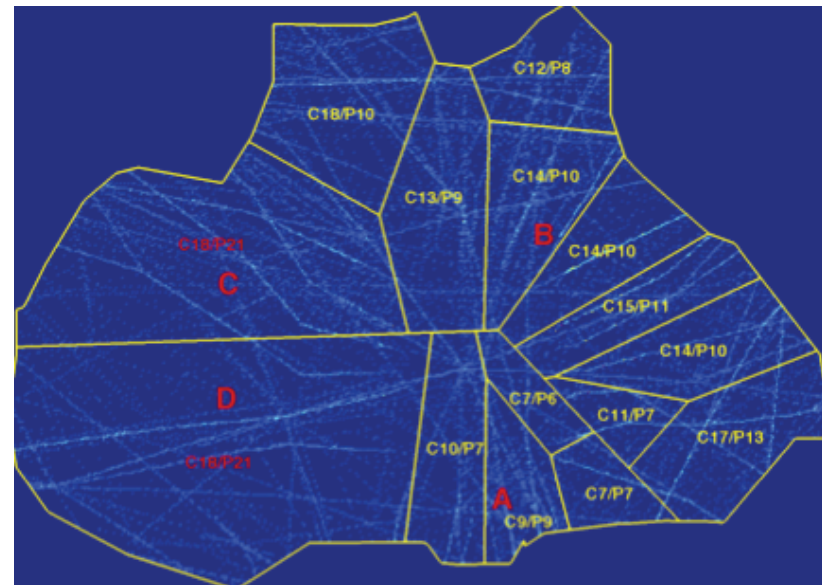
Yuefeng Wu

Celeste Tretto

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
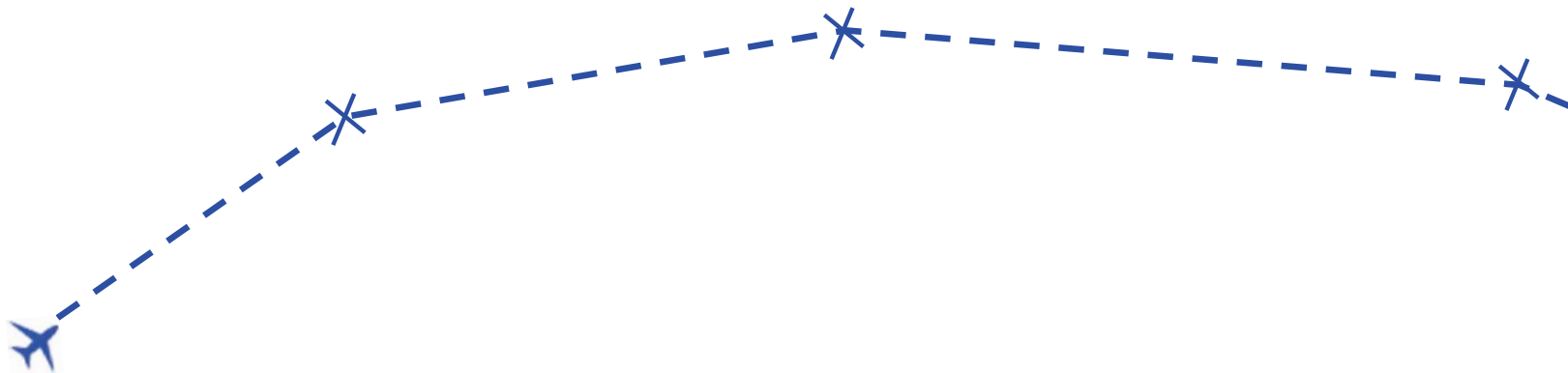
Outline

- 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
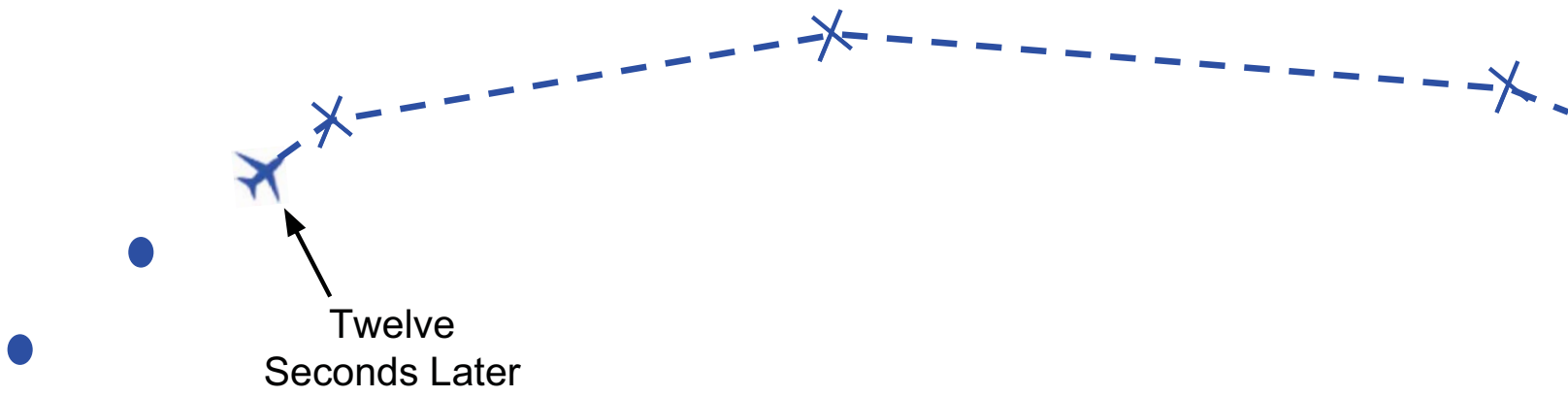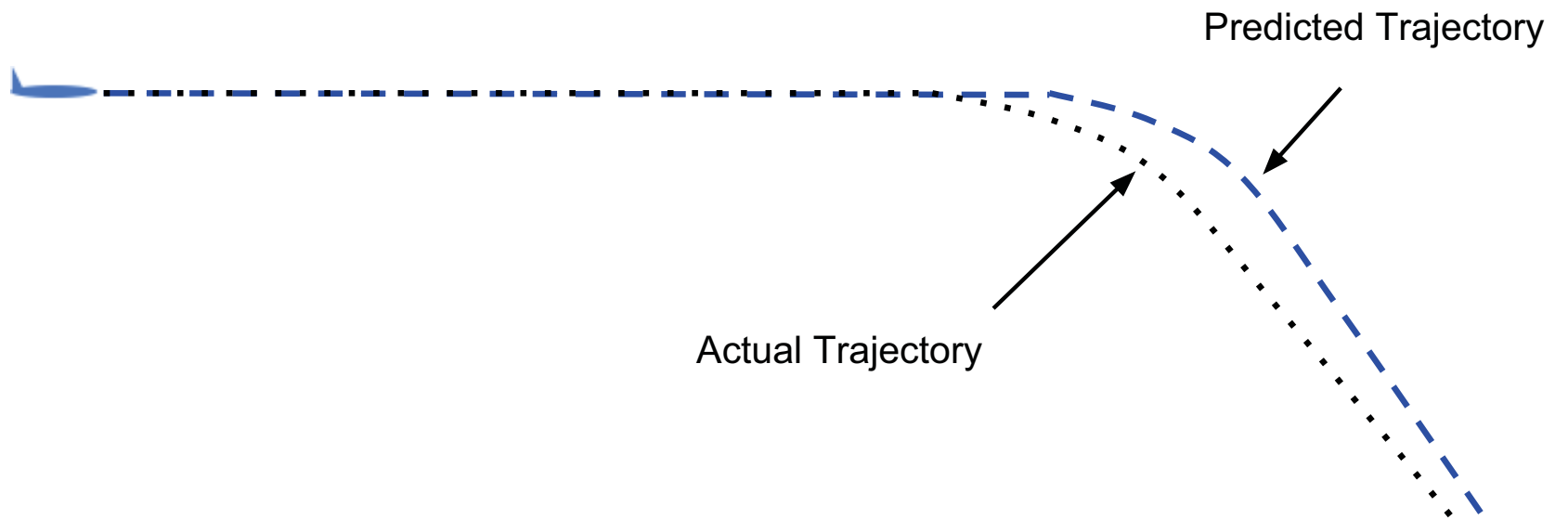
Trajectory Predictions

Trajectory Predictions

Twelve
Seconds Later

Trajectory Predictions

Twelve
Seconds Later

Nobody is Perfect

Predicted Trajectory

Actual Trajectory
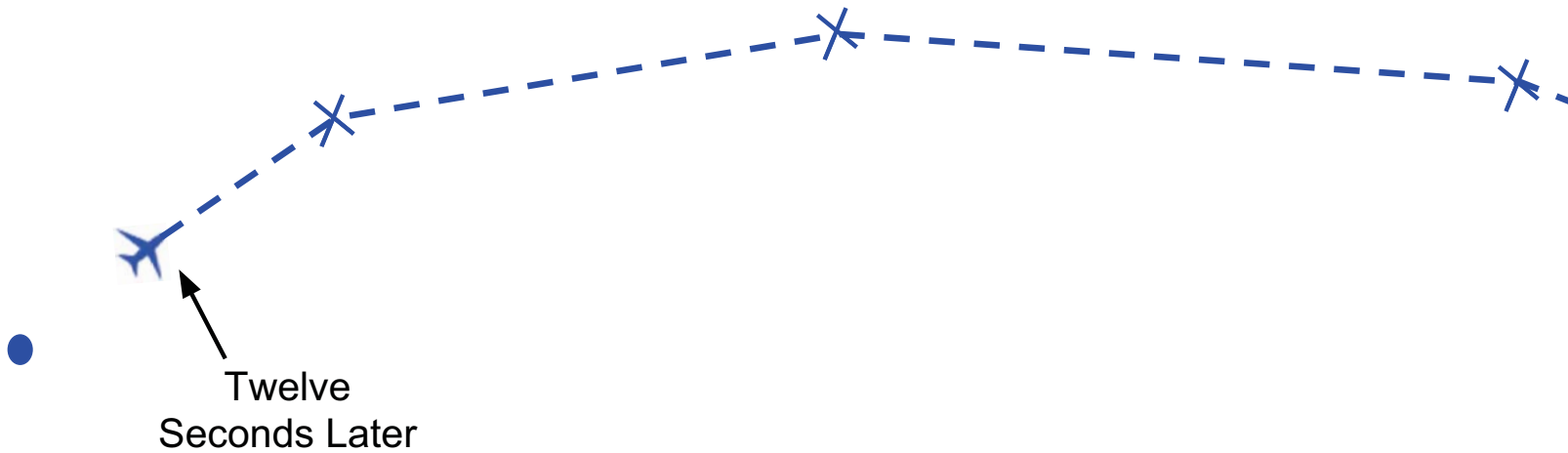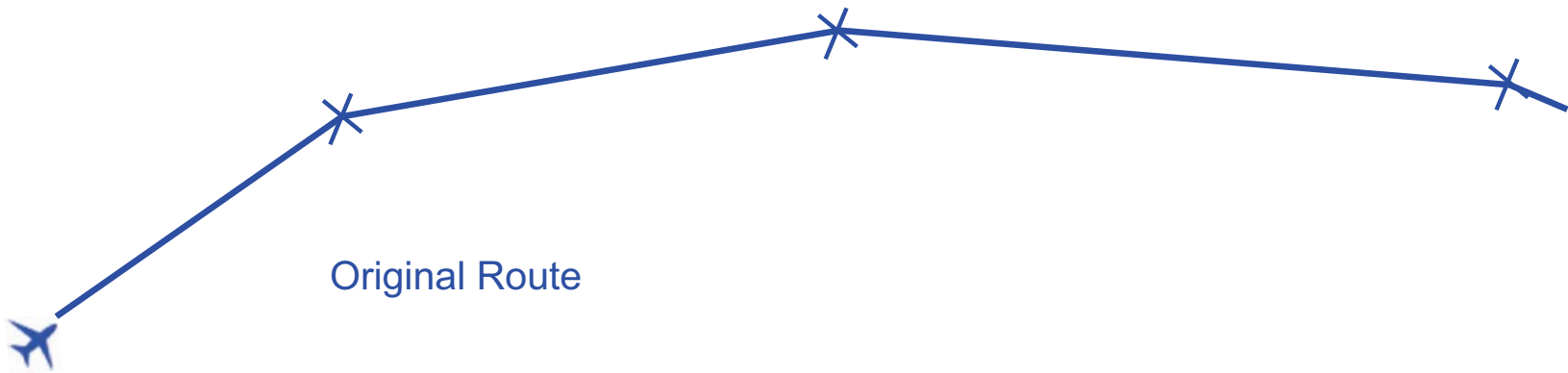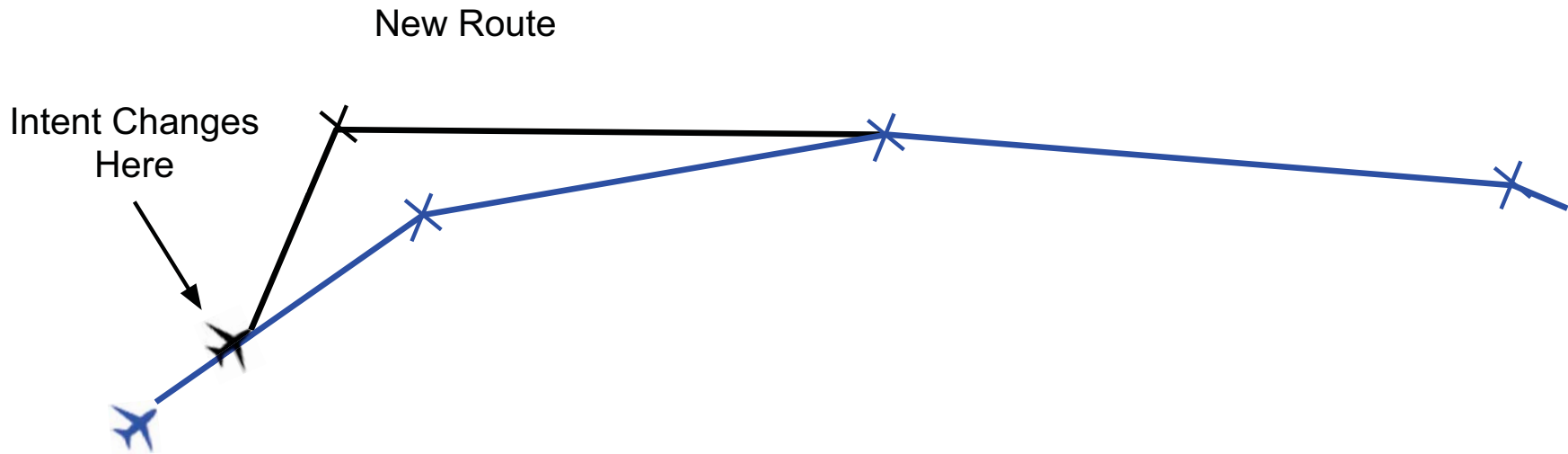
Some Causes of Prediction Errors

- Unknown wind speed

- Unknown aircraft weight

- Communication delays

- Incorrect aircraft dynamic models

- Unknown intent

Change of Intent
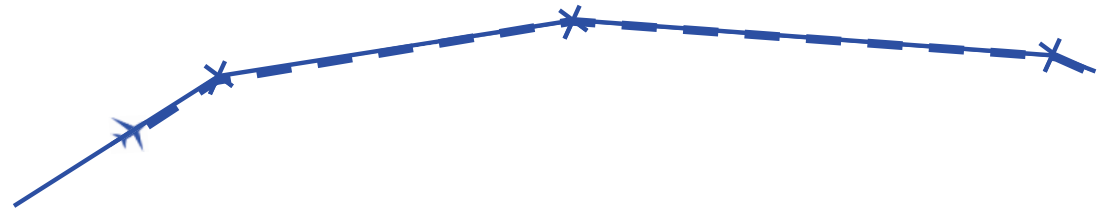
Original Route

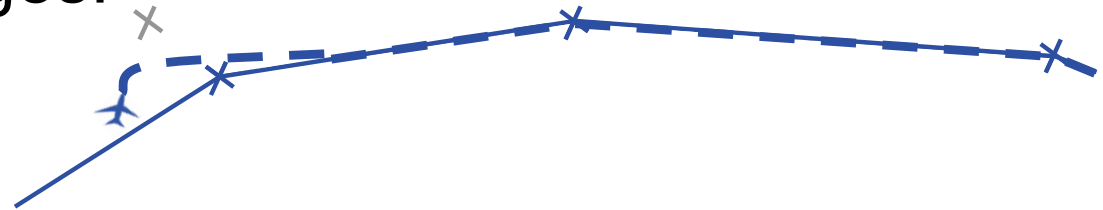# Change of Intent

New Route

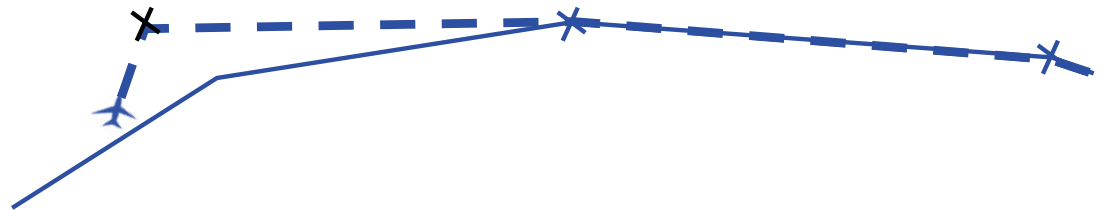Intent Changes
Here

Trajectory Prediction Behavior

- No intent change:

- Hidden intent changes:

- Known intent changes:

Two Types of Data

One Day

Flown Trajectories

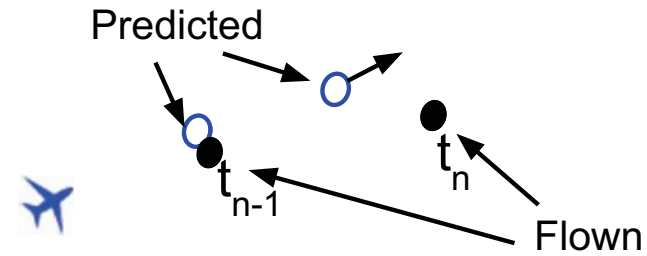Predicted Trajectories
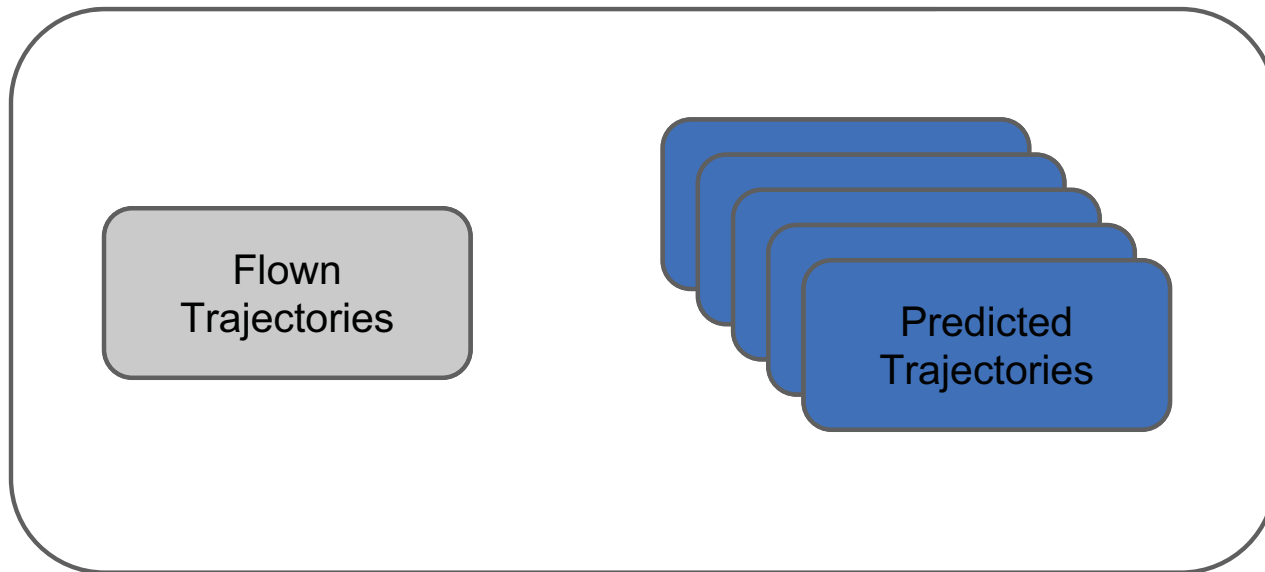
Error Components

Along-track error:

Cross-track error:
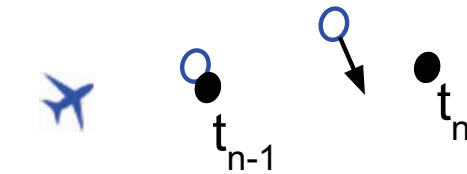
Altitude errors:

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

Actual Flown
Trajectory

Predicted
Trajectory
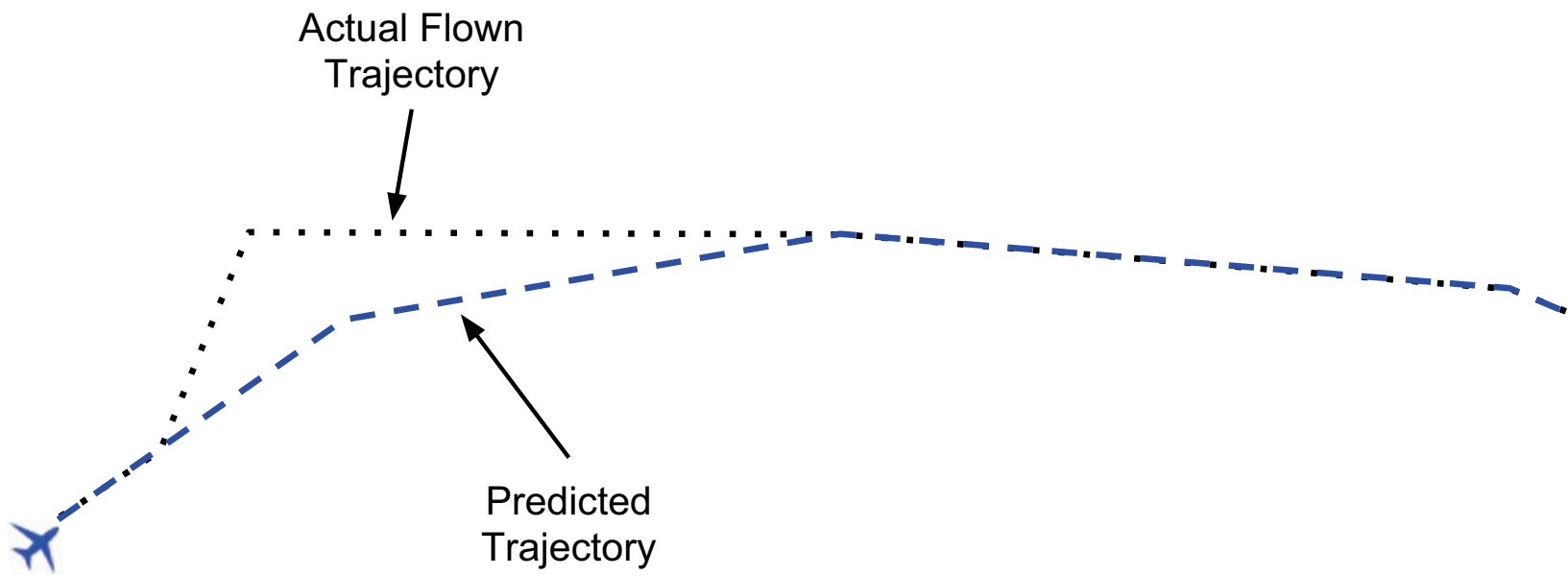
Looking at the Distributions

Heavy tails indicative of times when errors are beyond standard levels

Normal Q-Q Plots - One Minute Look-Ahead
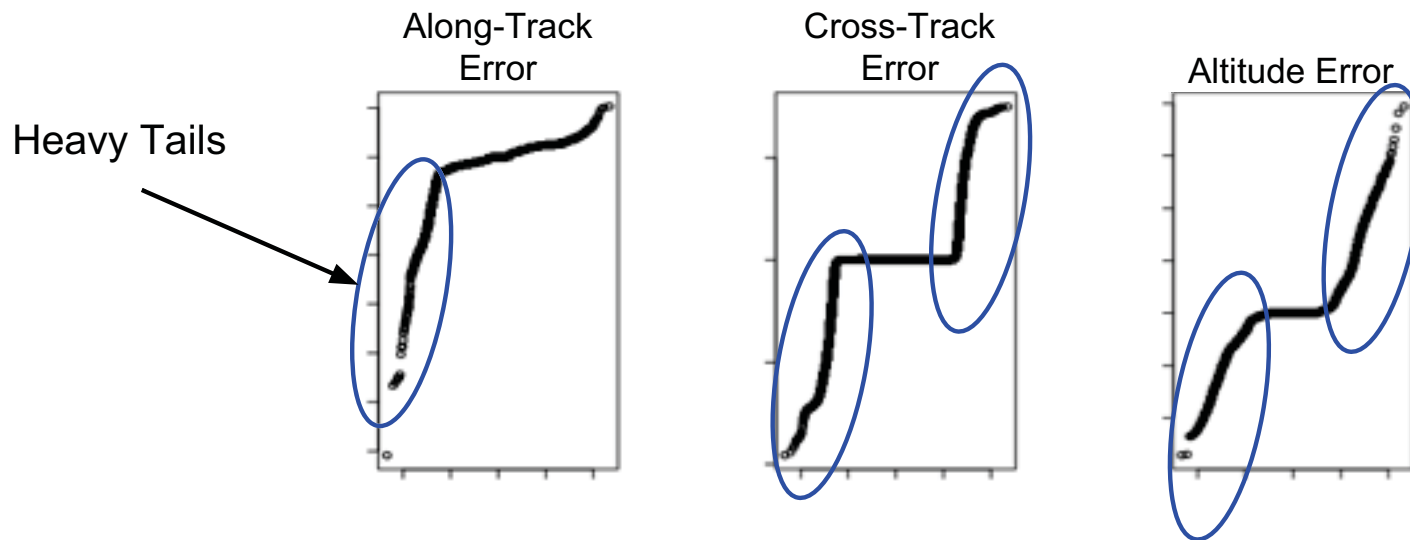
Results Using Outlier Approach

- 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$_n$

Actual Flown
Trajectory

Predicted
Trajectory

Prediction at Time t_{n+1}
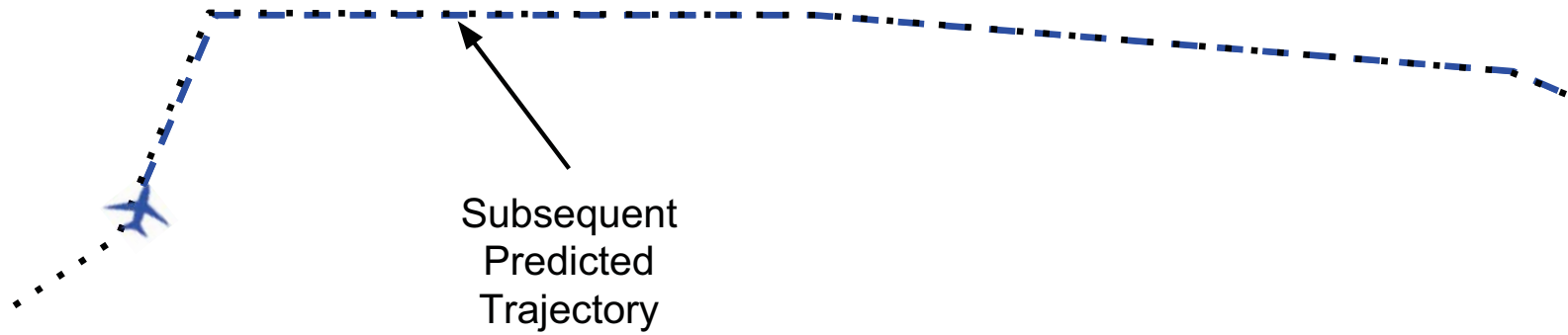

Subsequent Predicted Trajectory
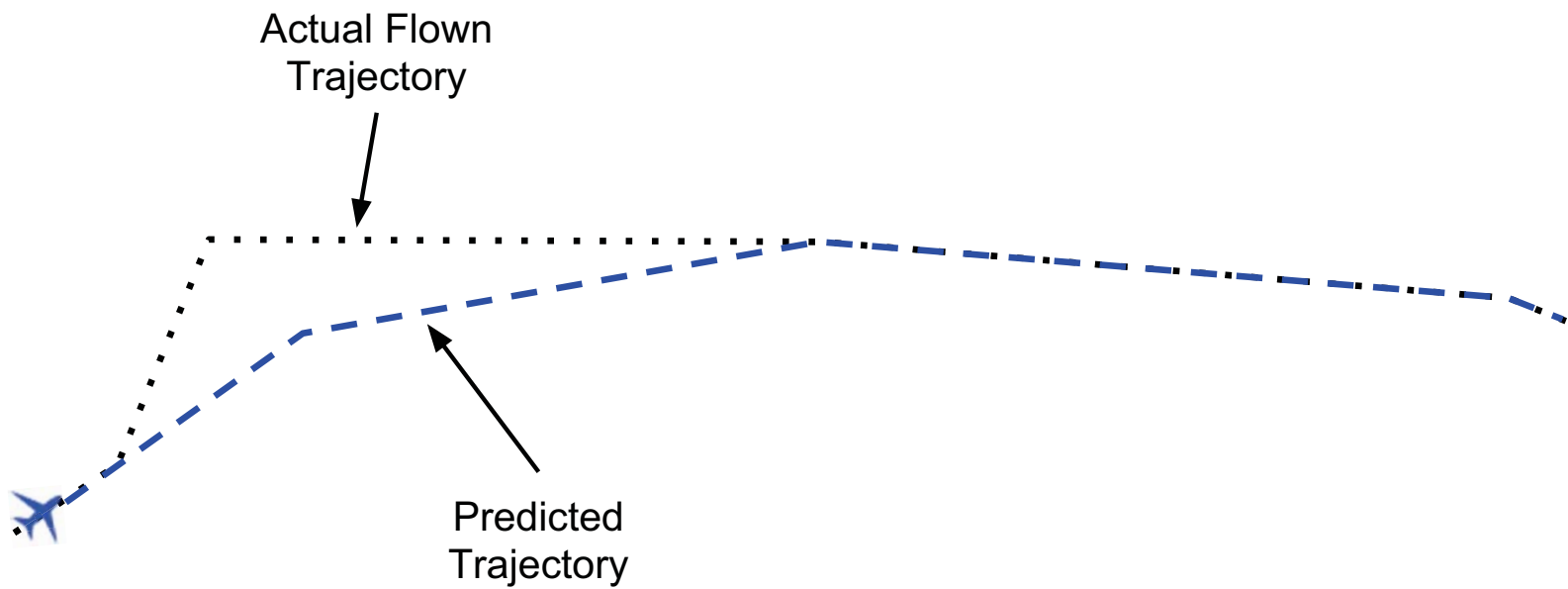
Time-Series Model

- 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

Maneuver Identification

2% Missed

25% Missed

30% Missed

Legend: Missed (red), Identified (blue)

X-axis: Horizontal, Vertical, Speed
Y-axis: 0, 1000, 2000, 3000, 4000
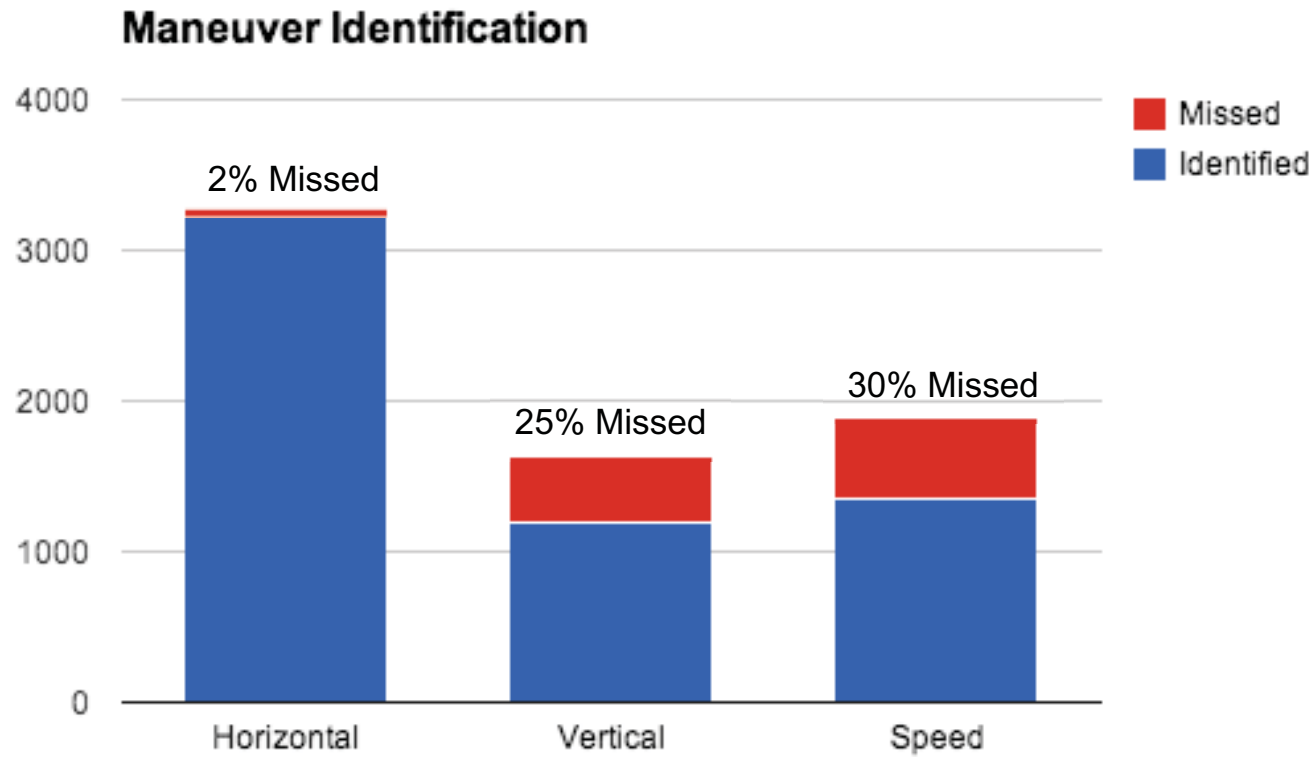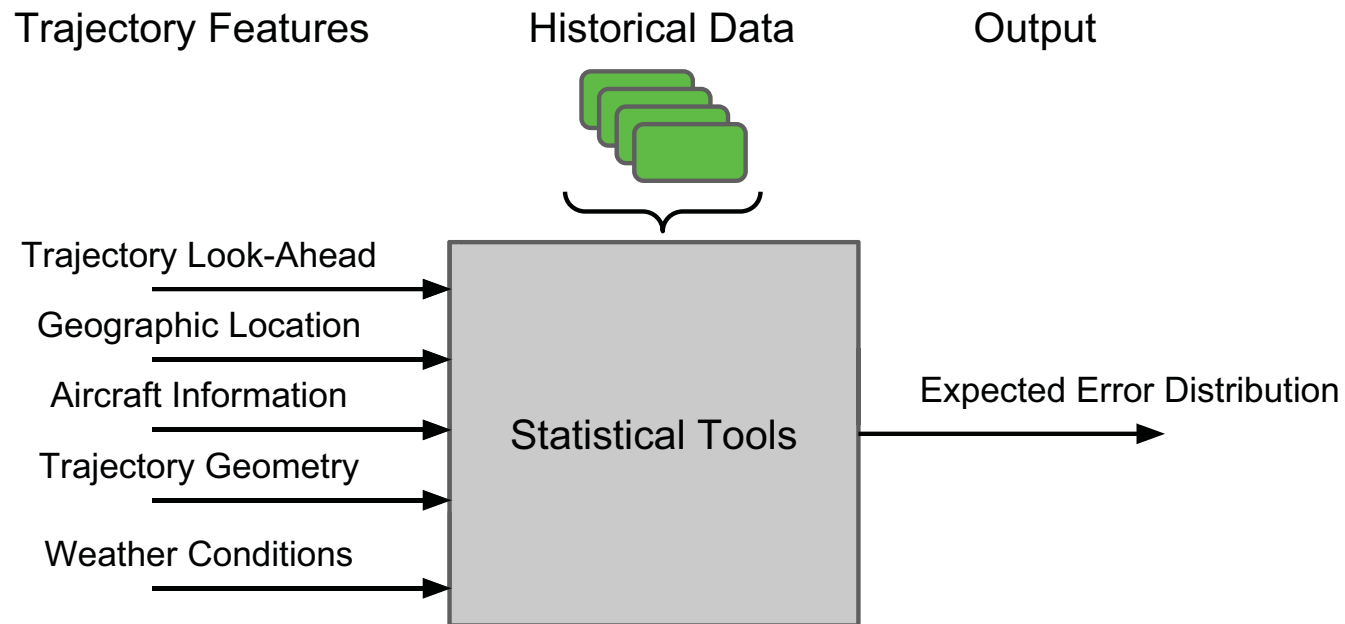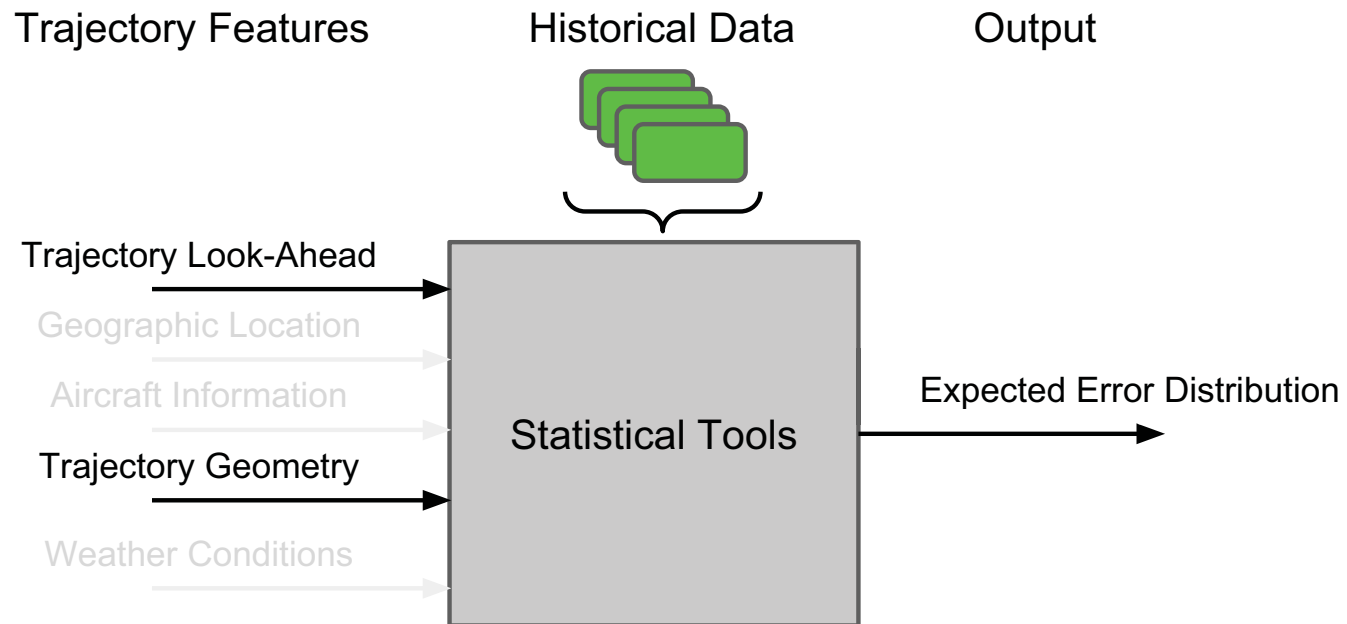
Discussion of Results

- 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

Trajectory Features

Historical Data

Output

Trajectory Look-Ahead

Geographic Location

Aircraft Information

Trajectory Geometry

Weather Conditions

Statistical Tools

Expected Error Distribution

Initial Attempt

Trajectory Features　　　Historical Data　　　Output

Trajectory Look-Ahead

Geographic Location

Aircraft Information

Trajectory Geometry

Weather Conditions

Statistical Tools

Expected Error Distribution
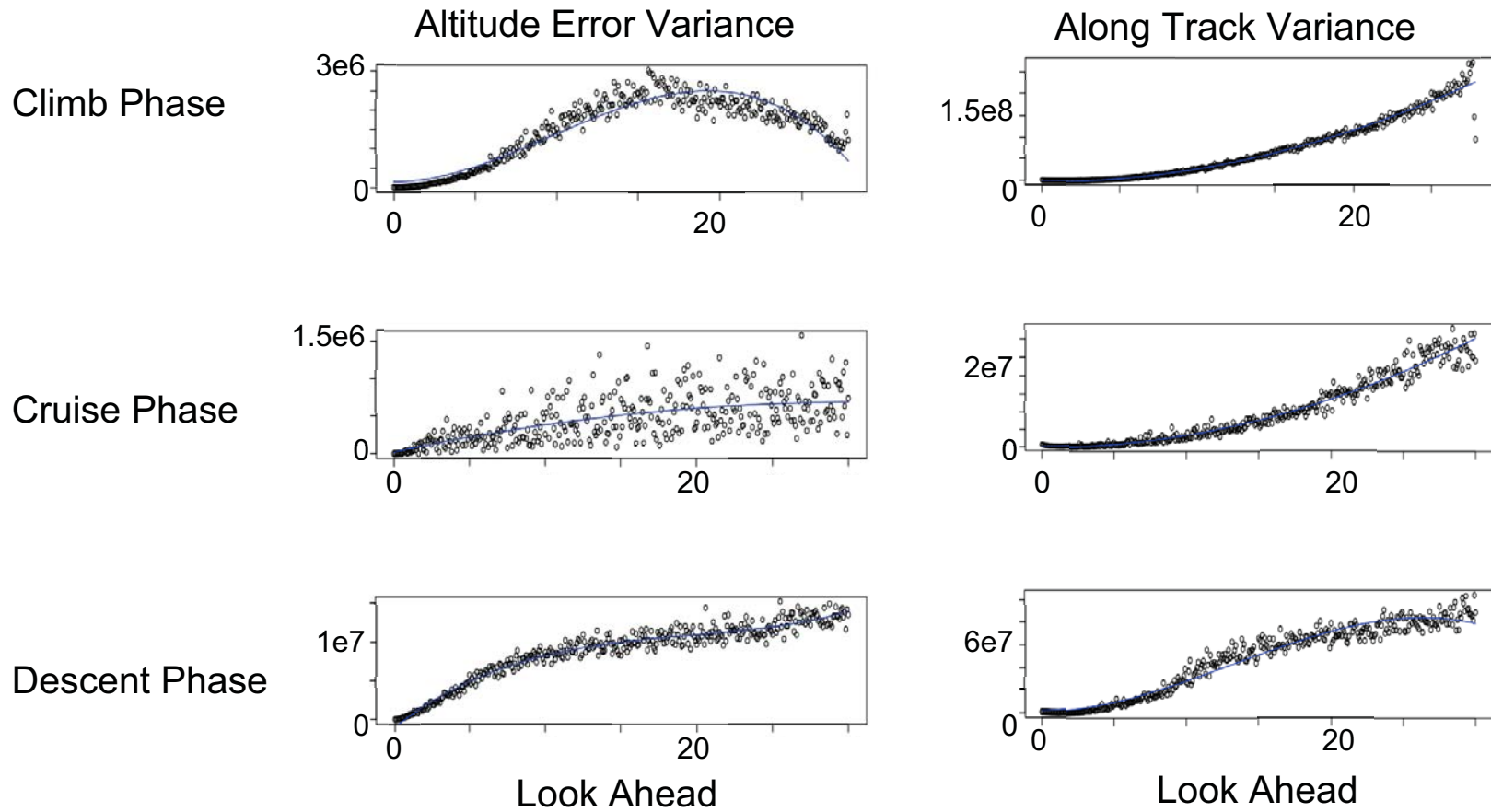
Initial Distribution Analysis

- 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

Altitude Error Variance - Climb Phase
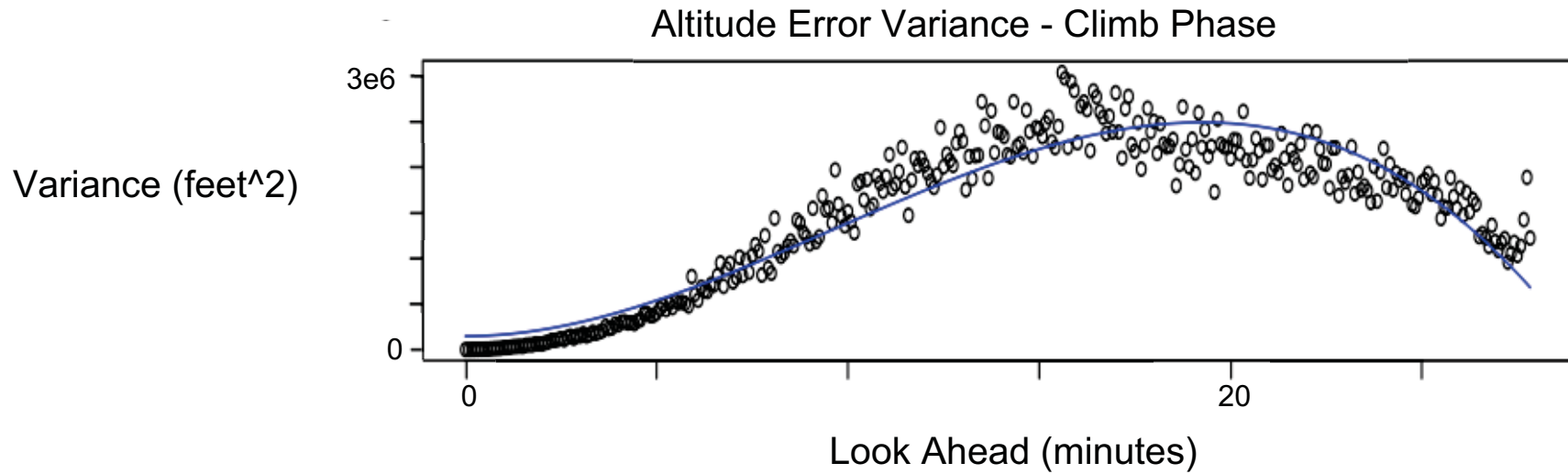
Preliminary Results

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