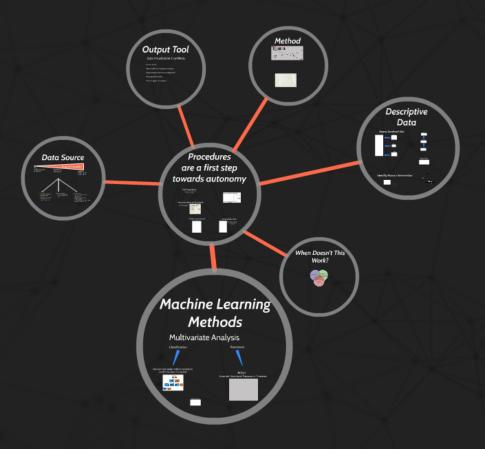
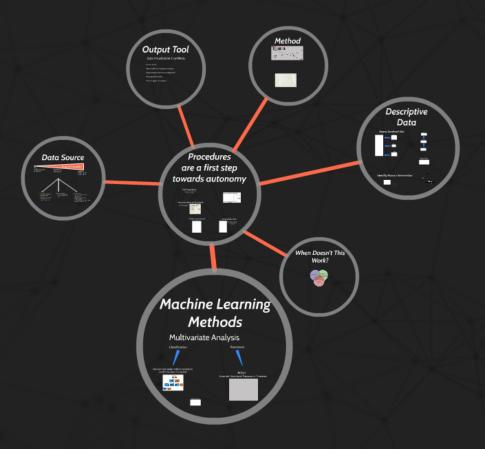
## RNAV STAR Procedural Adherence



## RNAV STAR Procedural Adherence



### Procedures are a first step towards autonomy

### No Procedures

Flying was dangerous and not standardized

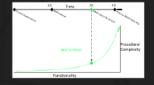
### Instrument Approach Procedures

A method to consistently



### STARs (conventional)





### STARs (RNAV OPD)



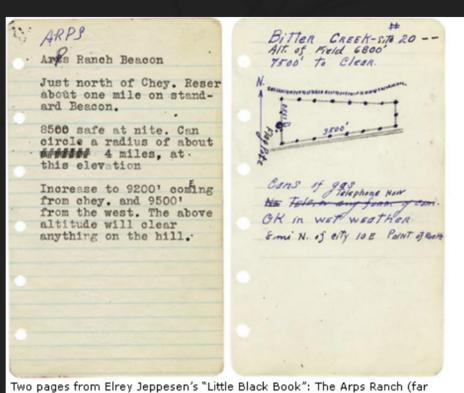
Noise reduction, fuel savings route standardization, and flow management. (FAA, 2014)

## No Procedures

Flying was dangerous and not standardized

### Instrument Approach Procedures

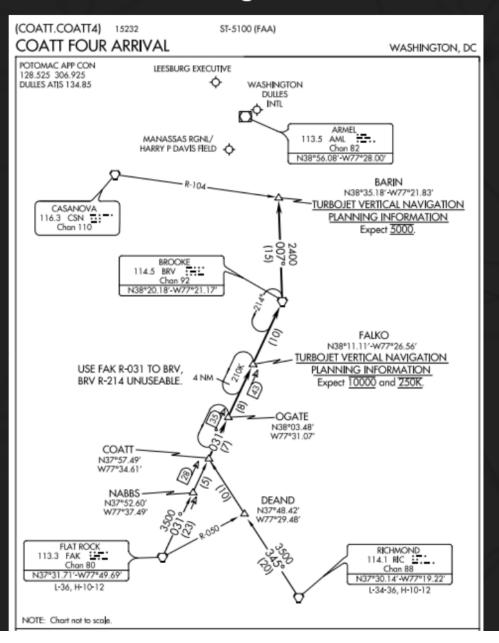
A method to consistently guarantee terrain clearance



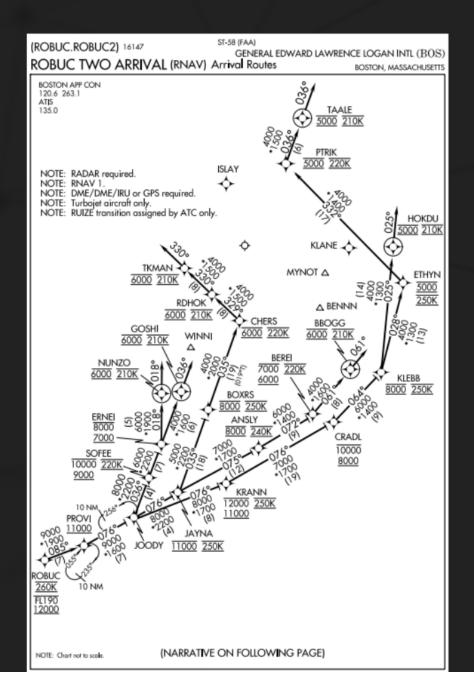
Two pages from Elrey Jeppesen's "Little Black Book": The Arps Ranch (far left) and Bitter Creek. At first, Jeppesen collected this navigational information to help his fellow pilots.

## STARs (conventional)

### Standardized Routing & Terrain Clearance

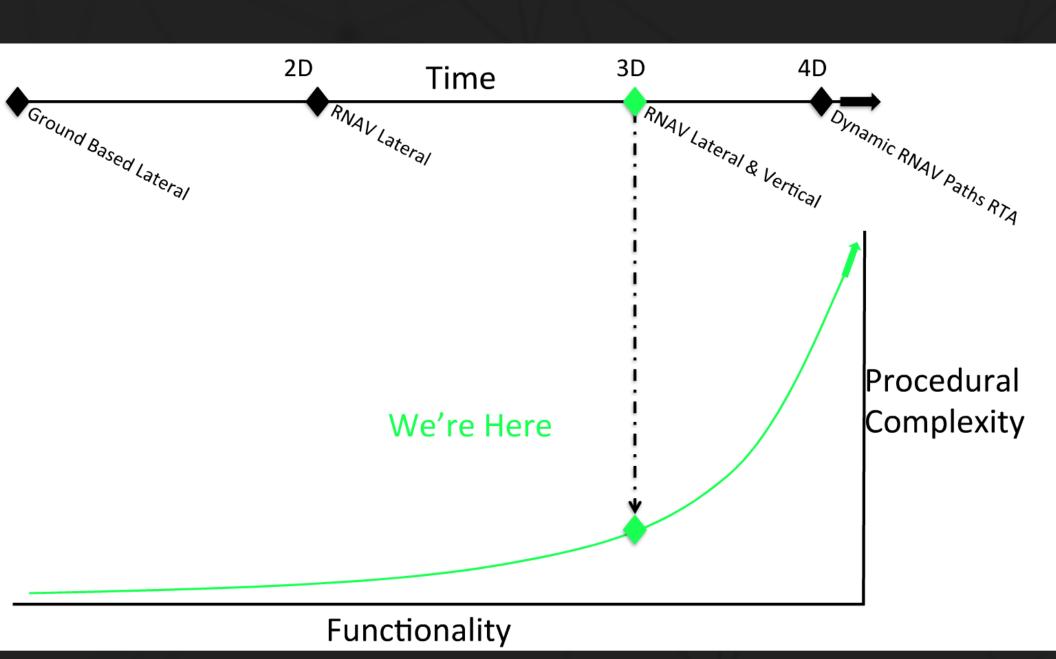


## STARs (RNAV OPD)



Noise reduction, fuel savings, route standardization, and flow management.

(FAA, 2014)



# When Doesn't This Work?



Weather

Mixed Equipment

**Traffic** 

### Data Source

Now

ARTCC radar tracks (CTAS data)

### **Expand Capability**

TRACON data (Sherlock2.0)

**Longterm**Aircraft sensors
(FOQA-type)

### Procedural Characteristic

- · Waypoint type, window size
- Speed Restrictions
- Altitude Restrictions
- · Route name (e.g., transition)
- Slope-degree angles
- Leg type (e.g., track to fix)

### Environmental Variables

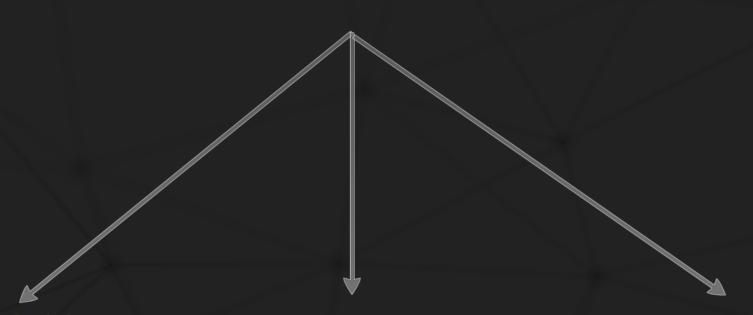
- Wind (tailwind component)
- Temperature (Rapid Refresh NOAA)

### Aircraft Variables

- · Type and equipment suffix
- Groundspeed
- · Altitude (several samples)
- · Rate of descent
- · Required slope to next restriction
- #of flights on the arrival

ita) (Sherlock2.0)

**Longterm**Aircraft sensors
(FOQA-type)



### **Procedural Characteristics**

- · Waypoint type, window size
- Speed Restrictions
- Altitude Restrictions
- · Route name (e.g., transition)
- Slope-degree angles
- Leg type (e.g., track to fix)

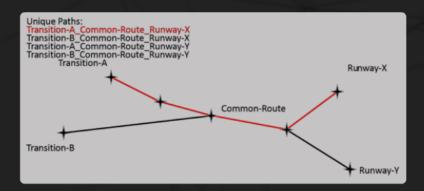
### **Environmental Variables**

- Wind (tailwind component)
- Temperature (Rapid Refresh NOAA)

### **Aircraft Variables**

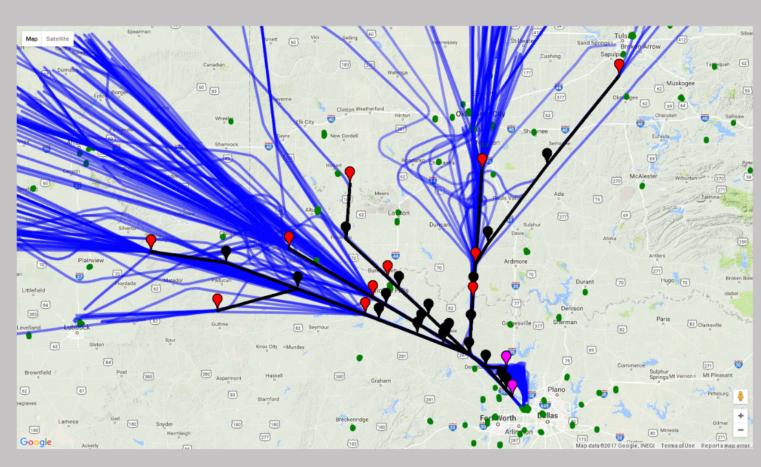
- Type and equipment suffix
- Groundspeed
- Altitude (several samples)
- Rate of descent
- Required slope to next restriction
- #of flights on the arrival

## Method



### **Overlay Flights on Routes**

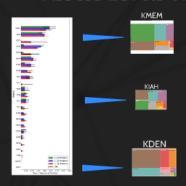
- Fintry Waypoint
- Waypoint in route
- Exit Waypoint
- Identify route flown
- Determine adherence of lateral flight trajectory with waypoint restrictions
- Characterize lateral adherence (join late/skip/ early exit)



Full Lateral Adherence of VKTRY2 into KDFW

### Descriptive Data

**Assess Levels of Use** 



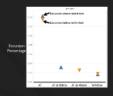


Miles Flown

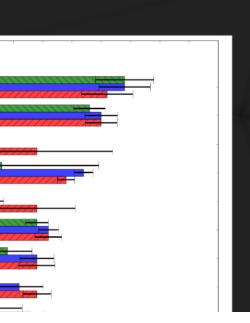
**Identify Human Intervention** 



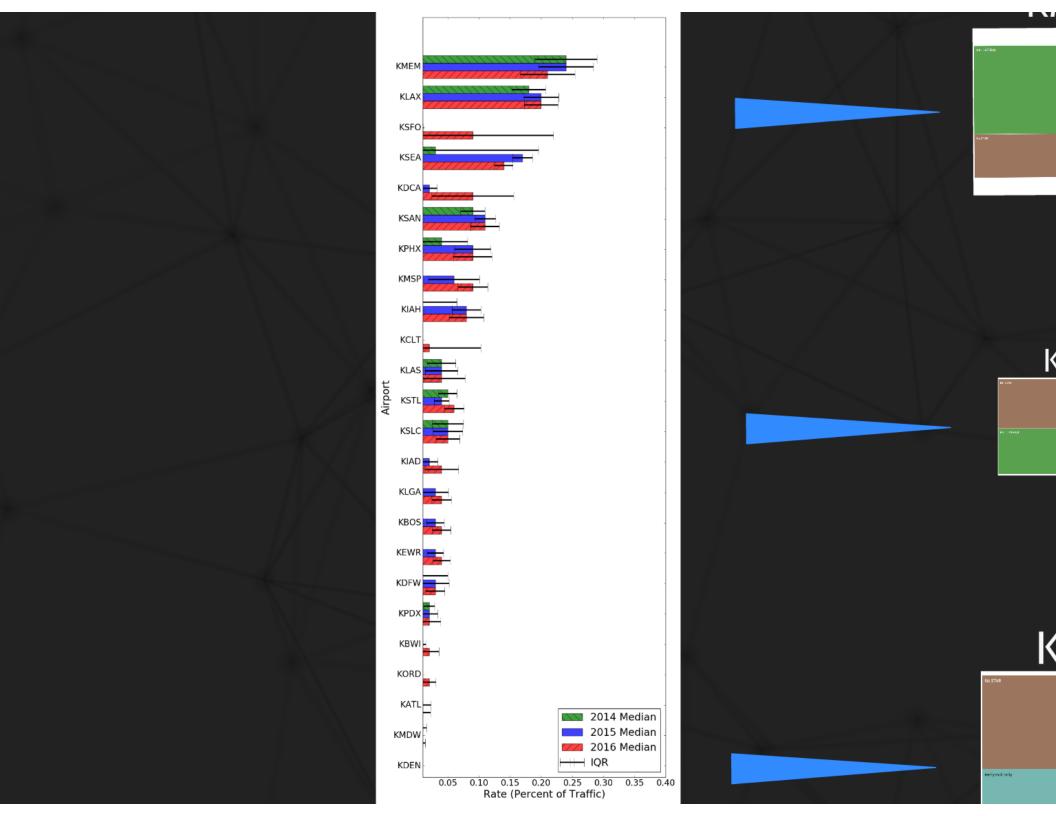




### Assess Levels of Use







## KMEM

FULL LATERAL	early exit only	LATE EN	TRY
No STAR	early and late	te	
	SKIPS		

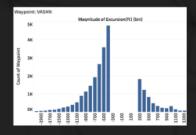
# KIAH

No STAR  FULL LATERAL	early exit only	LATE ENTRY	
	SKIPS	early and late	early and skip

# ICEN

No STAR	early and skip	early and late
early exit only	late, skip and early	LATE ENTRY
	SKIPS	late and

### Identify Human Intervention





Waypoint: VASHN Magnitude of Excursion(ft) (bin) 5K 4K Count of Waypoint 3K 2K 1K

-700

-500

-300

-100

100

300

500

700

900

-900

1100

1300

0К

-1300

-1500

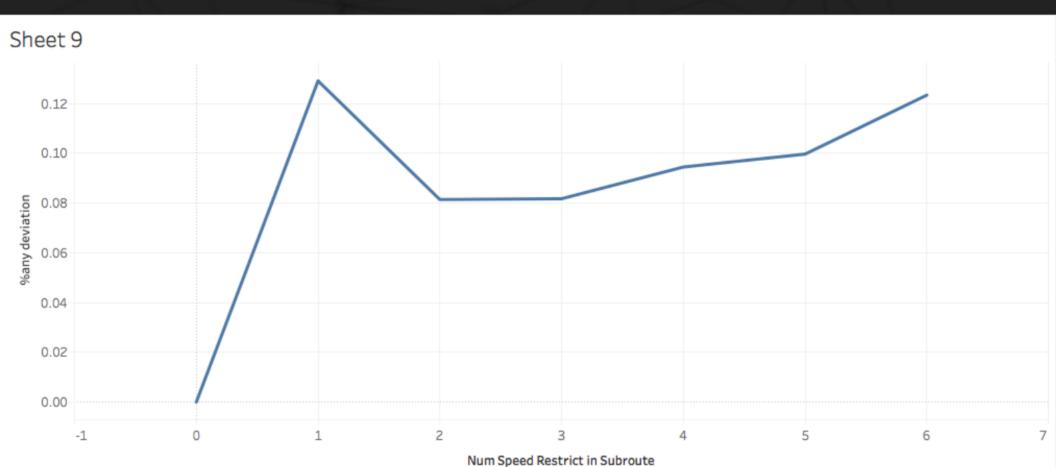
-1700

-1900

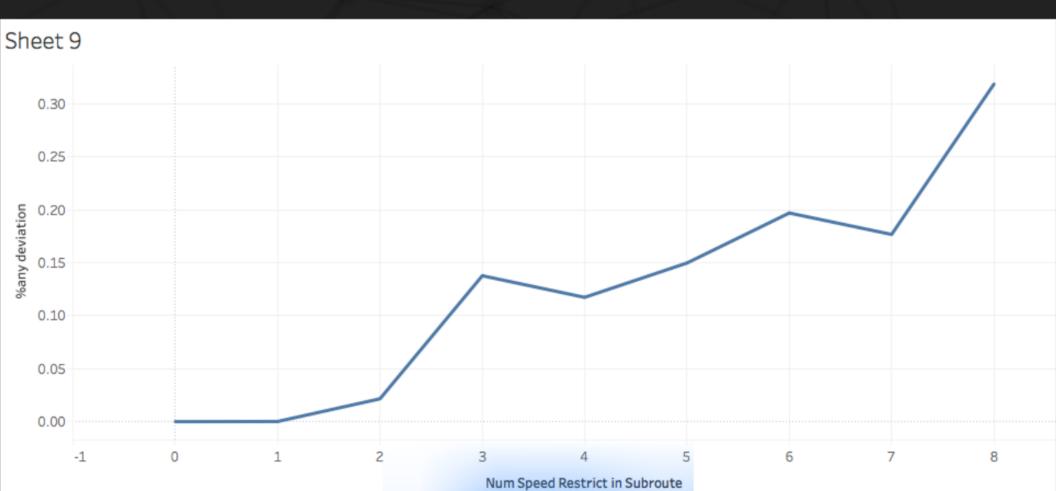
-1100

Waypoint: JOBEE Magnitude of Excursion(ft) (bin) 1600 1400 1200 Count of Waypoint 1000 800 600 400 200 0 -2600 -3000 -2800 -2400 -2200 -2000 -1800 -1600 -1400 -1200 -1000 -600 -400 -800

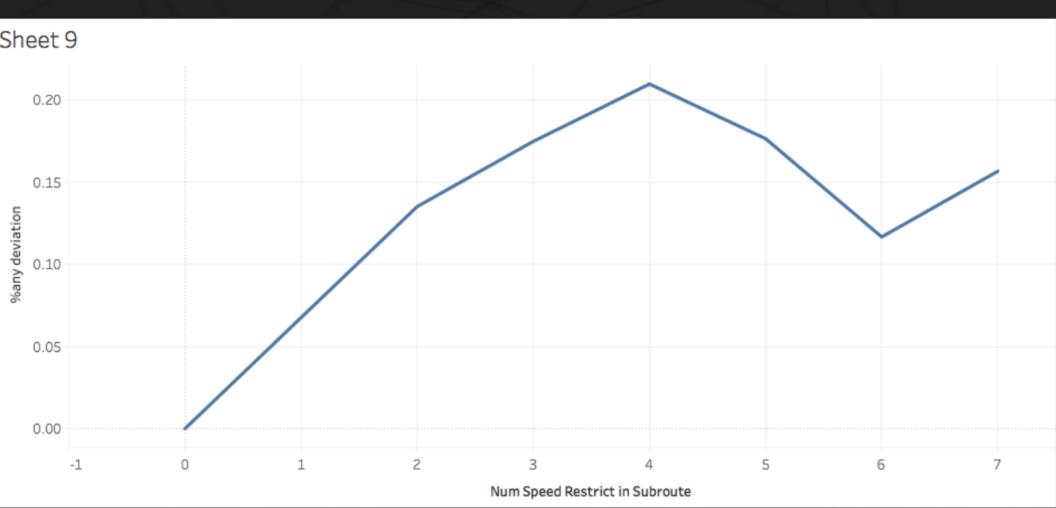
# KMEM



# KIAH

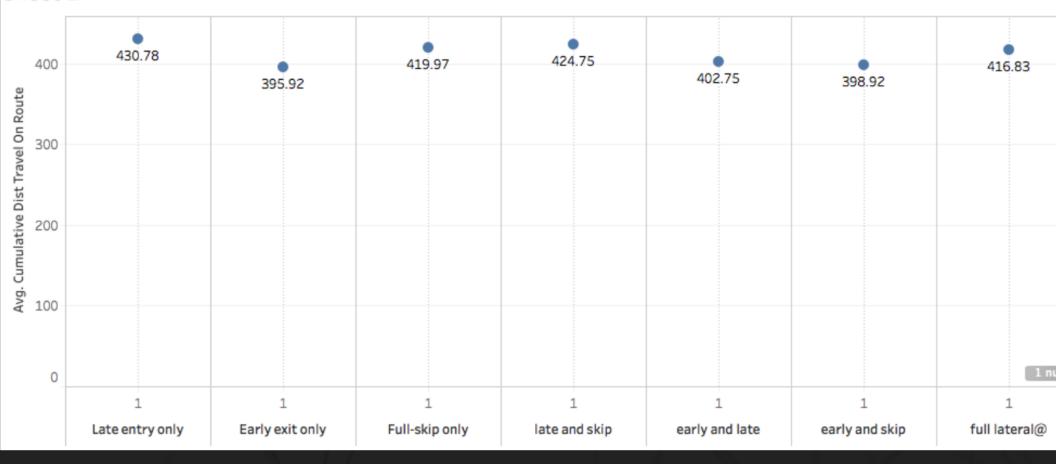


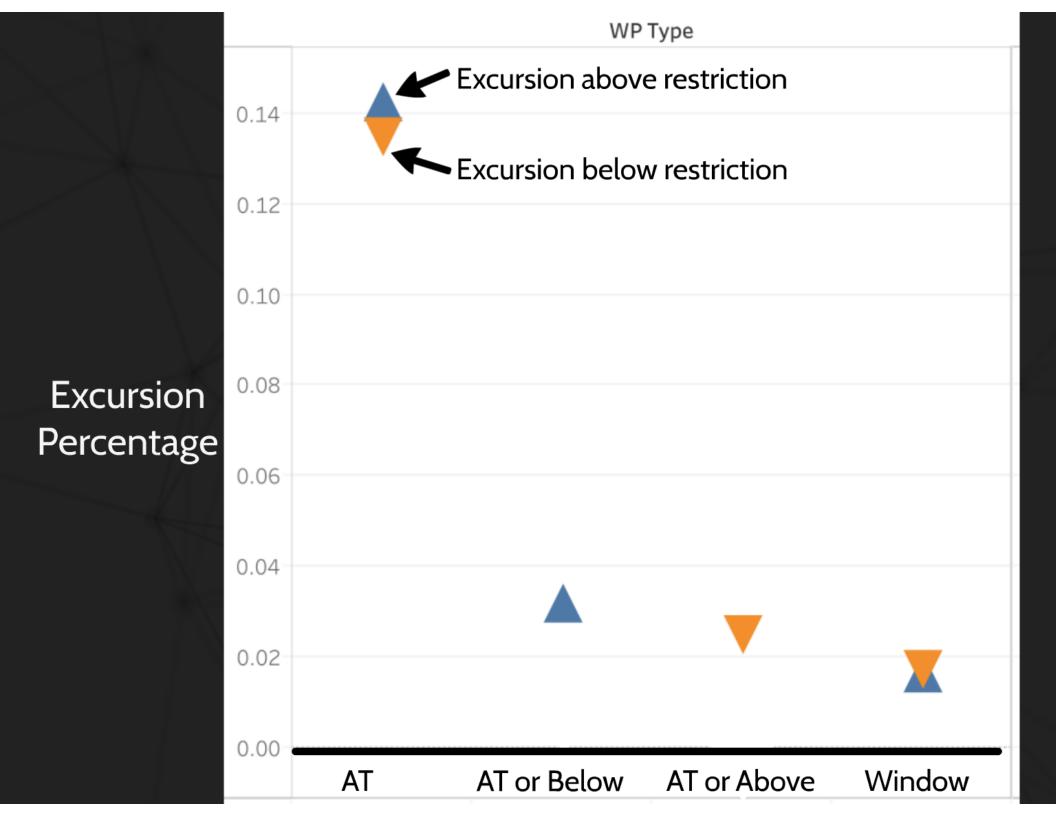
# KDEN



# Miles Flown

Sheet 1







# Machine Learning Methods

Multivariate Analysis

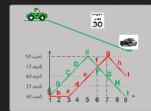
Classification

Precursors

Decision trees weigh multiple variables to predict the class of a variable



Adopt
Automatic Detection of Precursors in Timeseries





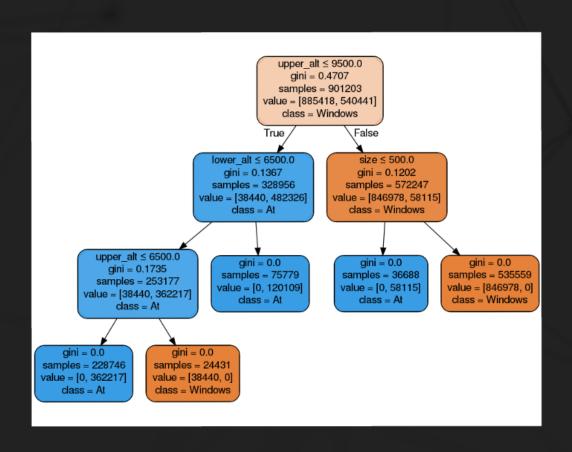
# Methods

## Multivariate Analysis

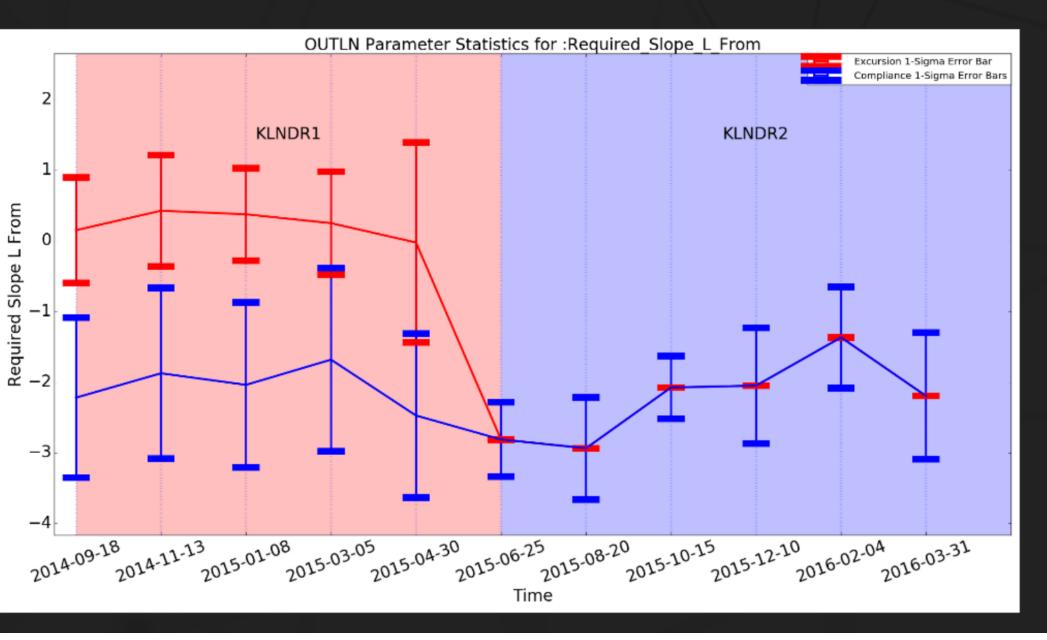
Classification

**Precursors** 

## Decision trees weigh multiple variables to predict the class of a variable

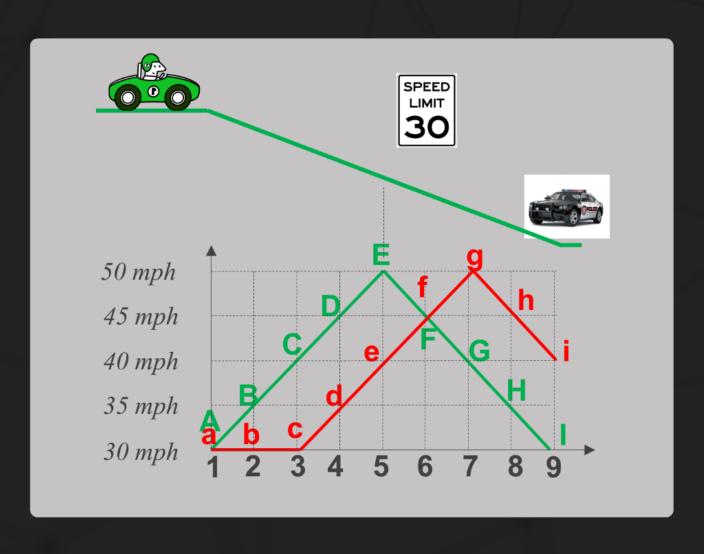


## Change in Behavior



### Adopt

### Automatic Detection of Precursors in Timeseries



## Output Tool

Data Visualization & synthesis

Monitor trends

Observe efficacy of mitigation strategies

Observe factors that influence degradation

Set acceptability metrics

Decision support for designers

Monitor trends

Observe efficacy of mitigation strategies

Observe factors that influence degradation

Set acceptability metrics

Decision support for designers

## RNAV STAR Procedural Adherence

