Projecting Air Traffic Impact of Blocked Airspaces

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Projecting Air Traffic Impact of Blocked Airspaces

Amal Srivastava
Neil Gahart

Space Traffic Management (STM) Conference
November 16-18, 2016
Problem: Airspace is a limited resource

Demand on its use is rapidly increasing

FL3300+ (Space)

Satellites

Orbital debris

FL600-FL3300

Spaceplanes

SAA

FL600

Recoverable rocket motors

Manned/Unmanned balloons

Manned orbital capsules

UAS

FL350: Commercial aviation

Hazard Areas

Source: MITRE

Note: Rendering notional. Sizes of buildings and representational air/space craft not to scale.

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Airspace Use – Differing Goals

FAA: Safe & Fair Balance

What is the **NAS impact** of blocking airspaces such as for a space launch?

What is the **right location** of a new space port?

Accommodate **accelerated growth** in new entrants on a **limited** budget

**Promote** space uses and users while maintaining NAS safety and efficiency

Space Users: Mission Priority

**Agile, fast-paced** environment where minimizing impact on NAS is rarely a top priority

No readily available tools to assess NAS impact of sometimes complex shaped airspaces

Interaction with FAA often occurs **late in the process**

**Bridge the difference** by enabling airspace users to proactively assess traffic impacted by blocking needed airspace
Factors affecting NAS Impact of blocking airspaces

- Location, size and orientation of the airspace relative to intersecting traffic
- Duration for which the airspace area is active
- Air Traffic Patterns, which depend on:
  - Time of the day
  - Day of the week
  - Seasons
  - Unusual traffic days such as holidays
Use historical air traffic flow patterns to predict future trends
Approach

- Considered Cape Canaveral and Vandenberg sites
  - Analyzed airspaces in high and moderate traffic areas
- Used historical air traffic data to assess number of flights intersecting the airspaces
  - Track data from 2010 to 2014 is used
  - Airspaces spanned 100 nm each
- Data is aggregated on week numbers to analyze the yearly traffic flow patterns
- Separate analysis of unusual traffic days such as certain holidays
Airspaces - Cape Canaveral Site

Traffic flow on August 18th, 2014, overlaid on image from Google Earth (product of Google Inc.)
Airspaces - Vandenberg Site

Traffic flow on August 18th, 2014, overlaid on image from Google Earth (product of Google Inc.)
Historical Air Traffic Pattern

VANDENBERG (Percent Variance from Average)

Cape Canaveral (Percent Variance from Average)
Holiday Air Traffic Trends

Thanksgiving (Percentage Variance from Average)

July 4th (Percentage Variance from Average)
Traffic Projection Algorithm

- Daily projection is generated by averaging 2010-2014 flight intersection data by week number and then day of the week.
  - Example: March 21 2017 is calculated as Tuesday average for week number 12

- Holiday & associated unusual traffic days metrics are generated by averaging same relative dates in the past years

- Hourly predictions are generated by averaging hourly numbers of the selected days
Potential Use – Simple Traffic Projection Calendar

Cape Canaveral Site - High Traffic
March 2017

Cape Canaveral Site - High Traffic
September 2017

Average by Day of Week - September 2017
Model Performance

- Compared predicted to observed traffic levels intersecting the airspaces for each hour of the year 2015
  - Three traffic levels were defined as follows:
    - High (30 or more flights intersecting airspace)
    - Moderate (between 16-29 flights intersecting airspace)
    - Low (15 or less flights intersecting airspace)

- Accuracy (of identifying the correct traffic level):

<table>
<thead>
<tr>
<th></th>
<th>Canaveral High</th>
<th>Canaveral Moderate</th>
<th>Vandenberg High</th>
<th>Vandenberg Moderate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80.2%</td>
<td>99.6%</td>
<td>100%</td>
<td>99.9%</td>
</tr>
</tbody>
</table>

Attempted alternate modeling for “Canaveral High” airspace
Alternate Models

- Smoothing over previous and next week
  - $c_1 \times \text{LastWeek} + c_2 \times \text{ThisWeek} + c_3 \times \text{NextWeek} = \text{FlightCount}$
  - Results:

<table>
<thead>
<tr>
<th>$C_1$</th>
<th>$C_2$</th>
<th>$C_3$</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>.25</td>
<td>.50</td>
<td>.25</td>
<td>81.3 %</td>
</tr>
<tr>
<td>.20</td>
<td>.45</td>
<td>.35</td>
<td>81.5 %</td>
</tr>
</tbody>
</table>

- Smoothing over previous and next hour
  - Highest accuracy achieved: 71.7 %
Alternate Models

- **Clustering and Logistic Regression**
  - Cluster training days using k-medioids clustering (k=20)
  - Use multiple logistic regression to train model
    - Consider all data categorical
  - Predict using meta-characteristics of future date
    - Day-of-week, Week-of-year and Seasons-of-year
  - Accuracy: 80.8%
Alternate Models

- Non-linear Regression Model
  - Each year follows (seemingly) regular pattern
  - Average coefficients of regression from different years
  - Accuracy:
    - Quadratic: 78.1%
    - Cubic 79.4%
    - Quartic 80.0%
Alternate Model Performance Measurement

- Compared predicted vs observed flight intersections for each hour in 2015 (instead of comparing traffic levels)
- Used Mean Squared Error (MSE) to compare, lower value indicate higher accuracy

\[
MSE = \frac{1}{n} \sum_{i=1}^{n} (\hat{Y}_i - Y_i)^2
\]

Results:

<table>
<thead>
<tr>
<th>Method</th>
<th>Mean Squared Error (MSE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>89.45</td>
</tr>
<tr>
<td>Smoothing</td>
<td>85.44</td>
</tr>
<tr>
<td>Clustering and Logistic Regression</td>
<td>84.92</td>
</tr>
<tr>
<td>Quadratic Regression</td>
<td>107.59</td>
</tr>
<tr>
<td>Cubic Regression</td>
<td>92.93</td>
</tr>
<tr>
<td>Quartic Regression</td>
<td>90.70</td>
</tr>
</tbody>
</table>

Lower MSE (better)  
Higher MSE (worse)
Conclusions and Next Steps

- Model output may be used as a rough guide to the level of traffic expected to be affected by blocking airspaces
- Alternate models did not significantly increase the accuracy of the original model. Possible outside factors limit accuracy of the models, such as:
  - Weather impact on traffic
  - Variations in flown path due to vectoring and other air traffic control actions
  - Changes in airline flight schedules
- **Possible improvements to the model include:**
  - Use of trajectories, i.e. planned flight paths to eliminate noise in flown tracks data
  - Include weather as a contributory factor
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