Data Science and Urban Air Mobility
Challenges and Opportunities

Vishwanath Bulusu

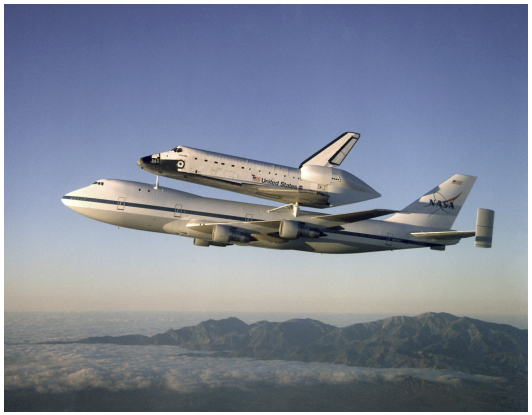
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NASA Ames Research Center
Moffett Field, CA 94035

Aviation Data Science Seminar 04/29/2020

Outline

- Conventional Aviation and Data Science
- Urban Air Mobility Challenges
- Addressing the Challenges
- Opportunities in Data Science for UAM

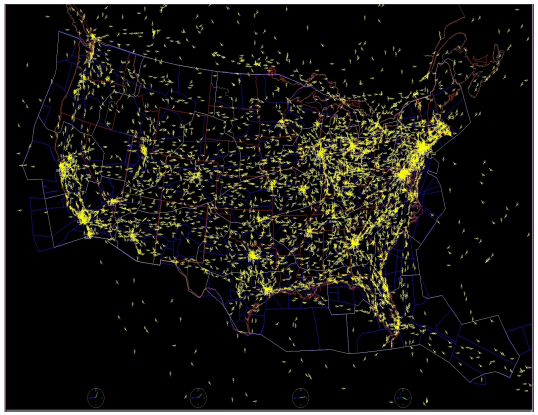
Aviation



Aircraft



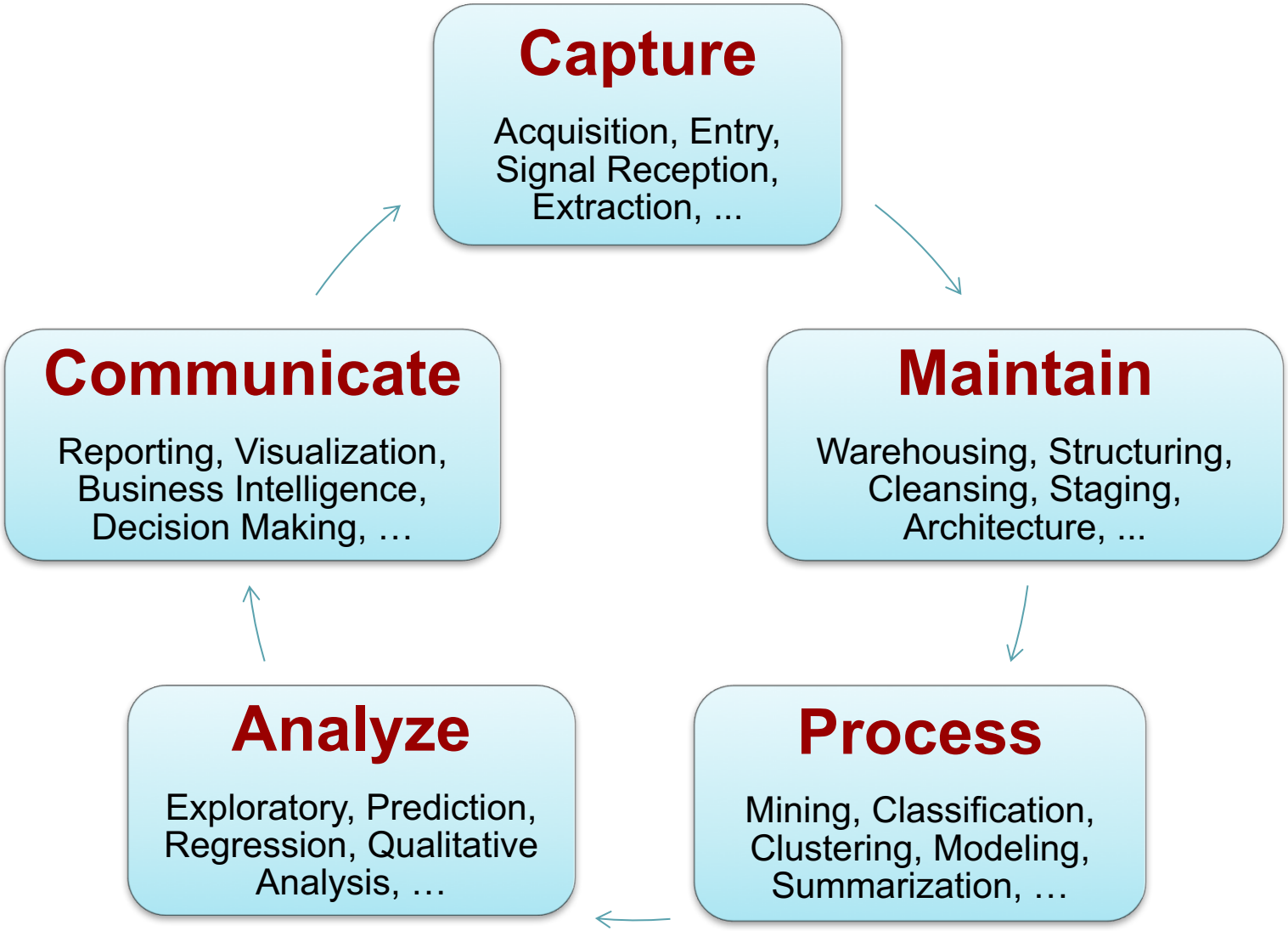
Airport



Airspace

Airport Image Source: Pixabay, Free to use https://pixabay.com/photos/newark-new-jersey-airport-airplanes-2021159/

The Data Science Life Cycle (DSLC)



*https://datascience.berkeley.edu/about/what-is-data-science/

Conventional Aviation in the DSLC

	Capture	Maintain	Process	Analyze	Commun.
Aircraft	Sensors, Datalinks	Log Books, Flight Data Recorder	Maintenance, Inspection	Fuel, Health Monitoring, Flight Perf., Fleet Analysis	Fleet Mgmt, NTSB Reports, Revenue Mgmt.
Airport	Structural, Env. Data, Gate Sensors, Parking Data, Passenger, Baggage	Archiving, Airline Counter Logs, Operation Logs	Terminal Maps, Operational Reports	Capacity improvement, Noise impact, Planning Decisions, Amenities	Terminal Design, Parking Maps, Information Display
Airspace	Flight plans, Surveillance, Wind and Weather	STARS, ERAM, Sherlock, Flight Databases	Flight, Radar, Weather, Wind, Trajectory modeling	Separation Assurance, TFM, Weather impact	SWIM, Advisories to Pilots, CDTI, ATC Displays, NOTAM, CDM

The skies today!





Urban Air Mobility (UAM)







Aircraft **Airport** **Airspace**

Data Science for UAM
Challenges

UAM in the DSLC

	Capture	Maintain	Process	Analyze	Commun.
Aircraft	Few sUAS, uncertified eVTOL				
Airport	Conceptual Designs				
Airspace	Flight test data, Simulated data, HITL data	UTM databases, Sherlock	Clustering simulated data, Trajectory modeling	Helicopter routes, separation assurance	Market Studies, HITL evaluations…

A rather nascent field ripe for innovation

Problems

Aircraft:

- Optimal Sizing, Type, Rider Comfort, Noise ….

Airport:

- Vertiport location, number, demand?
- Interoperability between air side and ground side
- Impact of traffic demand changes…

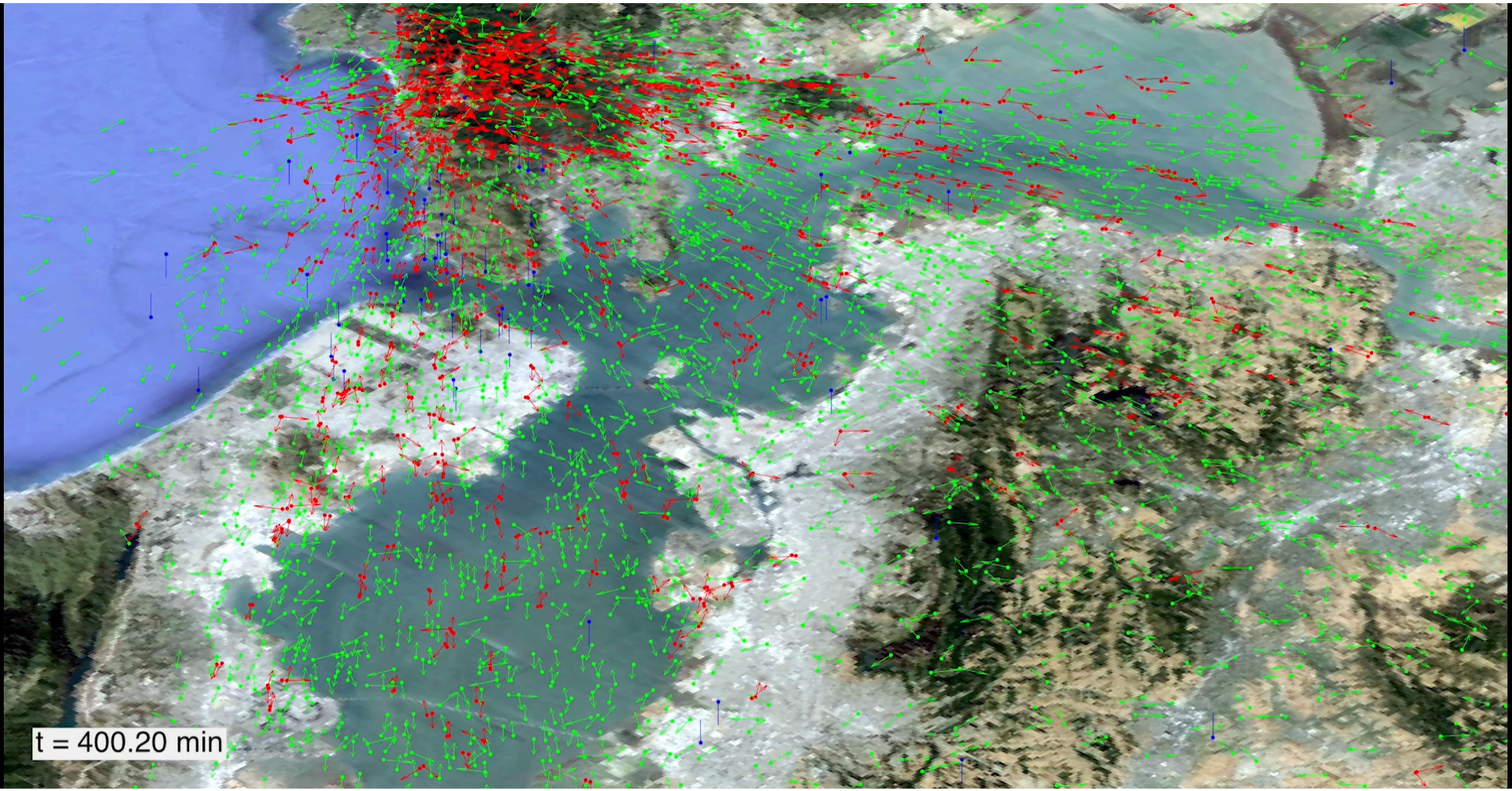
Airspace:

- Airspace capacity?
- Optimal flight planning and routing?
- Network designs for scale?
- Point to point vs arterial networks?
- Contingency planning?
- ATM Decision making?....

Air transportation in operation
Road transportation like in scale

Leverage research from both fields

Ex 1: Estimating airspace capacity

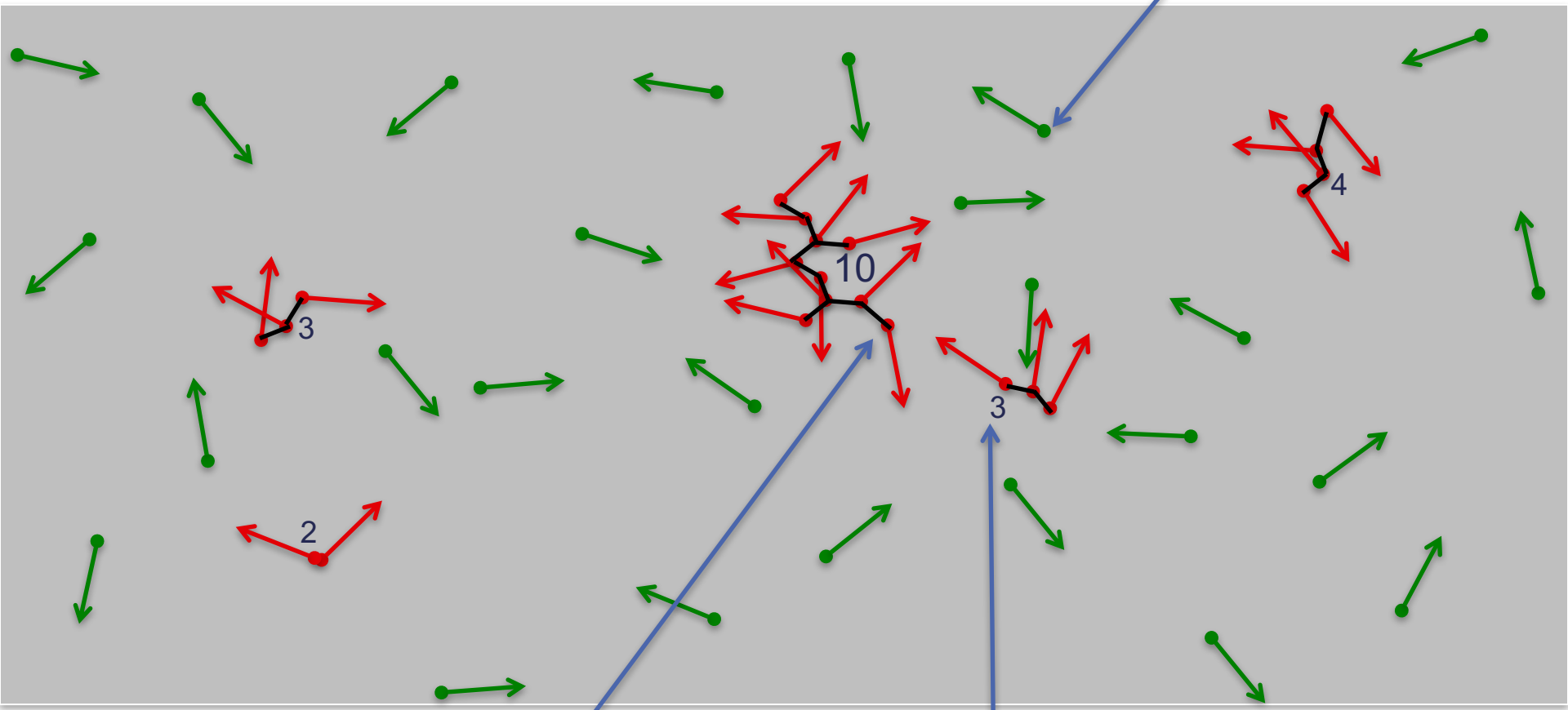


SF Bay Area Simulation – 100, 000 trips/day

*Bulusu V, Sengupta R, Liu Z., “Unmanned aviation: To be free or not to be free?” ICRAT’16.

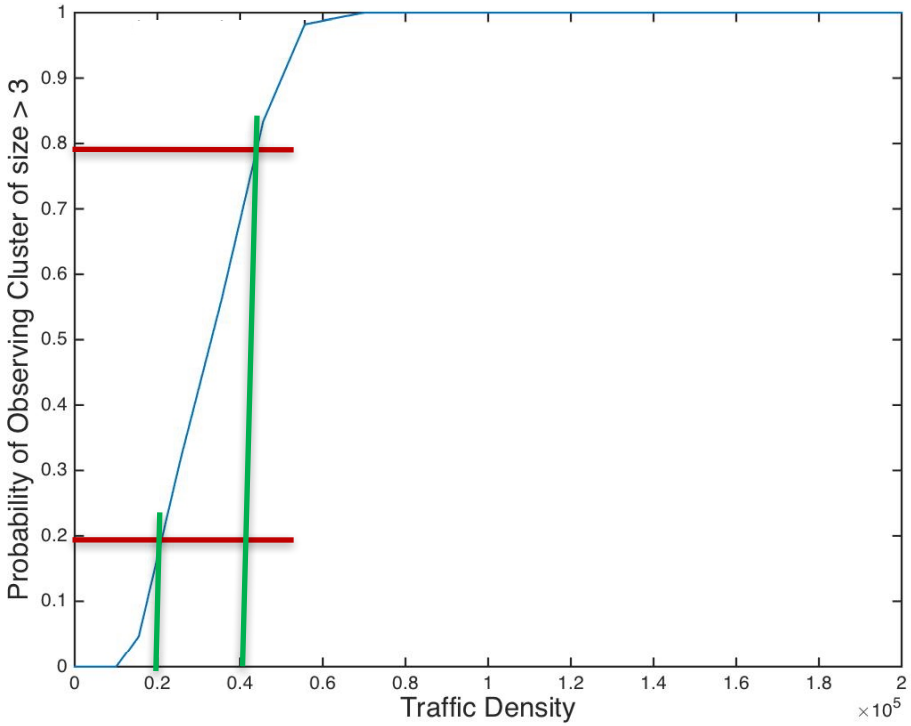
Ex 1: Estimating airspace capacity

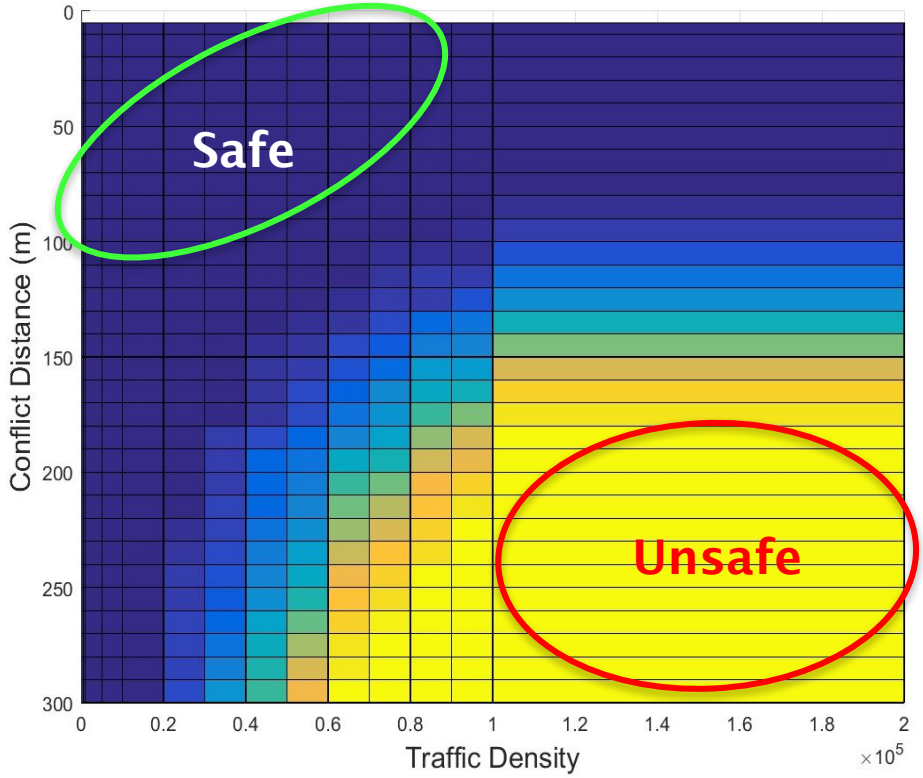
Airspace abstracted as a Graph



Ex 1: Estimating airspace capacity

- Pop. Density ⟹ generate sUAS traffic
- Simulate, abstract Airspace as a Graph
- Estimate Probability of observing multi-aircraft conflict clusters > 4
- Estimate capacity from the threshold.
- Repeat for different conflict distances.

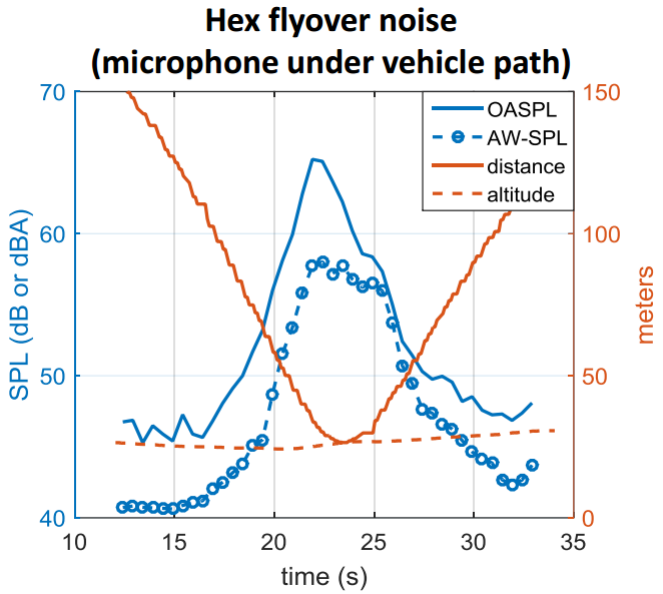




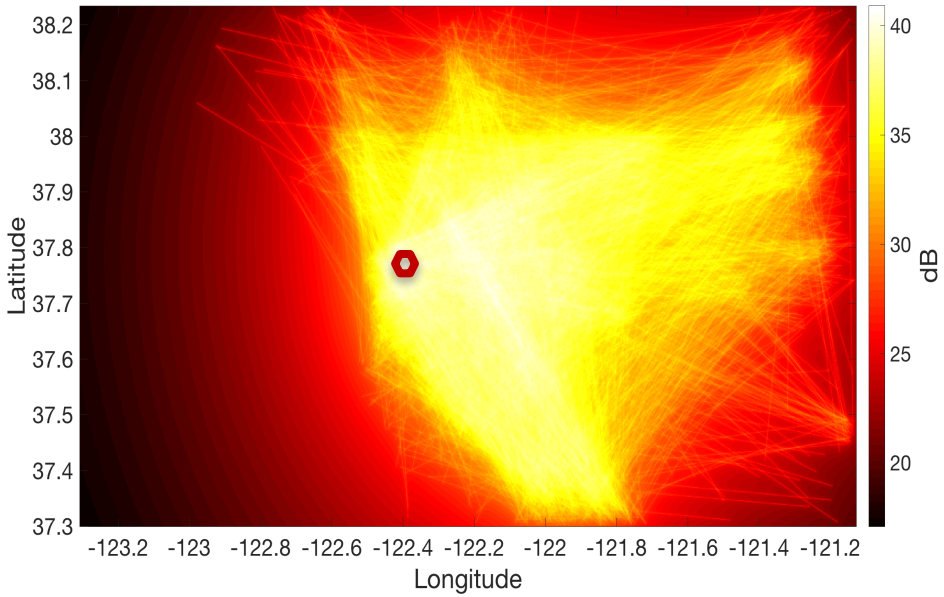
Bay Area – [20,000, 40,000] flights/day

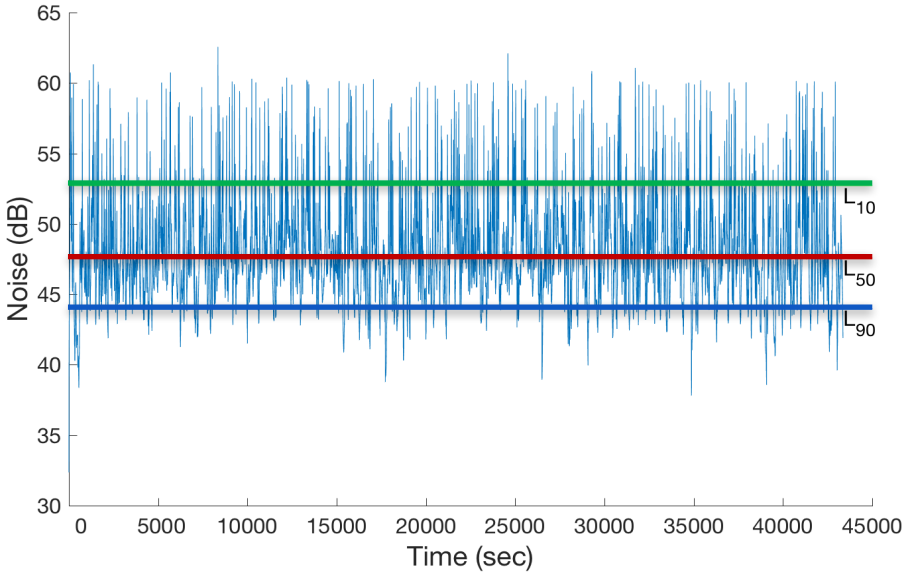
Ex 2: Estimating Noise Impact

- sUAS Noise model – 55 dB 400 ft below.
- Noise Propagation and Overlap - AEDT
- Simulate sUAS traffic based on Pop. Den.
- Noise Metrics
  - Avg Intensity (Noise Map)
  - Variation over worst pixel (Ln)



Bay Area Average Noise





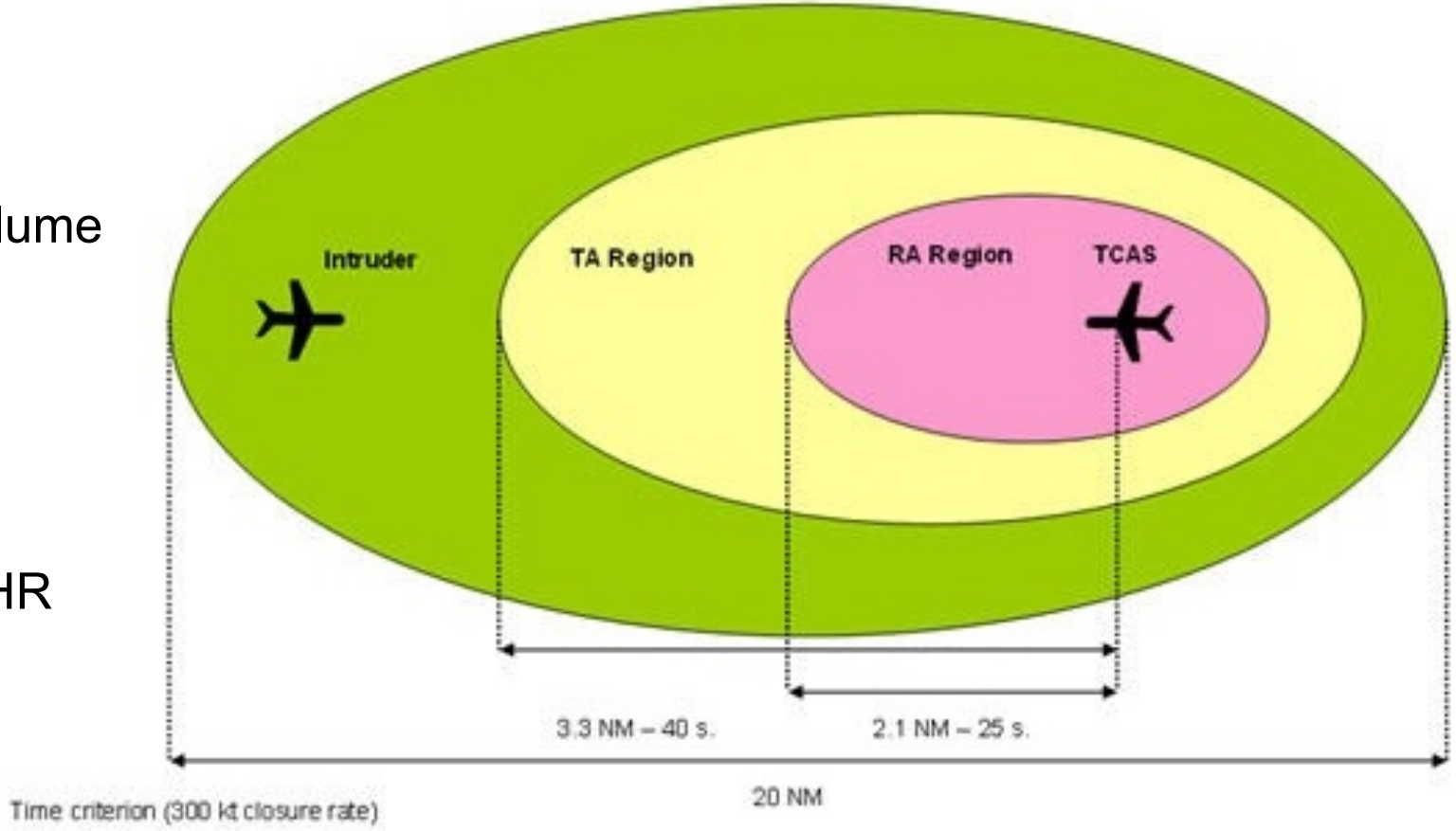
Ex 3: Impact of UAM on TCAS Alerts

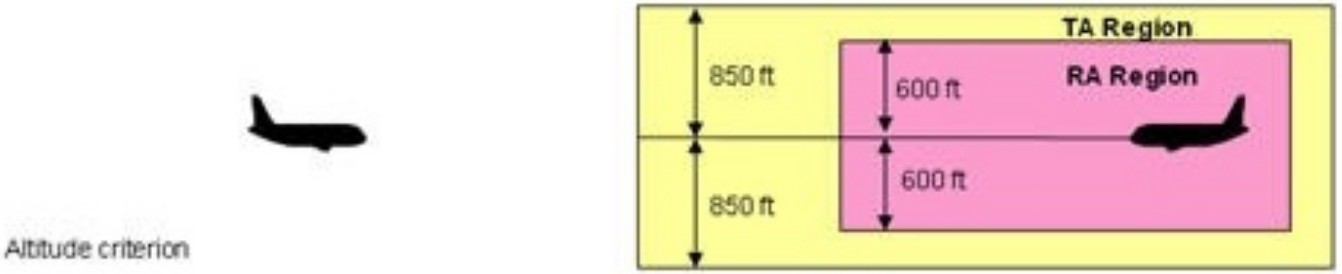
Criteria:

DMOD –
Protected Volume

Time –
τ_{mod} and τ_{vert}

Altitude - ZTHR

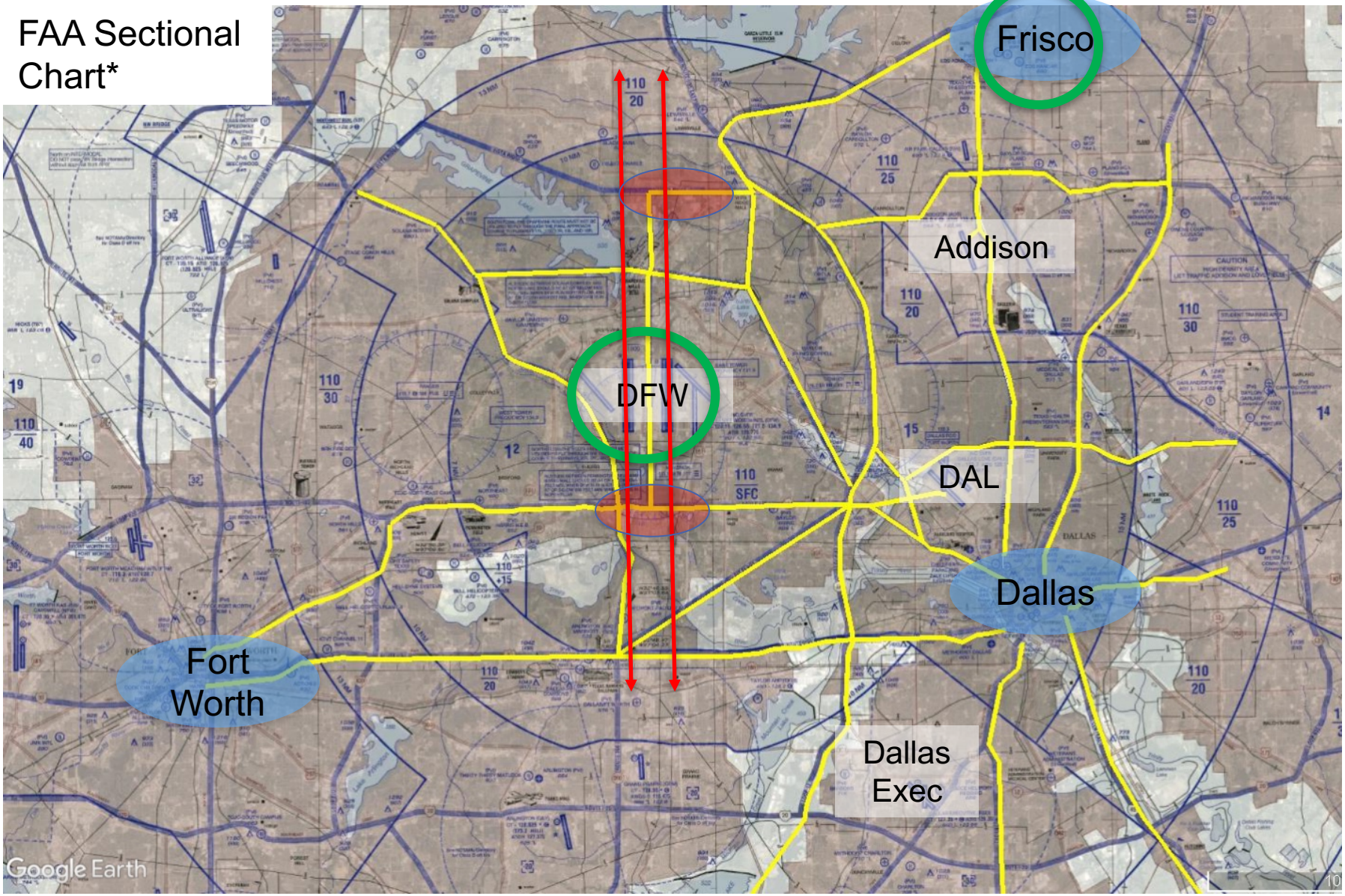




Source: http://www.eurocontrol.int/msa/public/standard_page/ACAS_Overview_Principles.html

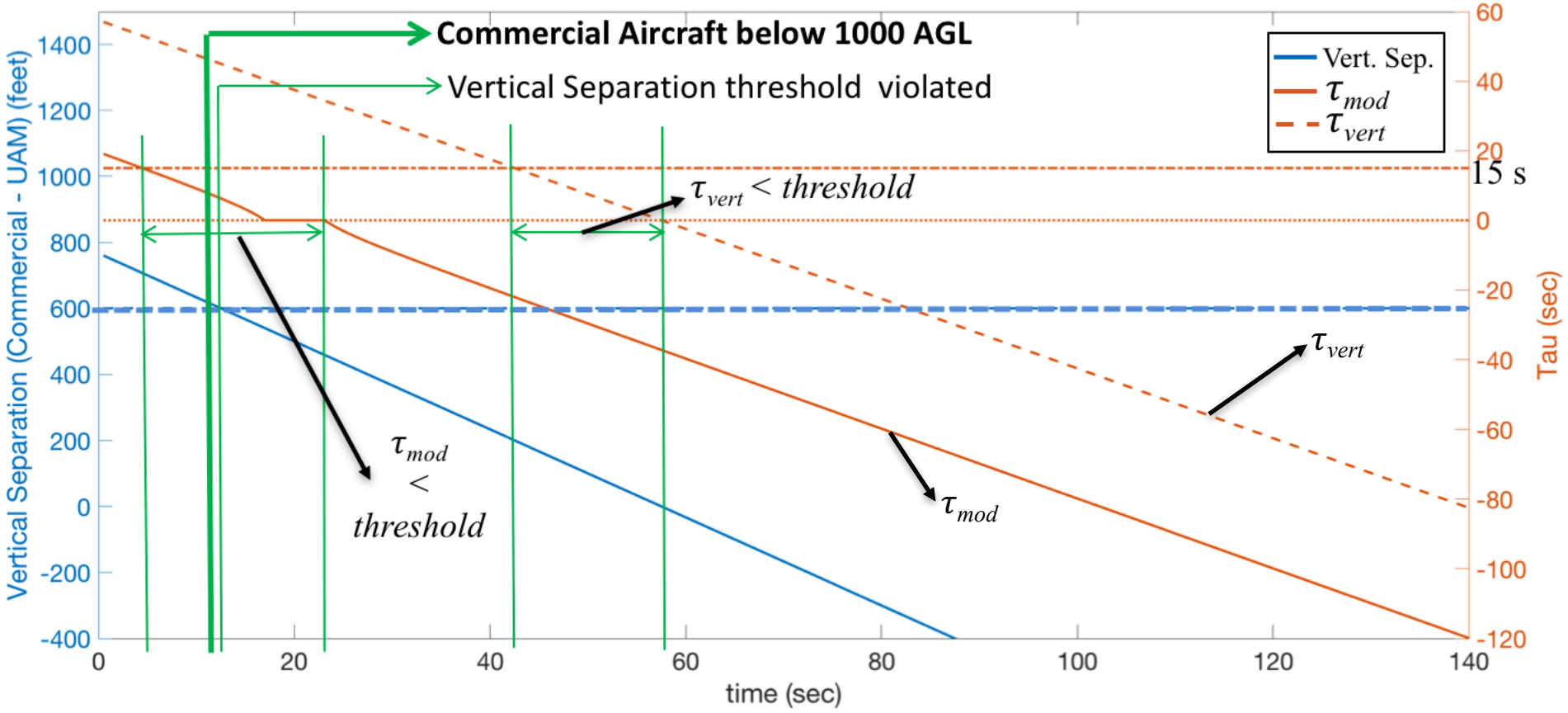
Ex 3: Impact of UAM on TCAS Alerts

FAA Sectional Chart*



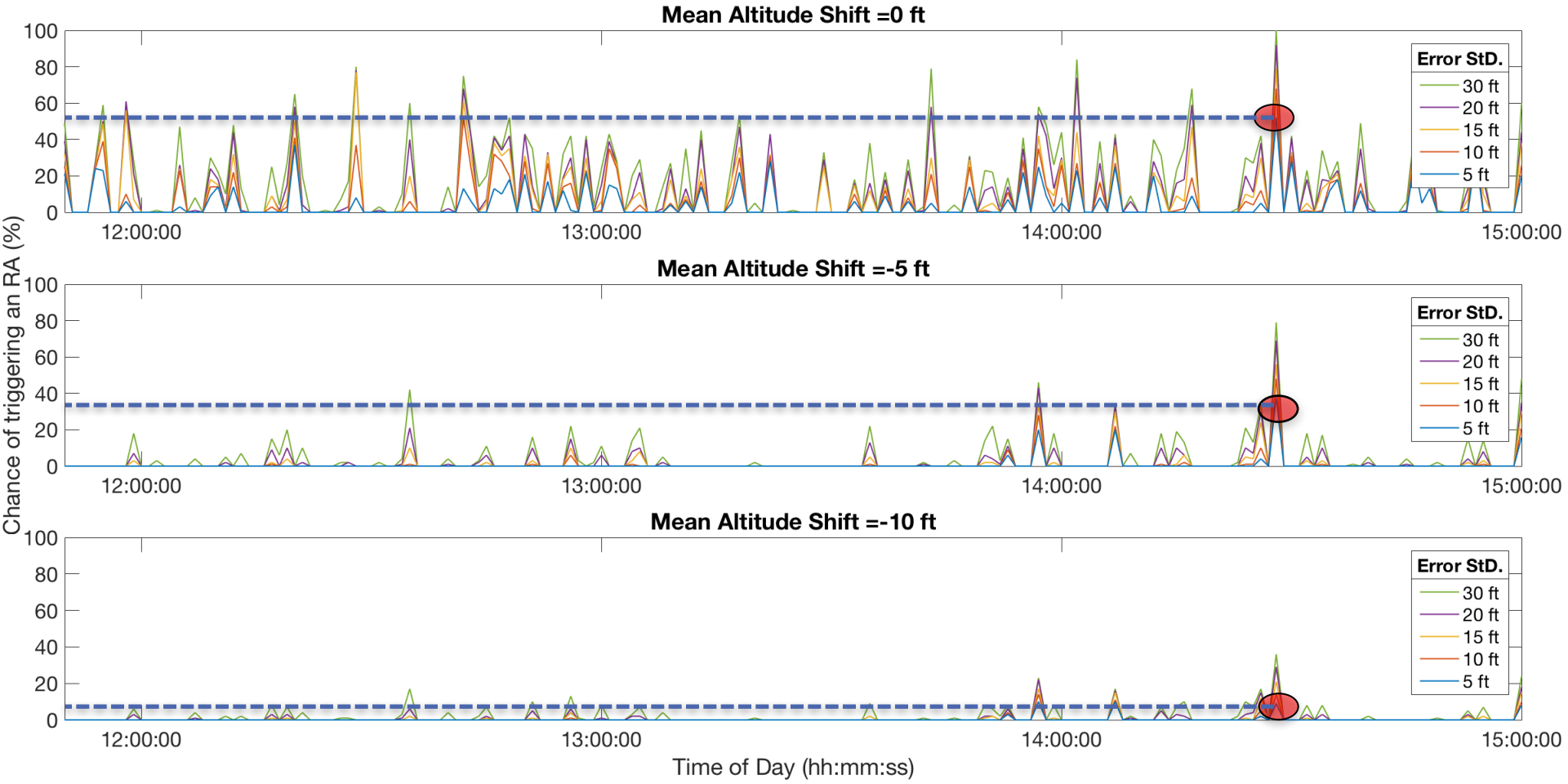
*"FAA Helicopter Routes Map for Dallas-Fort Worth Area," http://aeronav.faa.gov/content/aeronav/heli_files/PDFs/Dallas-Ft_Worth_Heli_7_P.pdf, 2019. Images produced by the U.S. Government and in the public domain.

South of DFW



But NOT SAFE!

Ex 3: Impact of UAM on TCAS Alerts



Lowering mean alt. by 10 ft reduces the RA chance to under 10%

Result – Redesigned South Routes

Ex 4: Airspace Availability Assessment

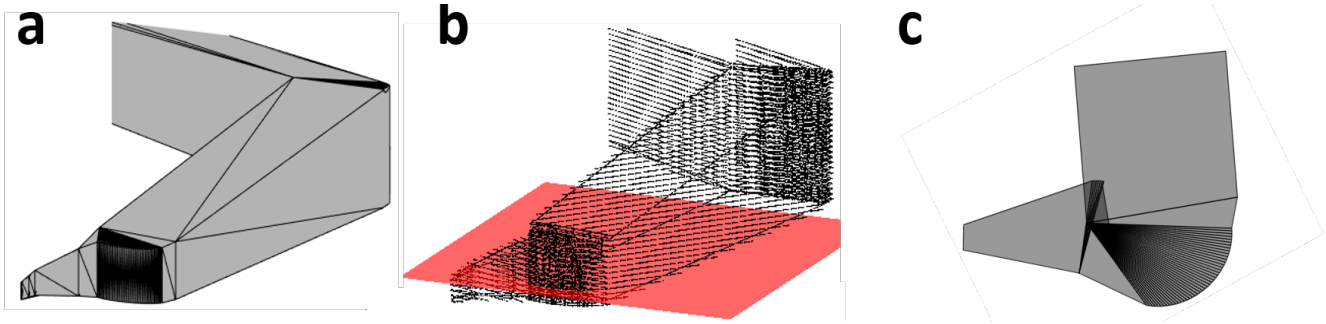
Airspace Constructs:

- *Terrain and Obstacles* – public terrain and parcel data
- *Controlled Airspace* – FAA 28 Day NAS Resource
- *sUAS FAR Part 107 airspace* – Facility maps from FAA Open ArcGIS data
- *Airport Approach and Dep. Procedures* – FAA Coded Instrument Flight procedures
- *Special Use Airspace* – TFRs from NOTAM FDC 7/4319
- *Minimum Vectoring Altitudes* – FAA Aeronautical Information Services
- *Special Flight Rules Area* – FAA Sectional Charts

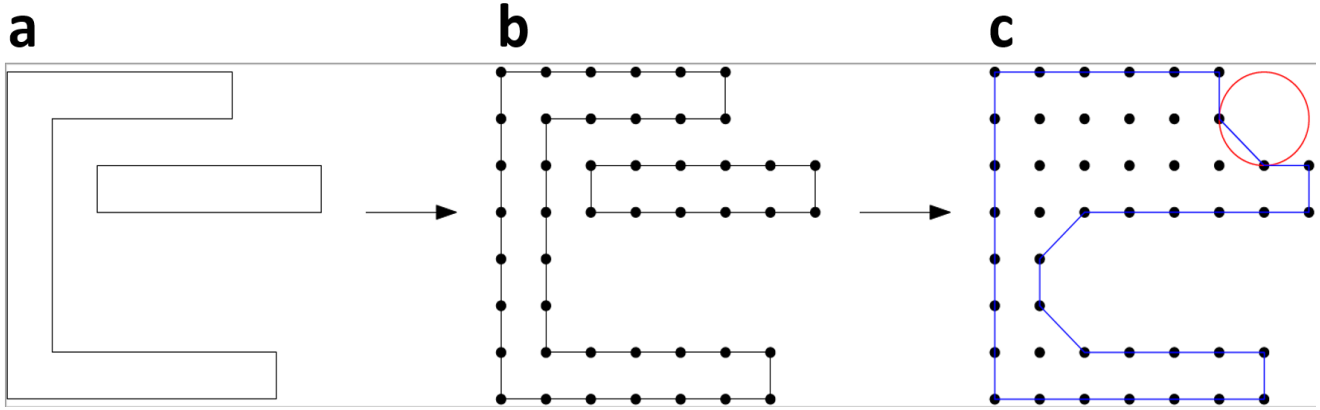
ATC Scenarios Modeled –

ATC Excluded, Fully Segregated, Statically Integrated, Dynamically Integrated

Ex 4: Airspace Availability Assessment

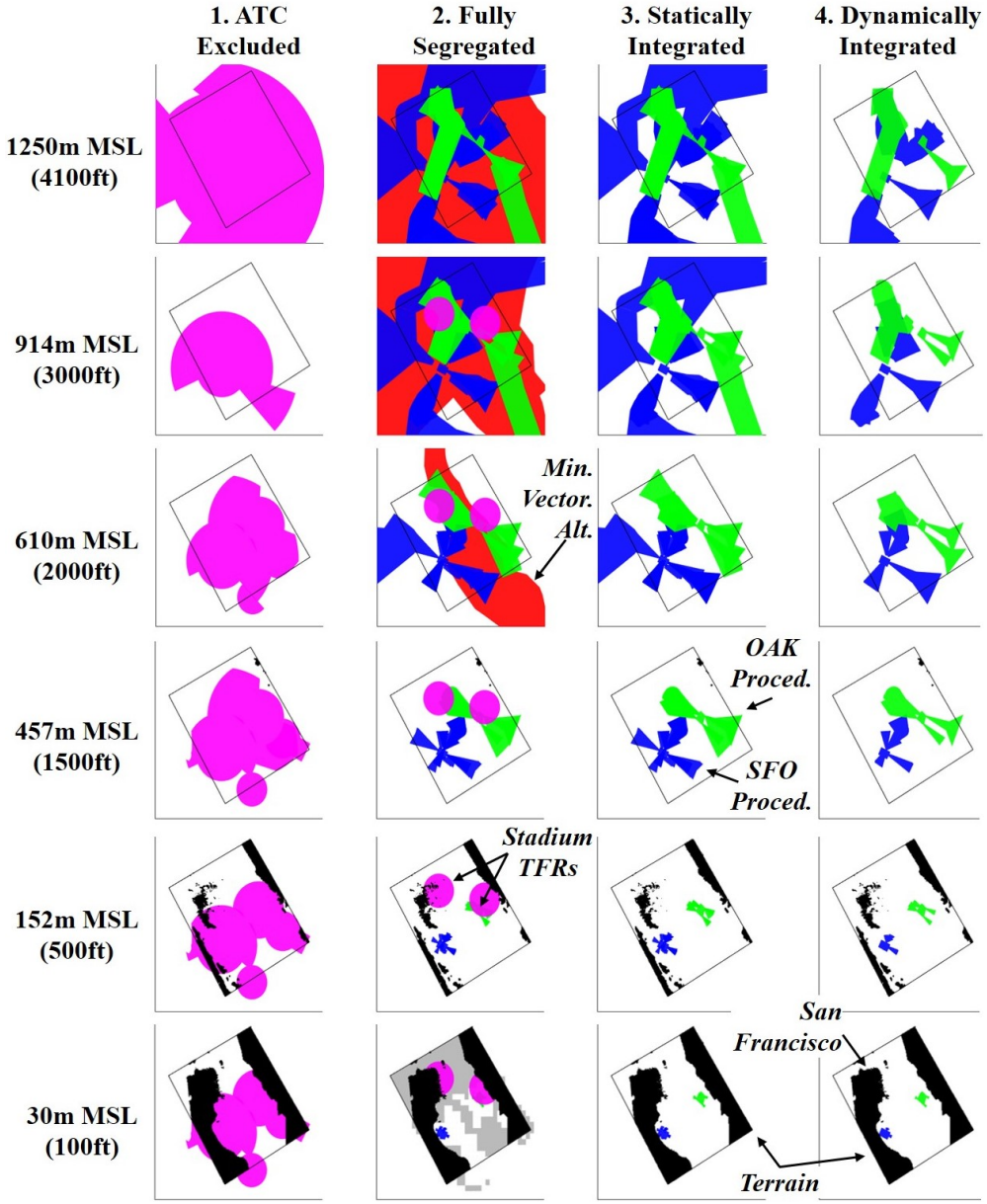


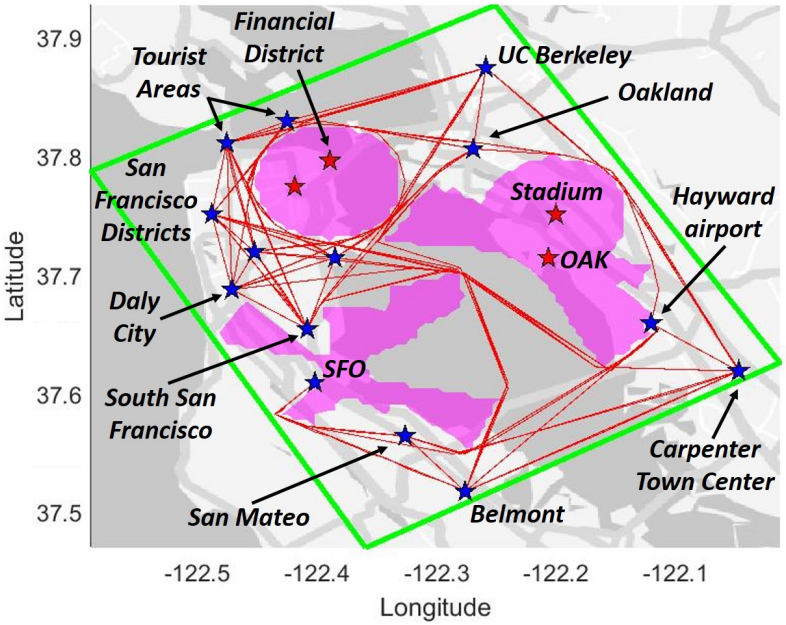
3D Polygon Discretize & Slice Sample Slice



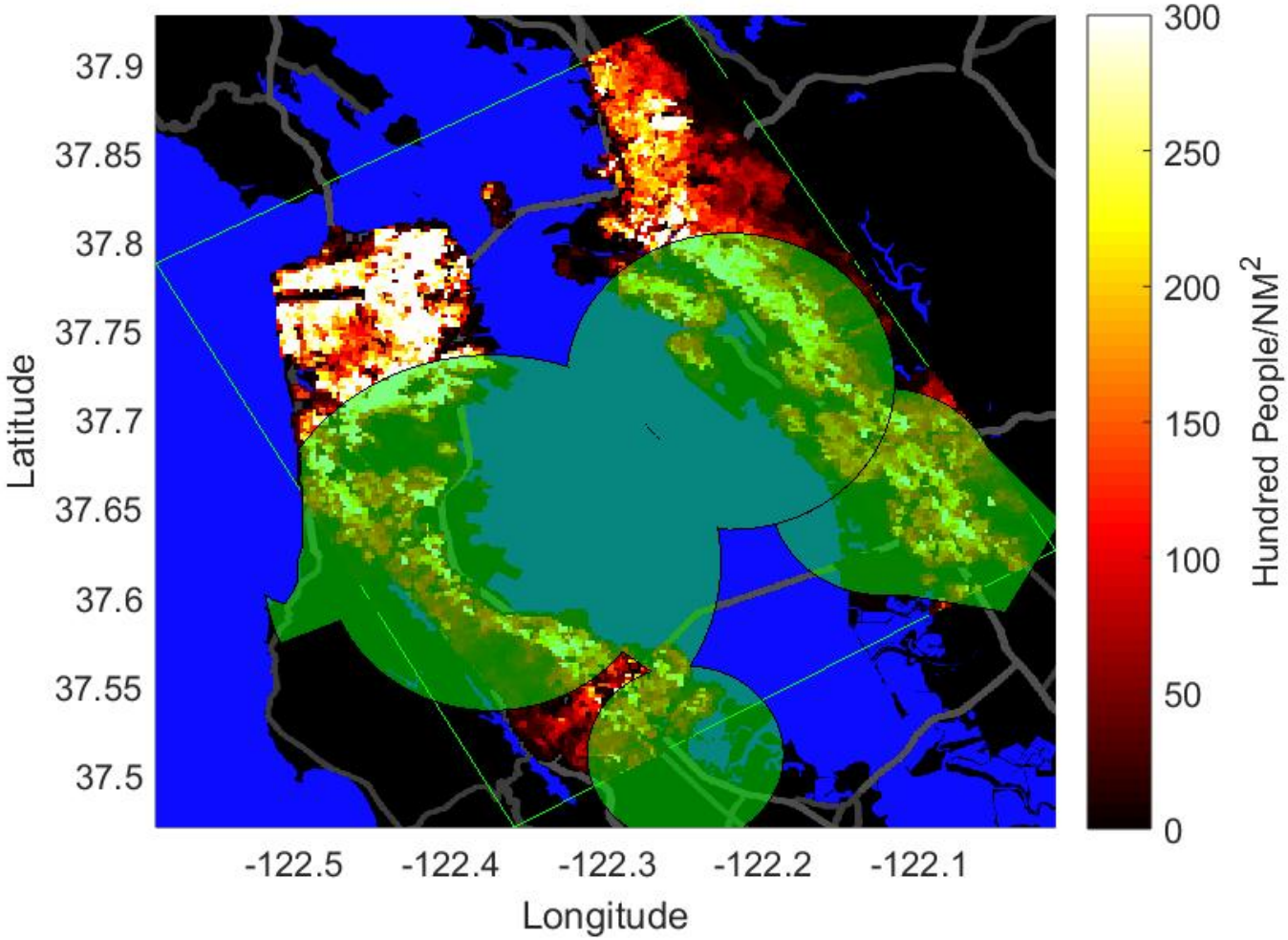
2D polygon Boundary Sampling Alpha Shape

Ex 4: Airspace Availability Assessment



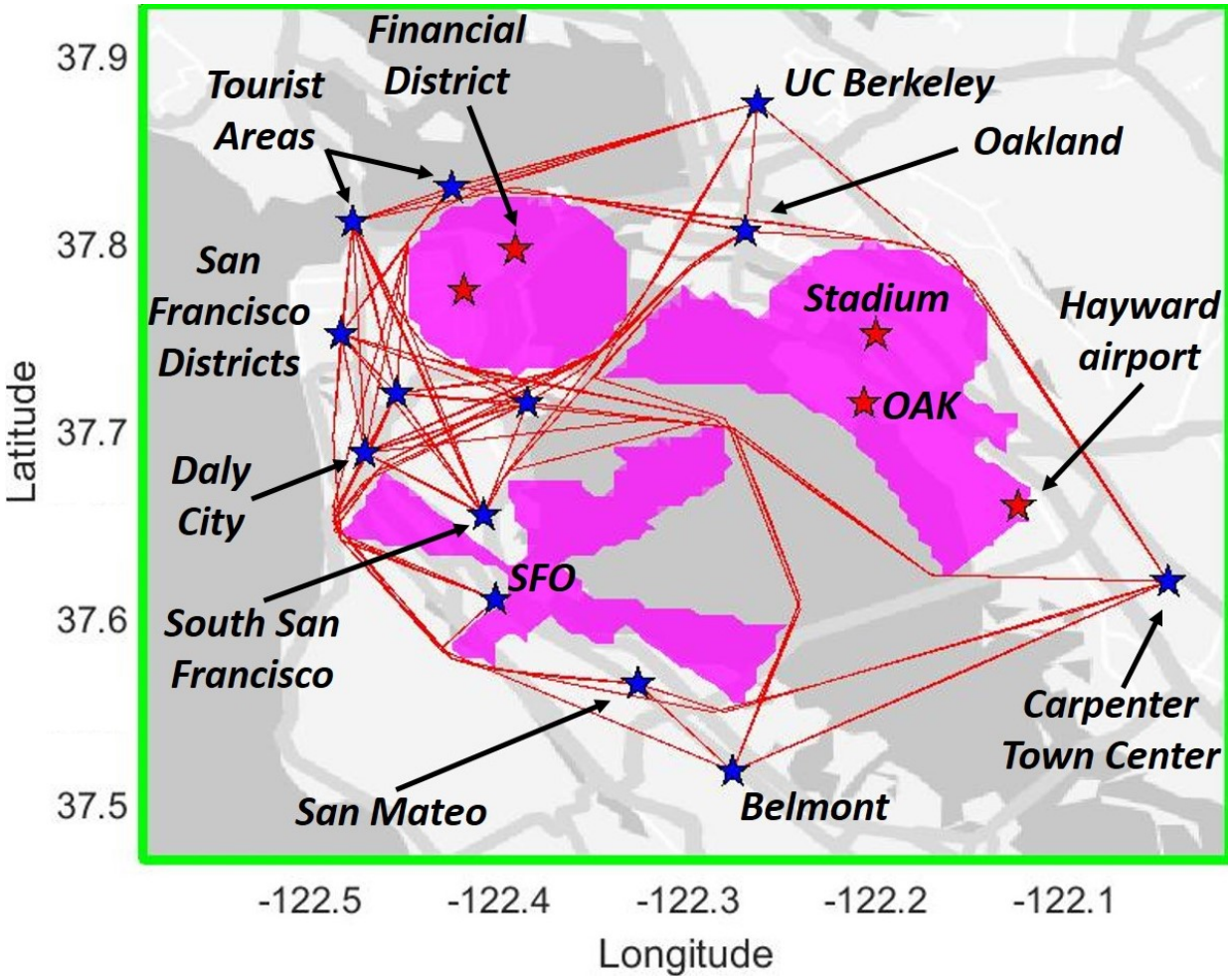


Ex 5: Airspace Availability Application



Estimate Population Accessibility

Ex 5: Airspace Availability Application



Connectivity and Network Design

Ex 6: Traffic Demand Analysis & Vertiport Location

Setup:

- 330,000 cross bay commute traffic
- Simulation data with congestion modeling
- Every trip 2 alternatives – all road, mixed mode (road, air, road)

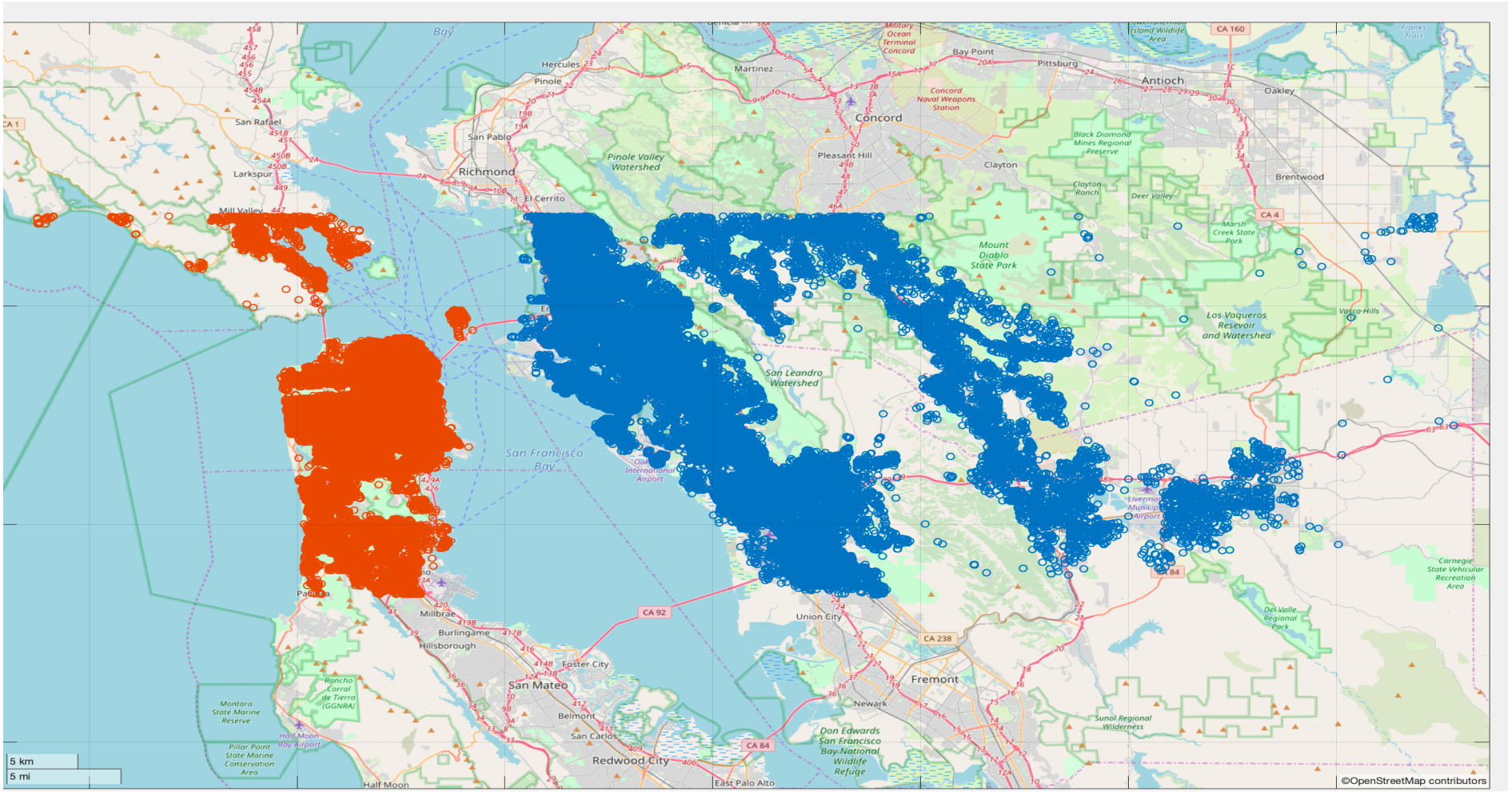
Analysis

- k-means clustering to identify vertiport location
- Estimate travel time for alternatives (vary transit time – 5, 10, 15 min)
- Commuters shift if time savings are 25% (flexible) or 50% (rigid)

Estimate optimal vertiport #, location and commuters benefitted -

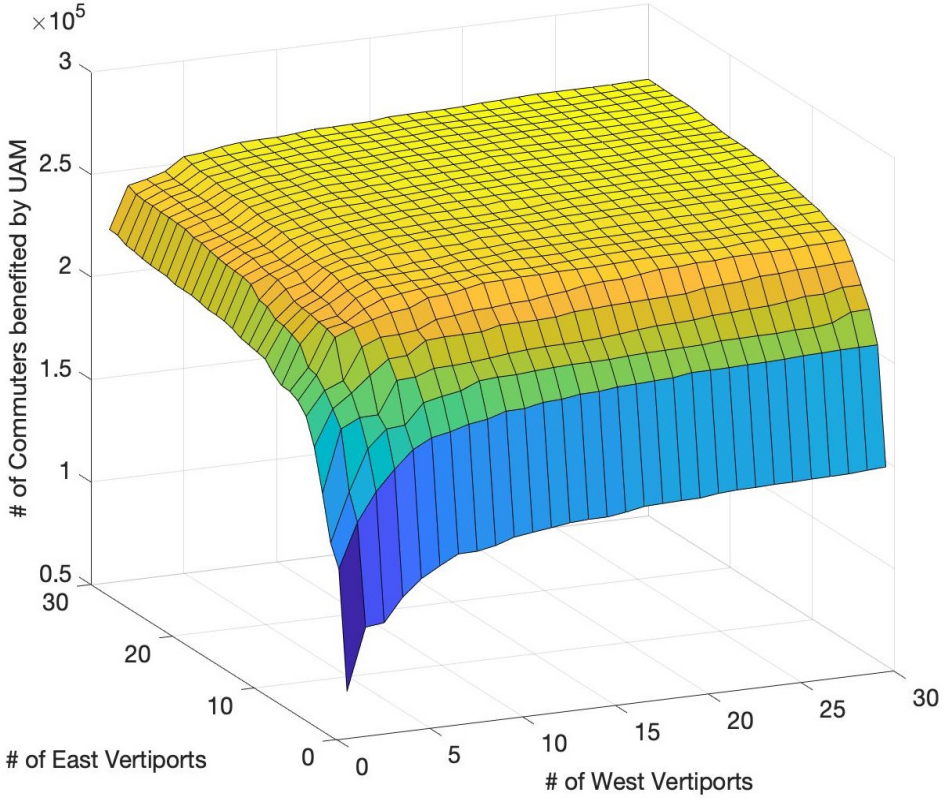
- Capacity Constraint <125 takeoffs per hour per vertiport
- Cost Justification Constraint – at least 1800 extra ridership per vertiport

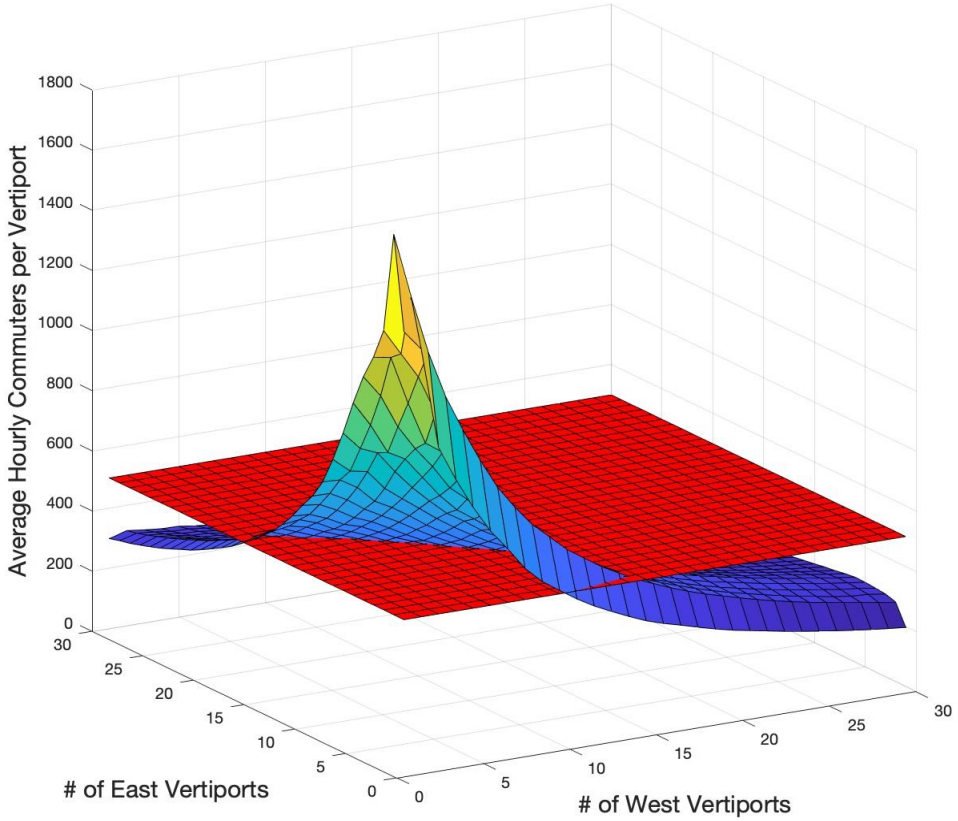
Ex 6: Traffic Demand Analysis & Vertiport Location



*Bulusu V., Onat E., Sengupta R., Macfarlane J., "A Traffic Demand Analysis Method for Urban Air Mobility," submitted JITS'20

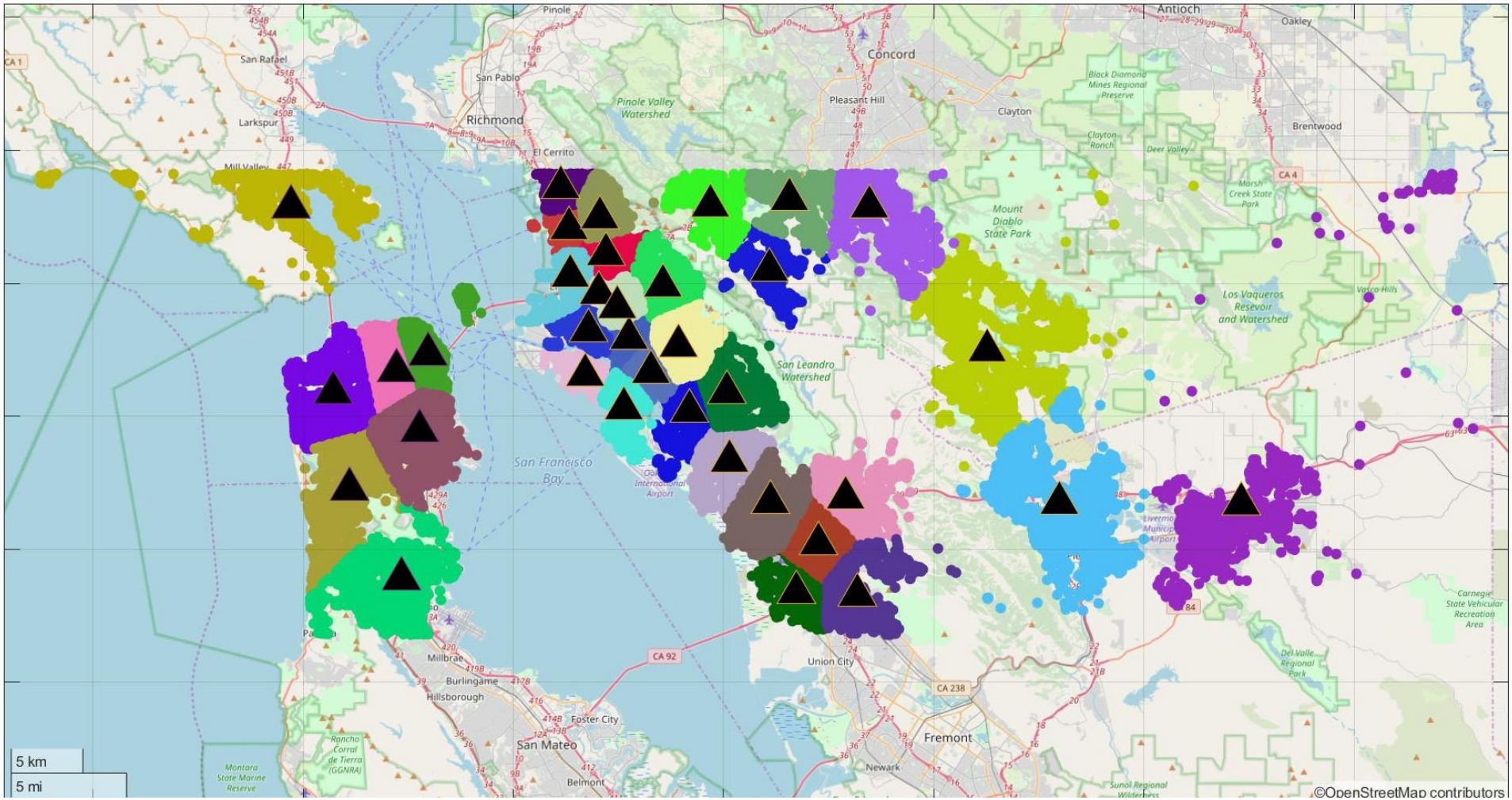
Ex 6: Traffic Demand Analysis & Vertiport Location





Flexible Commuters: Demand Shift – 47,914 (15 min transfer)
Rigid Commuters: Demand Shift – 11,085 (10 min transfer)

Ex 6: Traffic Demand Analysis & Vertiport Location



Summary: Examples in the DSLC

Examples	Capture	Maintain	Process	Analyze	Communicate
Airspace Capacity *(Pop. Den.)*	Simulation	Flights as objects	Cluster by Conflict Size	Graph component analysis	Traffic visualization, Capacity maps
Noise Impact *(Pop. Den., Noise models)*	Simulation	Flights as objects	Aggregate Noise by Trajectories	Noise footprint and metrics	Noise intensity maps, Ln levels
UAM & TCAS Rates *(ASDE-X, TCAS)*	ASDE-X track data, UAM simulation	Sherlock Data Warehouse, Flight matrix	Selection of nominal and off nominal days	TCAS alert prediction, Altitude uncertainty	Encounter graphs
Airspace Availability *(Airspace, Terrain, Pop. Den.)*	Data acquired from 8 sources	Airspace constructs, Terrain and Parcels as 3D polygons	2D slicing, Alpha shape conversion	Available airspace, connectivity, convexity	Airspace availability, Population accessibility, Route network maps
Vertiport Demand *(Mobiliti)*	Data from Mobiliti Sim. and Google Maps API	Trip Matrix	K-means clustering	Travel time analysis	Vertiport location maps, Vertiport demand graphs

And this is just beginning…

Opportunities

Aircraft:

- Optimal Sizing, Type, Rider Comfort, Noise ….

Airport:

- Vertiport location, number, demand?
- Interoperability between air side and ground side
- Impact of traffic demand changes…

Airspace:

- Airspace capacity?
- Optimal flight planning and routing?
- Network designs for scale?
- Point to point vs arterial networks?
- Contingency planning?
- ATM Decision making?....

And More….

How to apply AI for human-to-automated controller interaction?

How to minimize transfer delays?

Vertiport layout and signage for fast passenger movement?

How to adhere to zoning laws?

What is the impact on land use?

How to resolve conflicting stakeholder concerns – cities, counties, operators, air traffic controller, FAA and so on ?

….

Data Sources

Traditional Data Sources:
Airspace Geometry, Flight-plans, Surveillance, Wind & Weather

Non traditional Data Sources:
Federal, county and state data.gov sites
ArcGIS
Land Parcel Geodata
Transit Hub and Network
Land Use and Zoning
Rights of Way (Railroads, Canals, Transmission Lines, Pipelines)
Boundary Layer Wind Plume Models
– environmental engineers
– used for anti chemical warfare research

Explore & Innovate !!!

Thank You for attending the first Aviation Data Science Seminar Series



Questions/Comments/Suggestions?