RNAV STAR Procedural Adherence
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Procedures are a first step towards autonomy

No Procedures
Flying was dangerous and not standardized

Instrument Approach Procedures
A method to consistently guaranteeherent clearance

STARS (conventional)

STARS (RNAV OPD)
Route evaluation, fuel savings, route standardization, and crew management (EPA 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)
2D: Ground Based Lateral

3D: RNAV Lateral & Vertical

We’re Here

4D: Dynamic RNAV Paths RTA

Functionality

Procedural Complexity
When Doesn't This Work?

- Weather
- Mixed Equipment
- Traffic
Weather

Mixed Equipment

Traffic
Data Source

Expand Capability

Now
ARTCC radar tracks (CTAS data)

TRACON data (Sherlock 2.0)

Long-term
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 (ballistic 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
(Sherlock2.0)

**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

**Longterm**
Aircraft sensors
(FOQA-type)
Method
Overlay Flights on Routes

- Entry 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

Identify Human Intervention

Miles Flown
Assess Levels of Use
KDEN
Identify Human Intervention
Miles Flown

Sheet 1

<table>
<thead>
<tr>
<th>Condition</th>
<th>Avg. Cumulative Dist Travel on Route</th>
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<tbody>
<tr>
<td>Late entry only</td>
<td>430.78</td>
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<tr>
<td>Early exit only</td>
<td>395.92</td>
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<tr>
<td>Full-skip only</td>
<td>419.97</td>
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<tr>
<td>Late and skip</td>
<td>424.75</td>
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<tr>
<td>Early and late</td>
<td>402.75</td>
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<tr>
<td>Early and skip</td>
<td>398.92</td>
</tr>
<tr>
<td>Full lateral</td>
<td>416.83</td>
</tr>
</tbody>
</table>
Machine Learning Methods

Multivariate Analysis

Classification

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

Precursors

Adopt

Automatic Detection of Precursors in Timeseries

Change in Behavior
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
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