ENGINEERING HONORS PROGRAM
UNIVERSITY OF MICHIGAN

Spaceport Location Optimization

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Introduction

There are currently 6 FAA licensed spaceports, and 8 non-FAA licensed spaceports spread across the United States[1]. Increasing demand, innovative technology, and diverse users will continue to drive the expansion of existing and new spaceports across the country.

Purpose

There are thousands of theoretical locations that a spaceport could be built in the US, with the only "rule" being that you can't launch above a populated area. With this said, there are many many drivers for which locations will be the best for operation, cheapest to build in, or provide the lowest costs for airlines. This project is focused around gathering all of the supporting data, and building an optimization model which will output the ideal counties for a new spaceport to be built in.

FPL Model Introduction

To determine the ideal location for a new spaceport, we will use the basis for a facility location problem. In this, the goal is to minimize the cost of a launch for the location, based on a set of conditions and constraints. The model is built to easily input additional conditions and constraints and to be able to weight them differently when needed.

Model Data Inputs

Data Collection: given by county

- Population Density: US Census[2]
- Local Weather: HRRR data[3]
- Flight Data: The OpenSky Network[4]

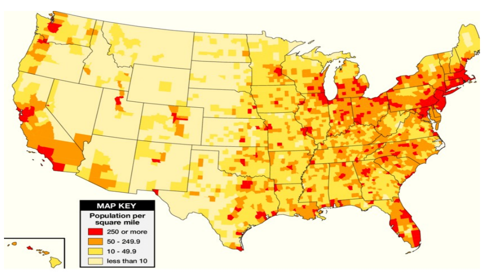

Fig 1. Heat map showing population density by county[5]

Flight Data Extraction

The initial phase of this project was able to be ran utilizing common flight paths. In order to improve upon this and give county specific information, specific flight information is required. Although there are multiple live flight trackers, OpenSky Network is the largest and has the most historical data. The data is filtered by time and location in order to give us full coverage of the US, and then is downloaded for analysis.

Fig 2. Map of United States Flight Corridors

Fig 3. Map of Random OpenSky Data Sample

Flight Data Analysis

1. Clean and remove extraneous data from OpenSky.
2. Separate data above continental US and above the ocean.
3. Calculate which county each flight point(above land) is in
4. Calculate which county each flight point (above sea) is nearest to.
5. Count how many flight points are in each county.
6. Count how many specific flights are in each county.

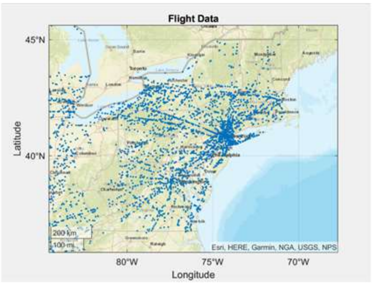

Fig 4. Map of OpenSky Data Flight Sample

	1 County Name	2 Flown Over X Times	3 Center Latitidude	4 Center Longitude
1	'Hancock County'	2	41.0019	-83.6665
2	'Stafford County'	9	38.4207	-77.4574
3	'Webster County'	3	40.1764	-98.4999
4	'Cedar County'	1	41.7723	-91.1324
5	'Deuel County'	6	44.7601	-96.6680
6	'Howard County'	6	43.3568	-92.3172
7	'Palm Beach County'	25	26.6476	-80.4365
8	'St. Lawrence County'	2	44.4964	-75.0690
9	'Clark County'	1	44.8583	-97.7295
10	'Dundy County'	3	40.1762	-101.6880
11	'Alamosa County'	1	37.5729	-105.7883
12	'Citrus County'	7	28.8476	-82.5201
13	'Walworth County'	12	42.6685	-88.5419
14	'Union County'	1	39.6255	-84.9251
15	'Waseca County'	3	44.0221	-93.5873
16	'Hitchcock County'	1	40.1763	-101.0423

Fig 5.Results of Flight Data Analysis

Conclusions

After running a basic FLP that considers population density, weather (precipitation, wind speed, visibility, temperature, dew point), flight corridors, and distance to coastline, the model gave us 5 counties. For these counties, the cost on airlines for 1 launch is shown below.

County Name	Cost On Airline
Brooks County(TX)	$4,980 (n=2)
Dixie County(FL)	$29,880(n=12)
Willacy County(TX)	$4,980 (n=2)
Tattnall County(GA)	$9,960 (n=4)
Kenedy County(TX)	$4,980 (n=2)

C= $n*c*t$
C: Cost on Airline[]
n: number of planes in the sky at a time
c: Delay cost/minute
t: Average delay time for a launch

Future Work

In order to improve upon the flight analysis, we'll be working to improve the calculation of which county an exact flight point is in. While continuing on the formulation of the FPL Model, we are working on evaluating historic launch trajectories in order to add them as a constraint.

Acknowledgement

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References

[1] White, J. (n.d.). 13_Space Operations_Jack White.pptx. Federal Aviation Authority.
[2] U.S. Census Bureau (2020). *Selected housing characteristics, 2020 American Community Survey 5-year estimates data profiles.* The Census Bureau.
[3] "Assimilation and Verification Innovation Division (AVID)." *High-Resolution Rapid Refresh (HRRR)*, https://rapidrefresh.noaa.gov/hrrr/.
[4]Matthias Schäfer, Martin Strohmeier, Vincent Lenders, Ivan Martinovic and Matthias Wilhelm. **"Bringing Up OpenSky: A Large-scale ADS-B Sensor Network for Research"**. In *Proceedings of the 13th IEEE/ACM International Symposium on Information Processing in Sensor Networks (IPSN)*, pages 83-94, April 2014.
[5](n.d.). Retrieved from https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.researchgate.net%2Ffigure%2FUS-Population-Density-by-County-US-Census_fig2_344433241&psig=AOvVaw0WBkGozg7QlXGQPb6D0Qq3&ust=1680453213112000&source=images&cd=vfe&ved=0CA8QjRxqFwoTCKCwmZmOif4CFQAAAAAdAAAAABAd.
[6] *U.S. passenger carrier delay costs.* Airlines For America. (n.d.). Retrieved April 3, 2023, from https://www.airlines.org/dataset/u-s-passenger-carrier-delaycosts/#:~:text=In%202021%2C%20the%20average%20cost,levels%20to%20%2428.14%20per%20minute.

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