Three Dimensional Sector Design with Optimal Number of Sectors

Min Xue
University of California at Santa Cruz,
Moffett Field, CA

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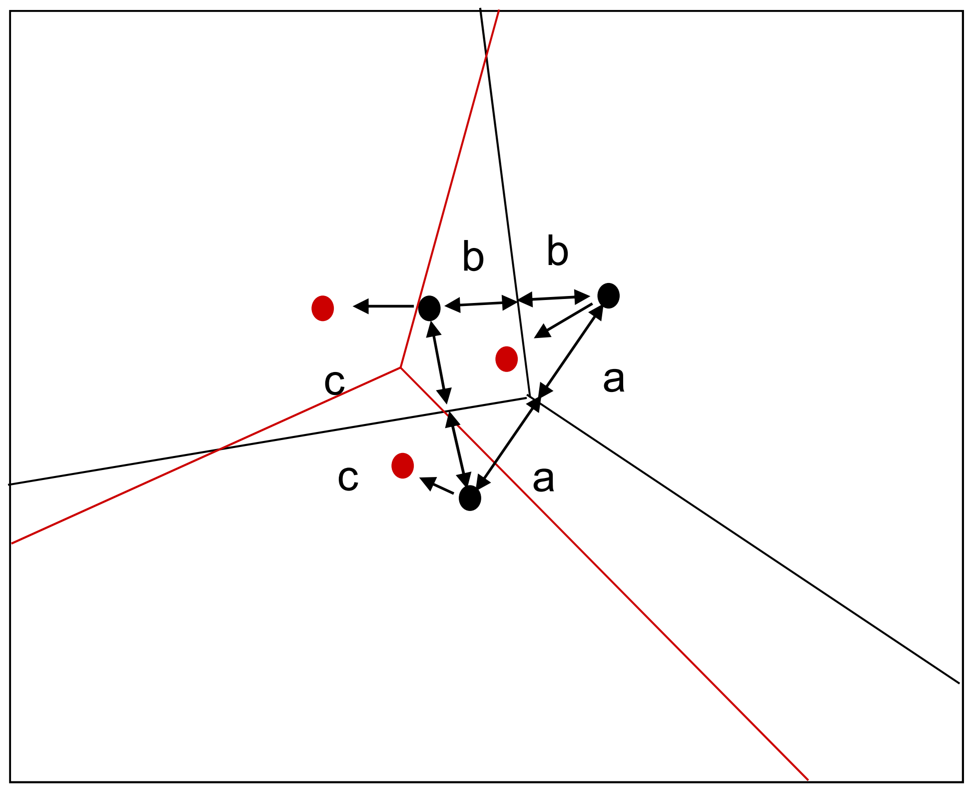
Introduction

Voronoi-based method



Main Message

The Voronoi-based method is enhanced by incorporating:

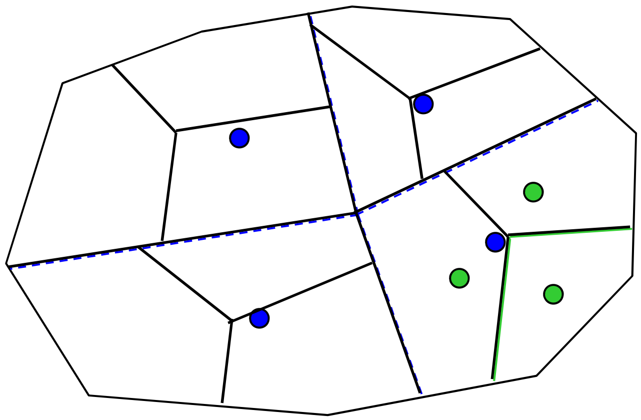
- **Optimal number of sectors**
- **Three dimensional partitions**
- **Traffic-pattern related costs**

Outline

- Background
- Tri-cost Strategy
- Partitioning costs
- Experiments
- Conclusions

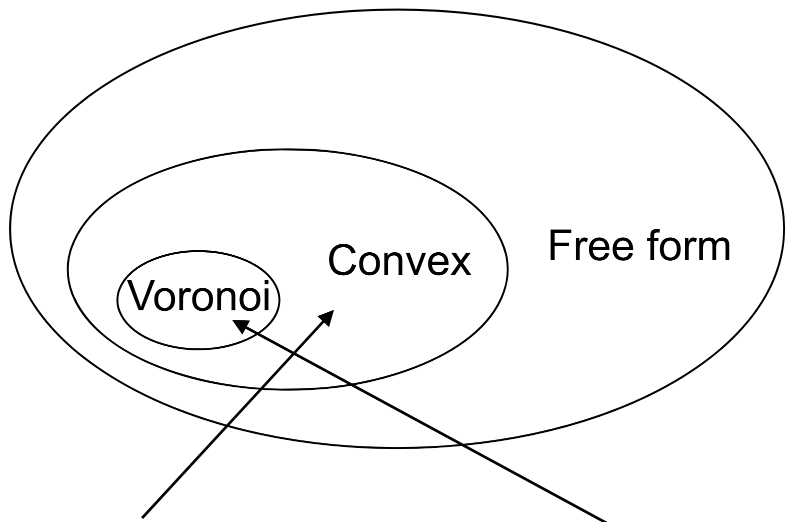
Background : Voronoi-based Method

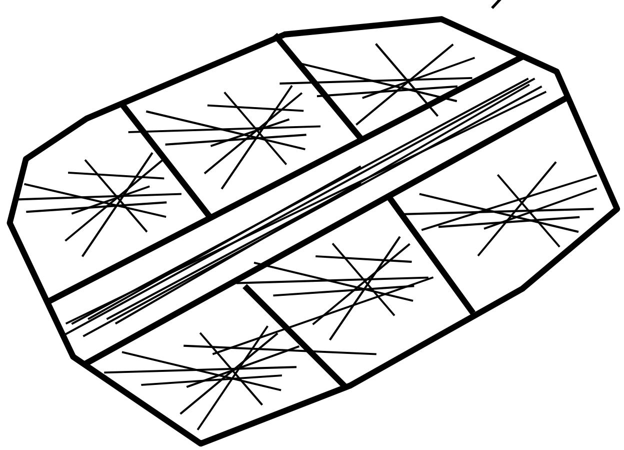
- **Partition** : Voronoi Diagrams
- **Optimization** : Genetic Algorithm
- **Efficiency** : Iterative Deepening Algorithm



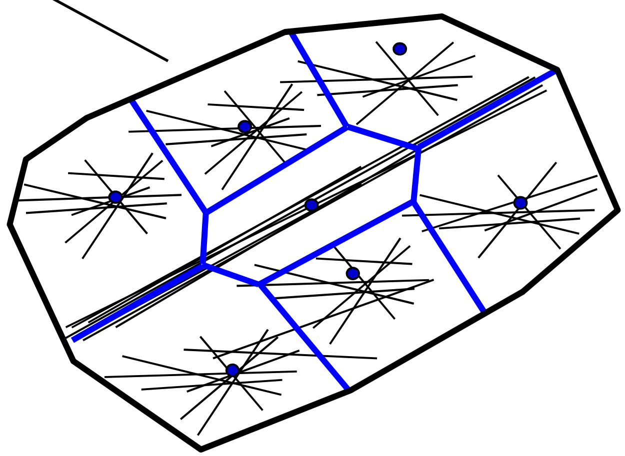
- **Properties:**
  - Convex shapes and smooth boundaries
  - Can be optimized for arbitrary costs
- **Necessary improvements:**
  - Increased solution space
  - Self-defined number of sectors
  - Three dimensional partitions
  - Costs involving traffic patterns

Solution Spaces in Sector Design





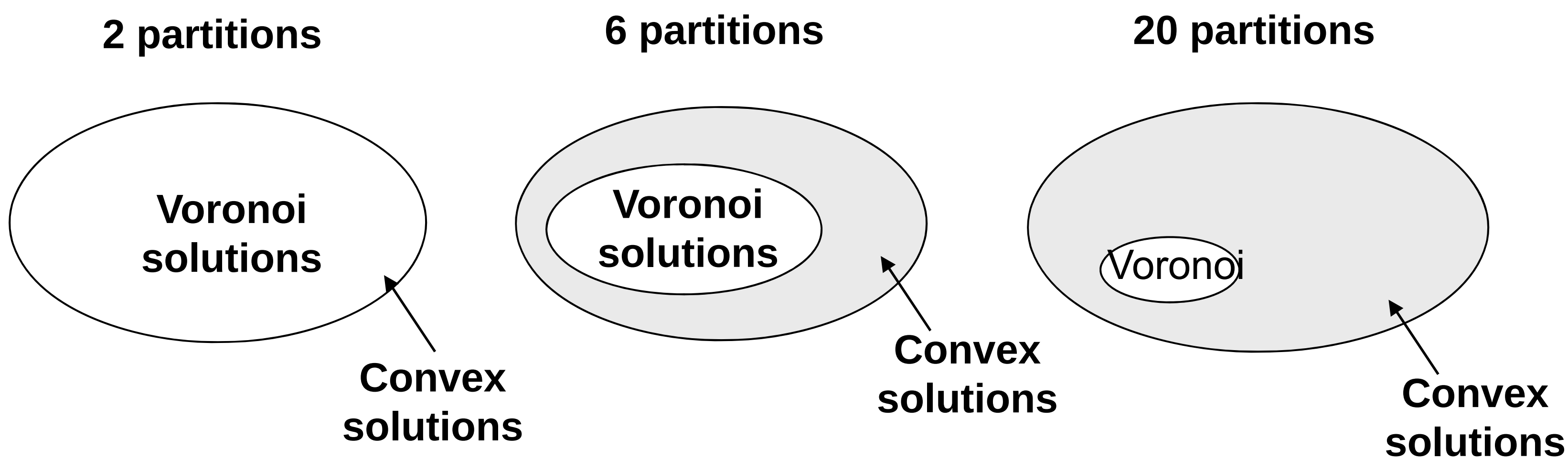
Most Wanted
(convex but non-Voronoi)



Voronoi Only

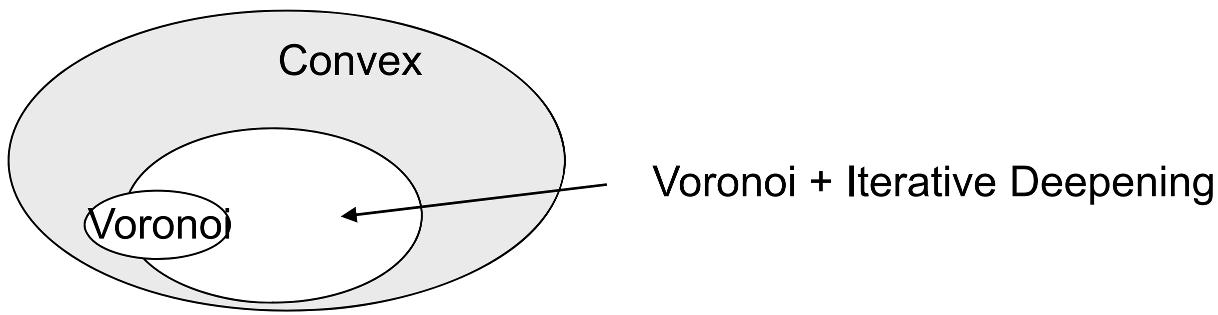
Voronoi Solution Space

Solution space becomes more and more limited when # of partitions becomes high.

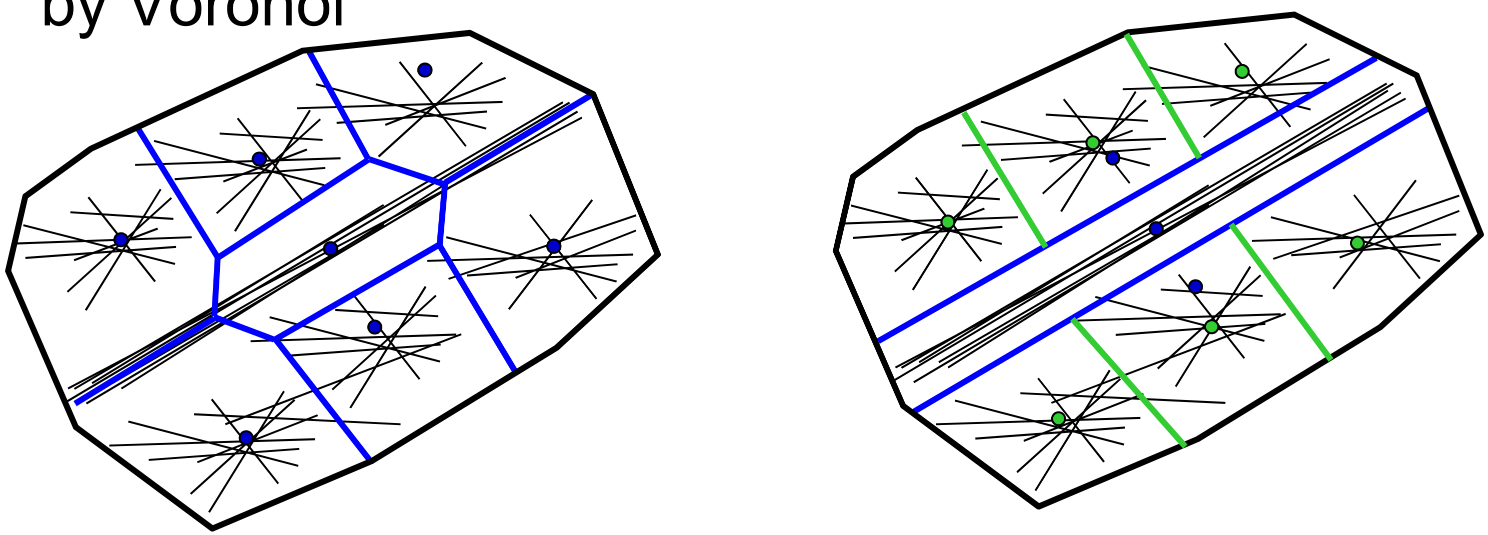


Necessity of Iterative Deepening

- Solution space is enlarged

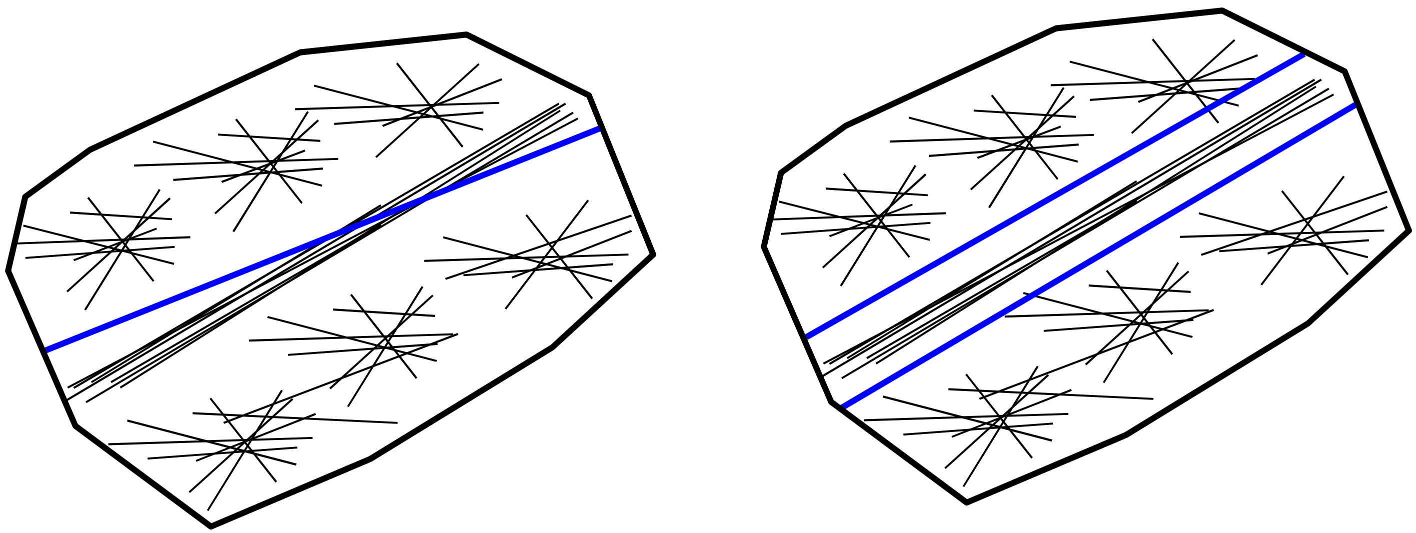


- Compensates for the limited solution space caused by Voronoi



Selecting the Number of Partitions

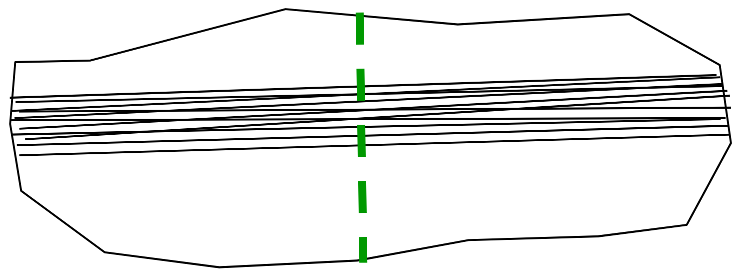
- Generate different number of partitions (e.g. 2-6)
- Use a cost to select the best partition



Vertical Stratification

Appropriate vertical stratification is better than horizontal partitions

Top View



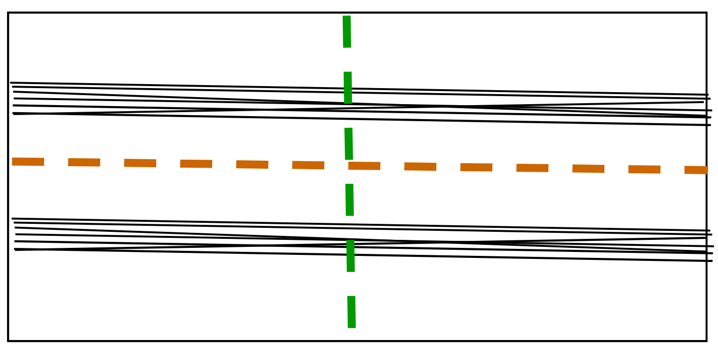
Peak = 30
Dwell = 15 min
(capacity=25)
Capacity – peak = -5

Peak = 15
Dwell = 7.5 min
(capacity=12.5)
Capacity – peak = -2.5

Side View

FL290

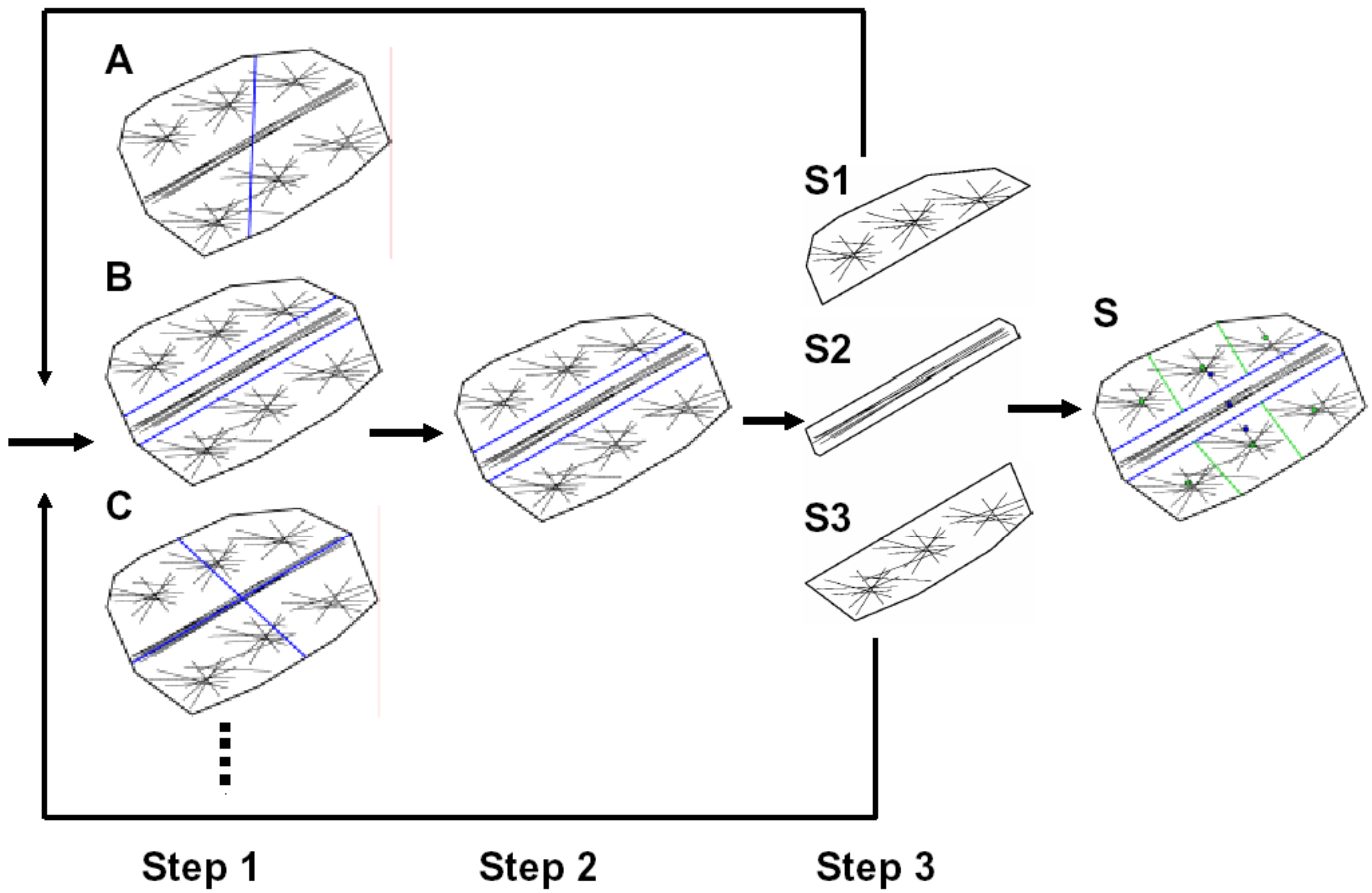
FL250



Peak = 15
Dwell = 15 min
(capacity=25)
Capacity – peak = 10

A Tri−cost Strategy

Multiple levels with a primary cost, a secondary cost, and a design cost



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Primary Cost

Principle:

“Long dwelling for region with high peak aircraft count”

Main:

- Ratio between sector dwell time and peak aircraft count

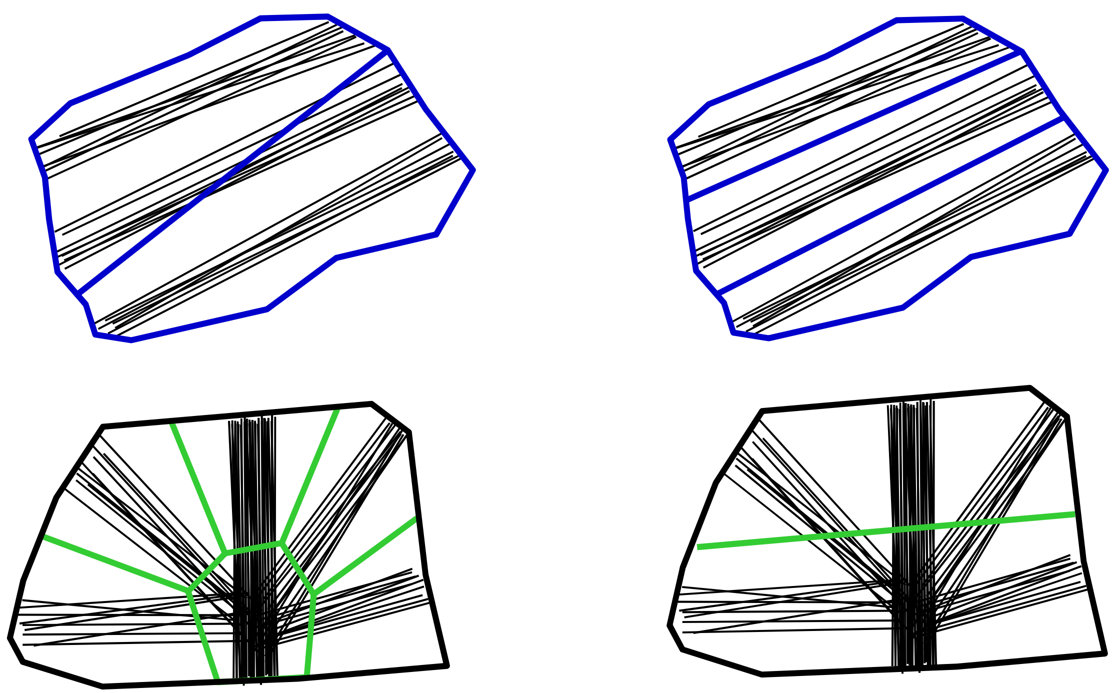
Minor:

- Intersections and major flows
- Sector boundary crossings
- Flights having short dwelling
- Sector peak count variance

Secondary Cost

- Sum of shallow crossing angles between trajectories and boundaries

- Examples



Design Cost

- Serves as a stop criterion

- Option 1 (CAP):

$$Capacity \geq Demand$$

  e.g.

$$Capacity = \frac{5}{3} \cdot average\_sector\_dwelling\_time$$
$$Demand = sector\_peak\_aircraft\_count$$

- Option …

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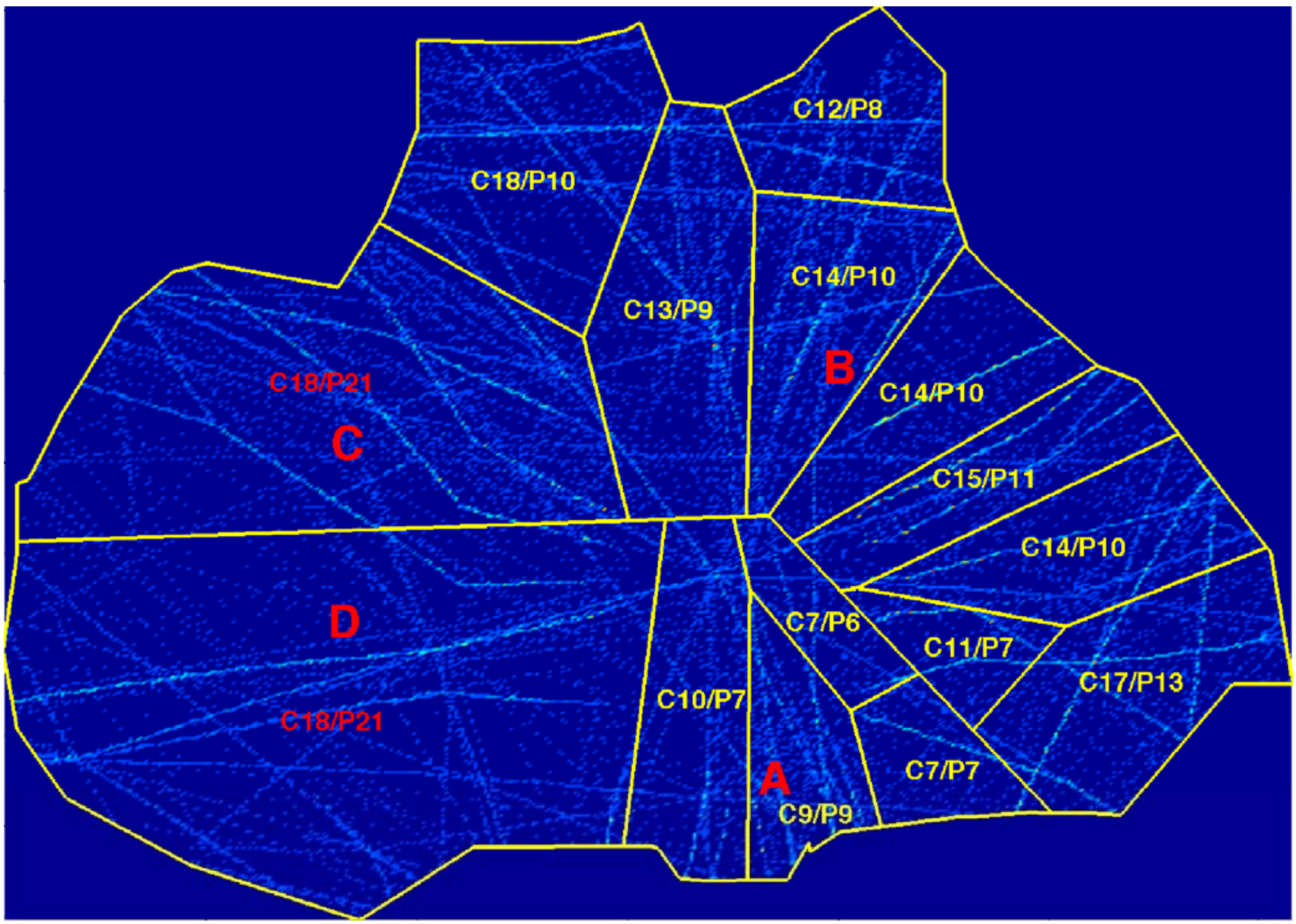
Experiment #1 Setup

- Data: Unconstrained simulated data from April 20, 2005
- Center: ZFW
- Altitudes: FL240 to FL350
- Design cost : “capacity > peak”
  - Maximum allowed capacity set to 18

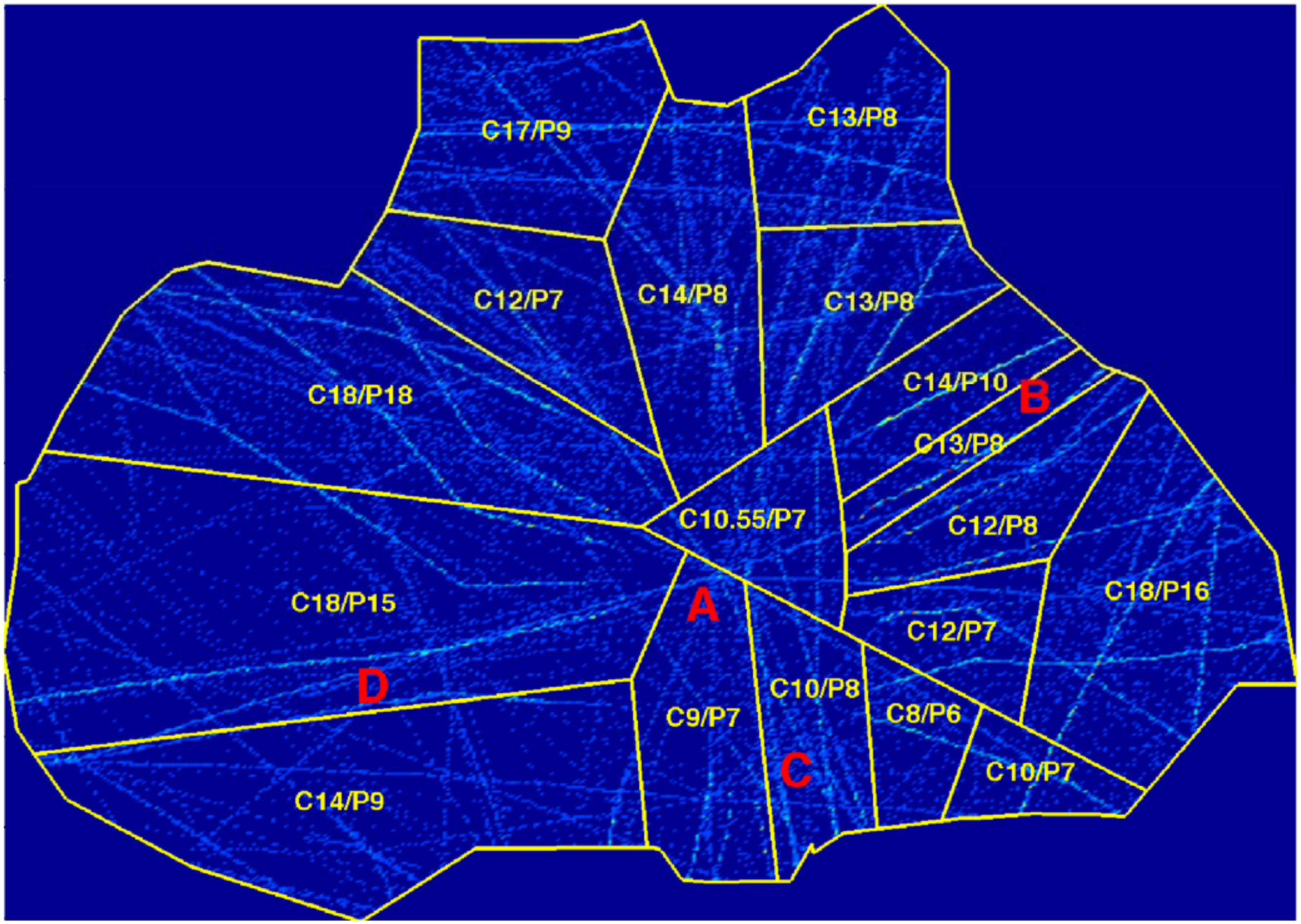
Case IA : Original Method (15-sector Design)

- Fixed number of sectors
- No Tri-cost strategy

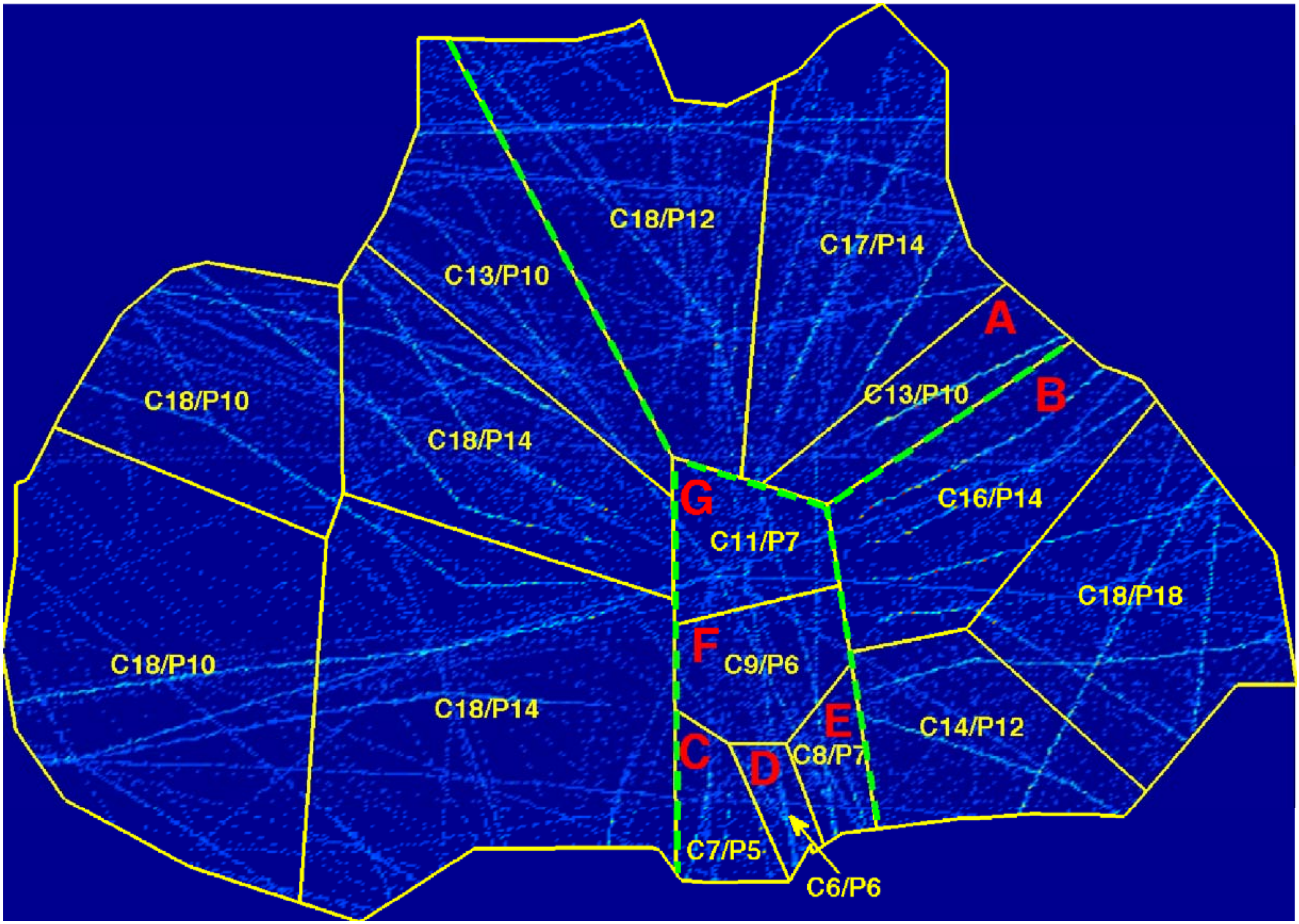


Case IB : Original Method (18-sector Design)

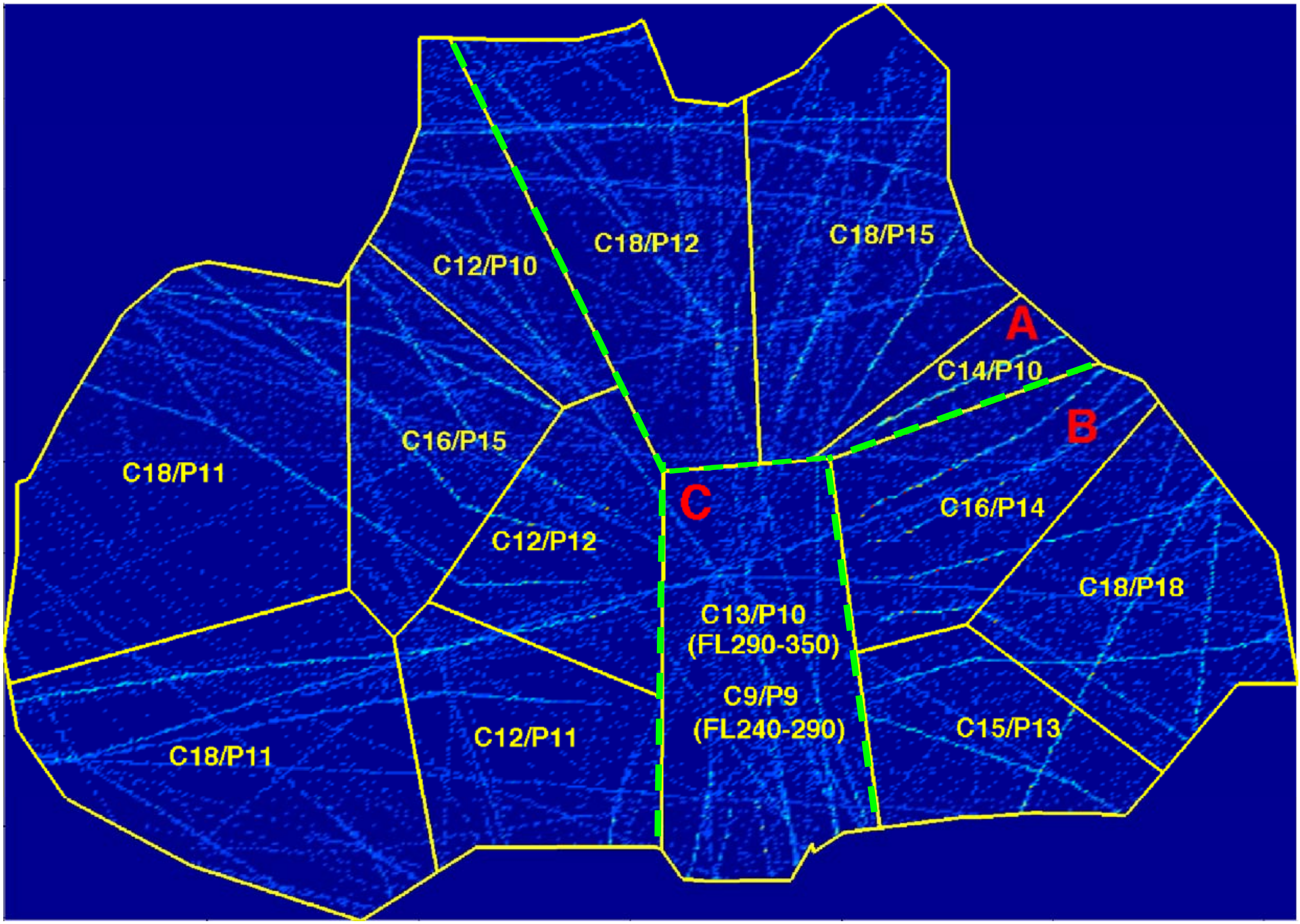
- Fixed number of sectors
- No Tri-cost strategy



Case II : Tri-cost Strategy with 2D only



Case III : Tri-cost Strategy with 3D



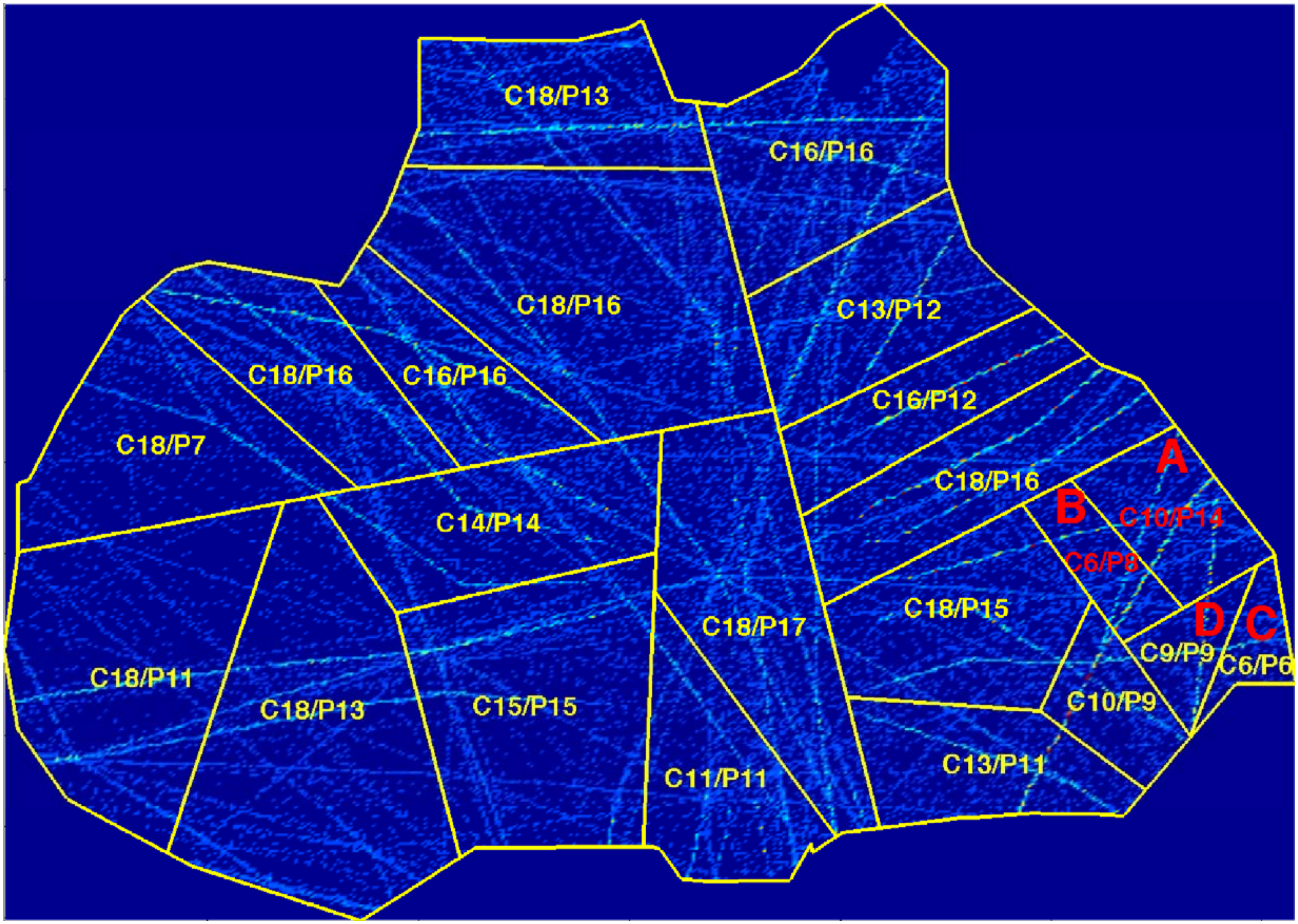
Comparisons of Experiment #1

	Case IA (15-sector)	Case IB (18-sector)	Case II (2D)	Case III (3D)	Current
Num. of Sectors	15	18	16	**14**	19
Violations of Requirements	2	**0**	**0**	**0**	1
Boundary Crossings	2,698	2,822	**2,368**	2,471	2,851
Variance of Peak Counts	97%	94%	69%	**47%**	69%
Dominant Flow Proximity Cost	2.89	3.70	2.39	**2.14**	2.96
Intersection Proximity Cost	253.7	271.7	4.55	**0.97**	44.6

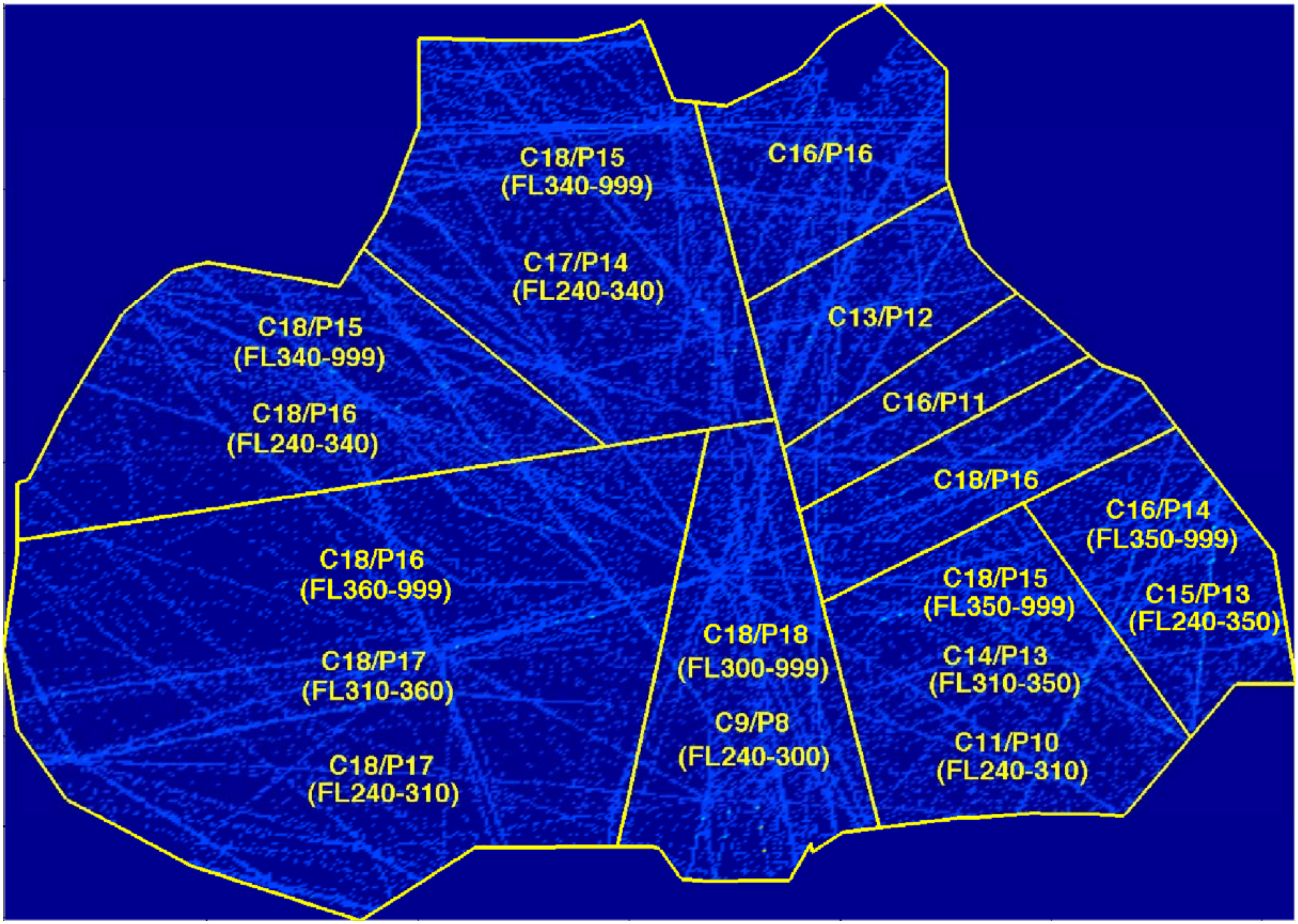
Experiment #2 Setup

- Data: Unconstrained simulated data from April 20, 2005
- Center: ZFW
- Altitudes: FL240 and above
- Design cost : “capacity > peak”
  - Maximum allowed capacity set to 18

Case I: Tri-cost Strategy with 2D



Case II: Tri-cost with 3D



Comparisons for Experiment #2

	Case I (2D)	Case II (3D)	Current
Number of Sectors	22	**18**	19
Violations of Requirement	2	**0**	6
Boundary Crossings	6.583	**4,889**	5,570
Variance of Peak Counts	60.3%	**43.8%**	78.5%
Dominant Flow Proximity Cost	3.55	**2.96**	3.16
Intersection Proximity Cost	74.1	**73.8**	288.5

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Conclusions

- A new tri-cost strategy with new cost functions is developed
- Results show the new method has
  - low number of sectors
  - low number of crossings
  - better proximity to intersections and dominant flows.