



3D Sectors Design By Genetic Algorithm Towards Automated Sectorisation

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Introduction

- An **elementary sector** is defined as a volume of the airspace, within which the air traffic controller can perform his controlling function.
- **Area Control Centers (ACC)** consists of several elementary sectors.
- When traffic demand capacity issue is identified or change of traffic patterns occurs a new **sector design** of the ACC should be proposed.

Motivation

- Implementation of the Free Routing concept.
- Continuous air traffic growth ➡ congested airspace.
- Limited flexibility of current sector design.
- Complexity of the sector design task.

Sector design problem

- The airspace sector design problem consists in searching a partition of a given airspace domain D into a set of N **operationally workable** sectors $[s_1, \dots, s_n]$.
- The quality of the sector design is evaluated according several geometrical and operational constraints.

Problem Description

- ✓ workload imbalance between elementary sectors

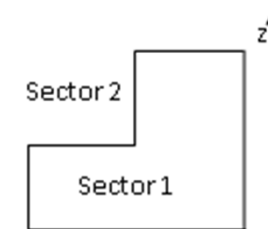
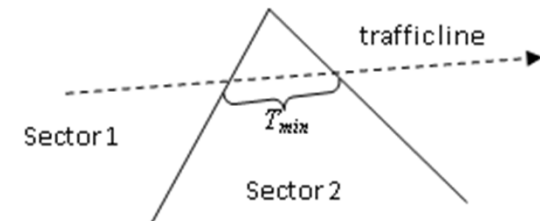
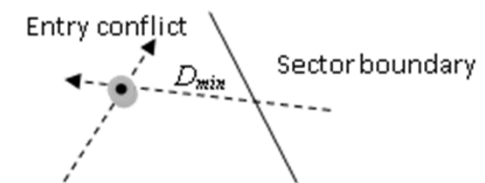
The workload is computed as:

$$(\text{crossing time for all aircraft}) * (\text{time to monitor one aircraft}) + \\ (\text{total number of conflicts}) * (\text{time to solve one conflict})$$

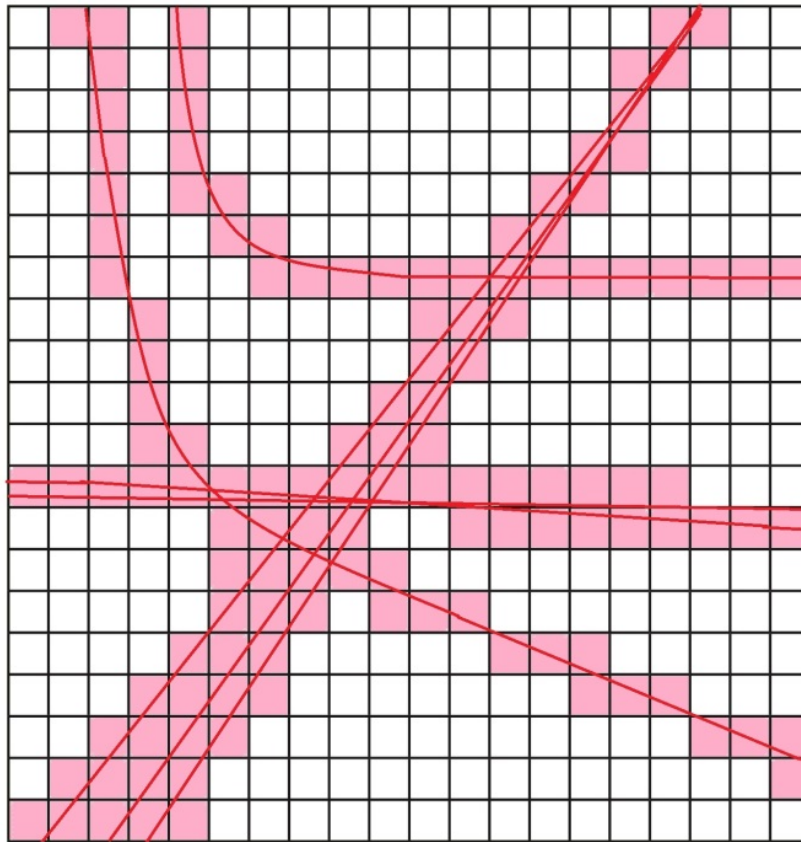
- ✓ ATC coordination workload

Problem Description

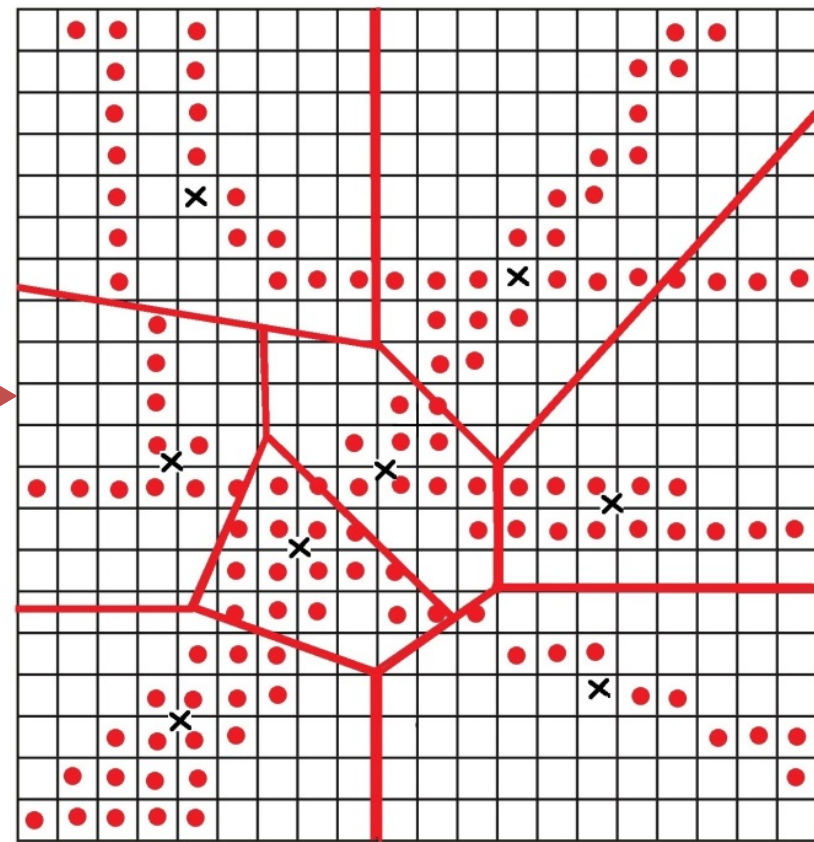
- ✓ the number of flight re-entry events
- ✓ the number of entry conflict points close to the sector borders
- ✓ the number of short crossings
- ✓ shapes of sectors such as "balconies"
- ✓ connectivity



Pre-processing step

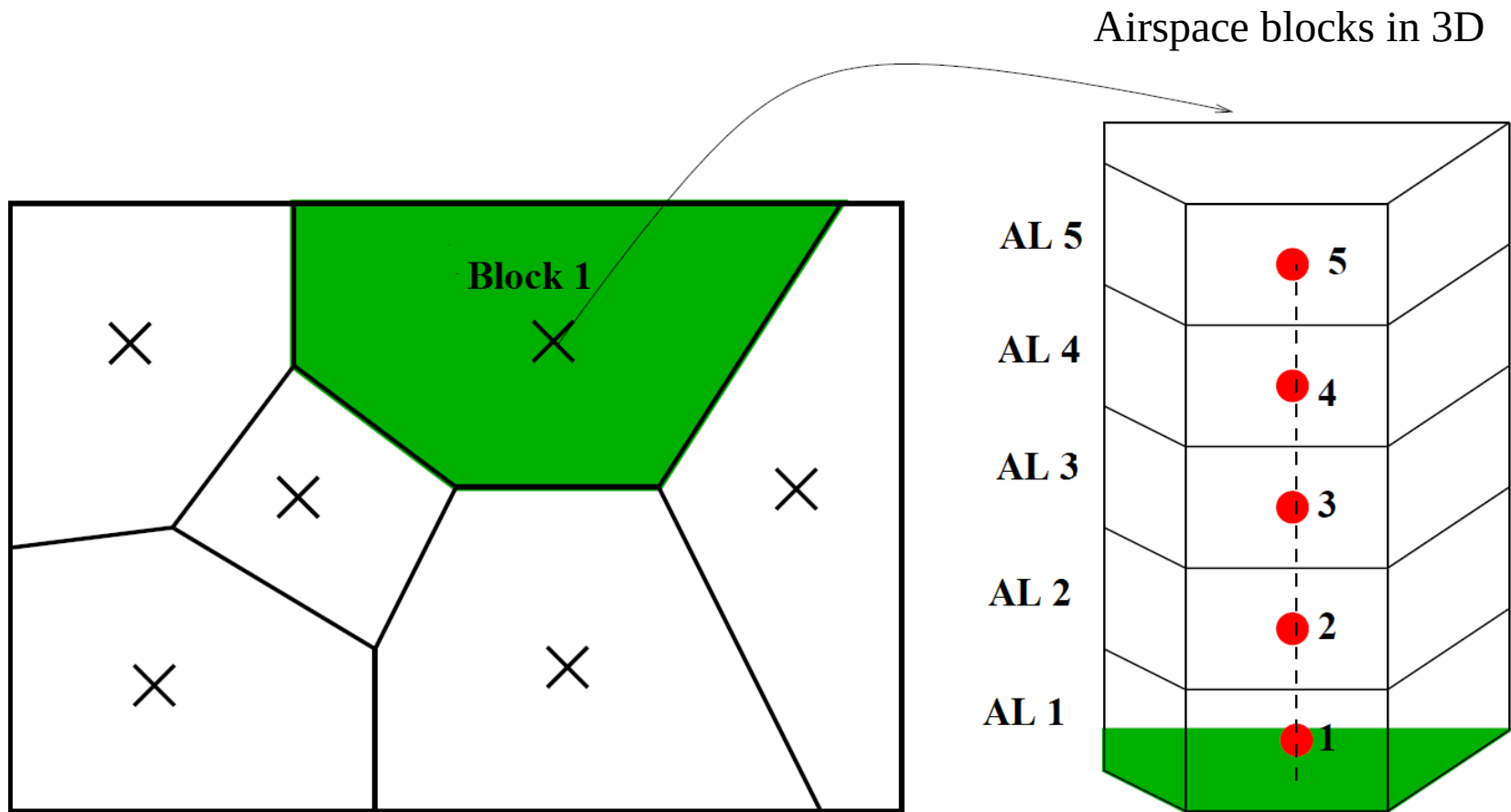


3D airspace discretized using grid cells ($<5\text{NM}$)
projected on the 2D plane



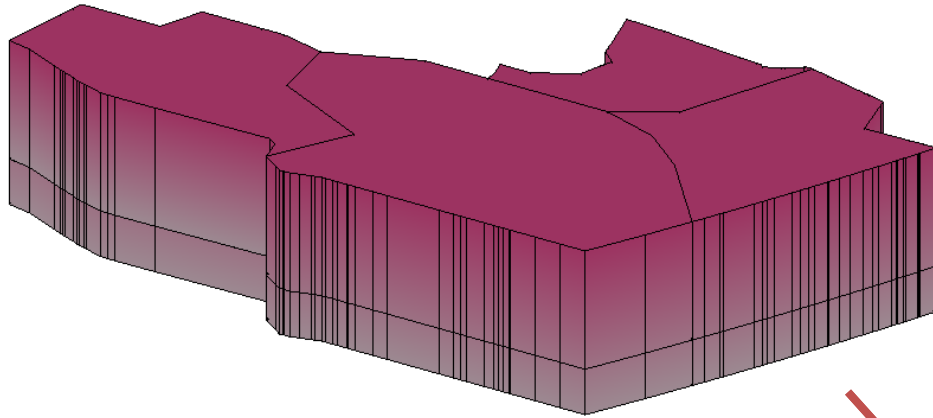
New cells built using k-means
algorithm

Preparing airspace blocks for sector building process

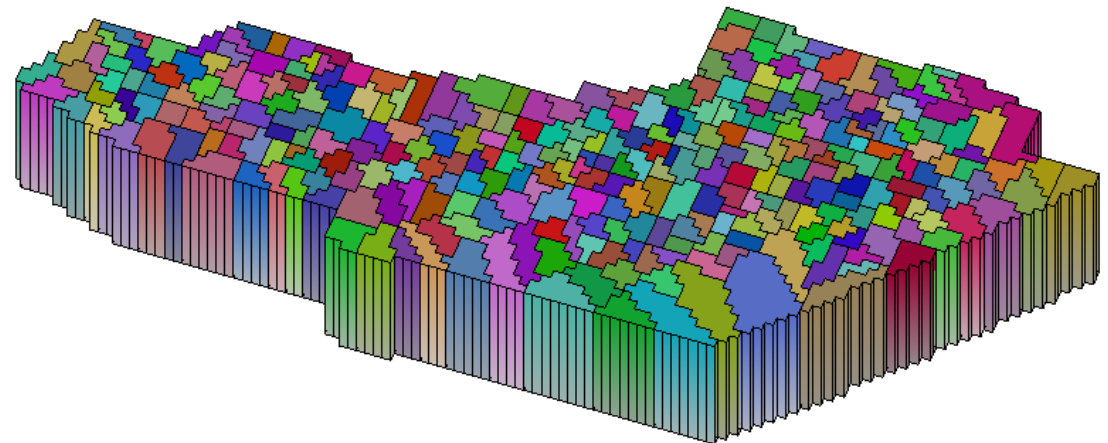


Preparing airspace blocks for sector building process

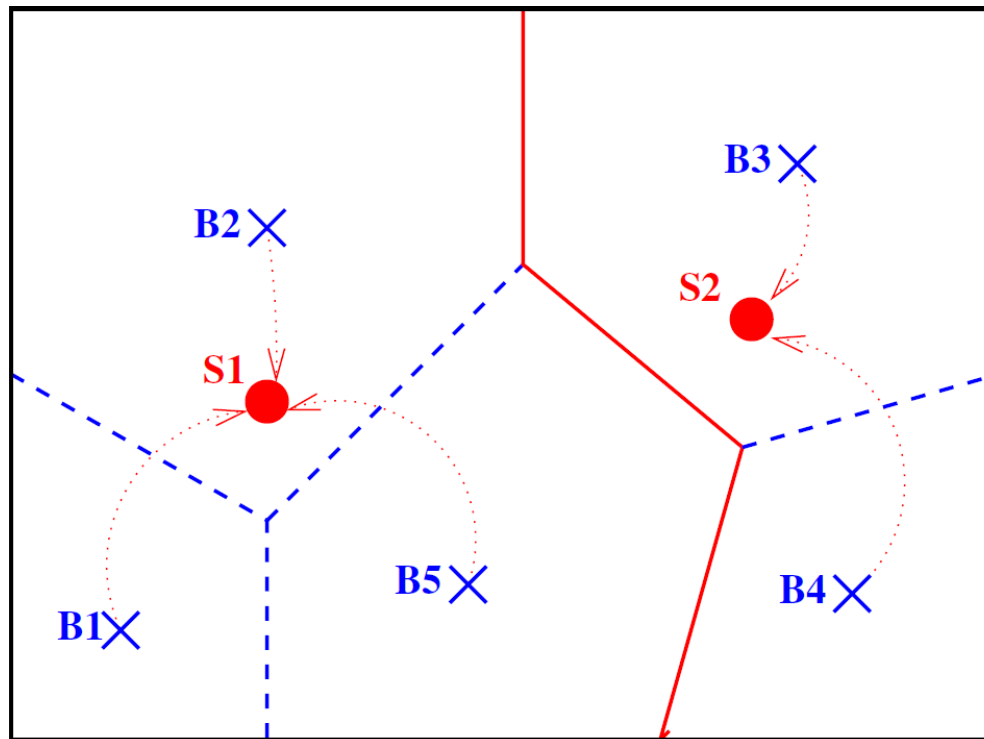
ACC



Airspace 3D blocks



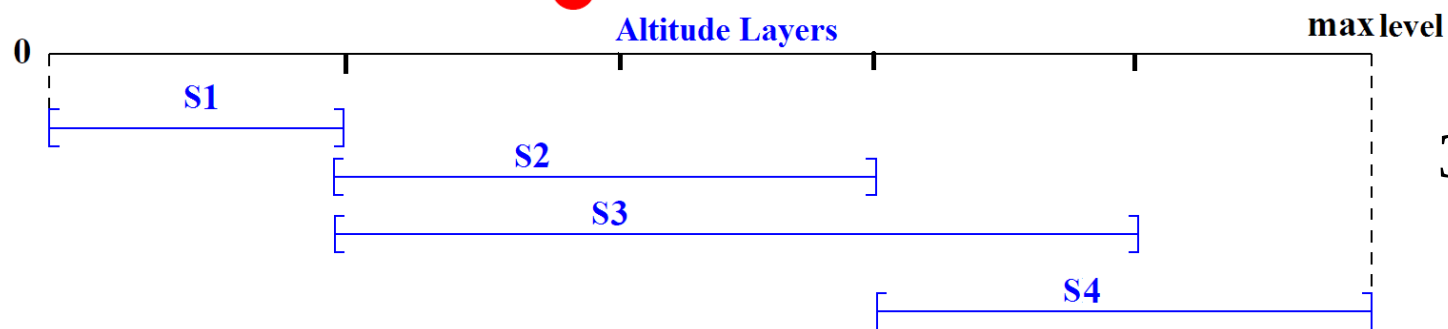
Sector building process



Process of building sectors in 2D

× Block center

● Sector Center
Altitude Layers



3D extension

Solution representation

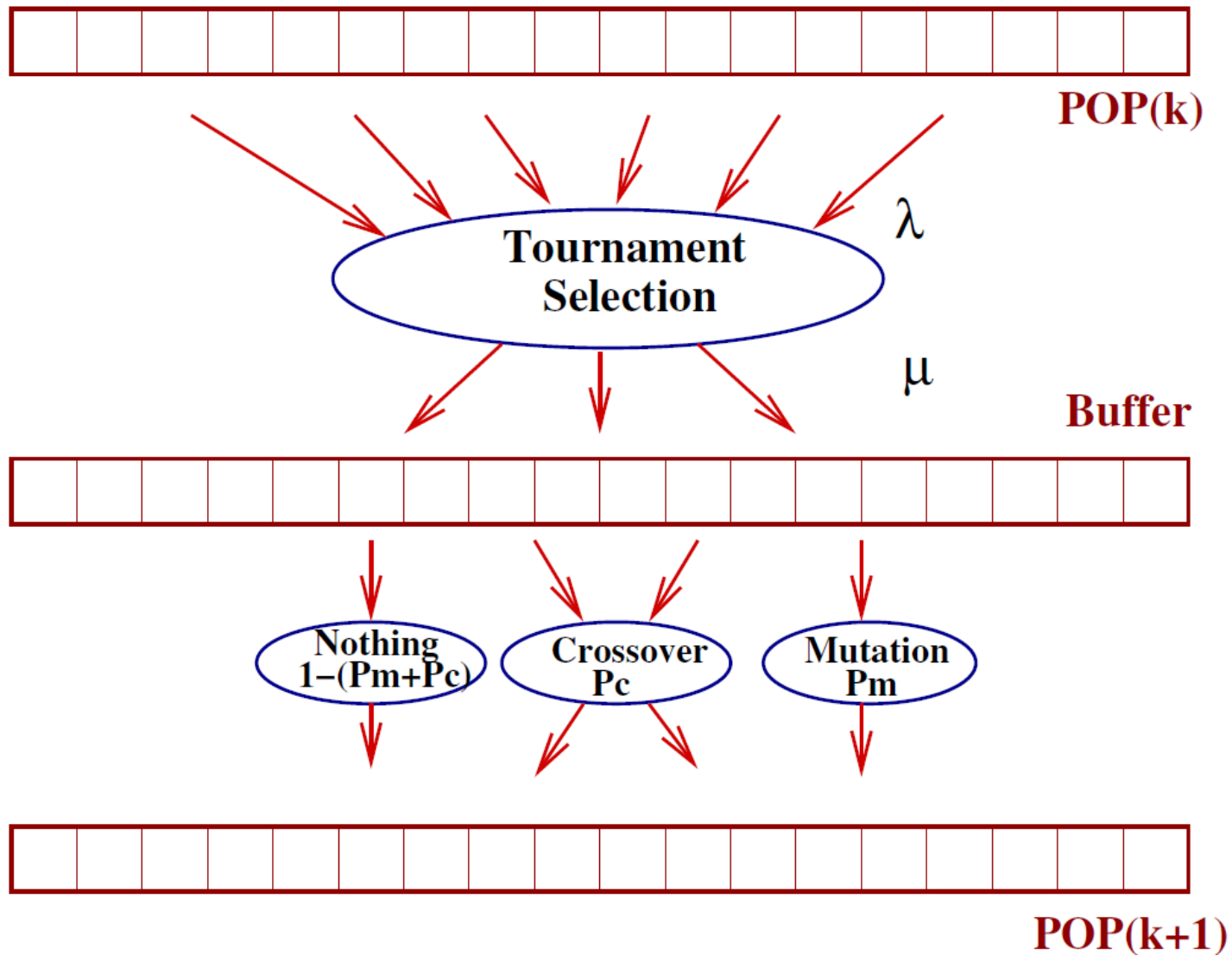
- The **solution** of the sector design process can be represented in the following form:

x_1	x_2	...	x_i	...	x_{N_s}
y_1	y_2	...	y_i	...	y_{N_s}

$Alt_{1_{min}}$	$Alt_{2_{min}}$	...	$Alt_{i_{min}}$	...	$Alt_{N_s_{min}}$
$Alt_{1_{max}}$	$Alt_{2_{max}}$	...	$Alt_{i_{max}}$	...	$Alt_{N_s_{max}}$

- With number of building blocks > 100 and the number of layers > 2 the number of possible combinations is big ➡ **stochastic optimization** is required.

Evolutionary Algorithm



Objective Function

$$y = a_1 * F_w + a_2 * F_c + a_3 * F_r + a_4 * F_{sh} \\ + a_5 * F_{ec} + a_6 * F_b$$

F_w - workload imbalance between all elementary sectors

F_c - total flow cuts

F_r - total number of re-entries

F_{sh} - total number of short-crossings

F_{ec} - total number of entering conflicts

F_b - total number of “balconies”

$a_1 - a_6$ - proportion coefficients

ASTAAC Interface

1 - Algorithm option
 Choice of algorithm: SAGA Sectorisation Automated by Genetic Algorithm Initial/Reference Secto: NONE

2A - Airspace grid decomposition
 Shape type: square Long size (nm): 5 Altitude min (FL): 245 Altitude step (feet): 500
 Lat size (nm): 5 Altitude max (FL): 595

2B - Final sector decomposition
 Number of sectors (max for COBOS): 6 Max number of layers per sector: 3 ☐ Smooth sector shape
 DFLs (Division Flight Levels): 245 345 355 365 595 Name prefix:

3A - Worload/load parameters
Macroscopic worload Monitoring one minute of crossing fligth (sec): 3 Conflict management (sec): 120
 Sector capacity (minute / hour): 42 Entry conflict management (sec): 240

3B - Sectorisation criteria and Objective Function

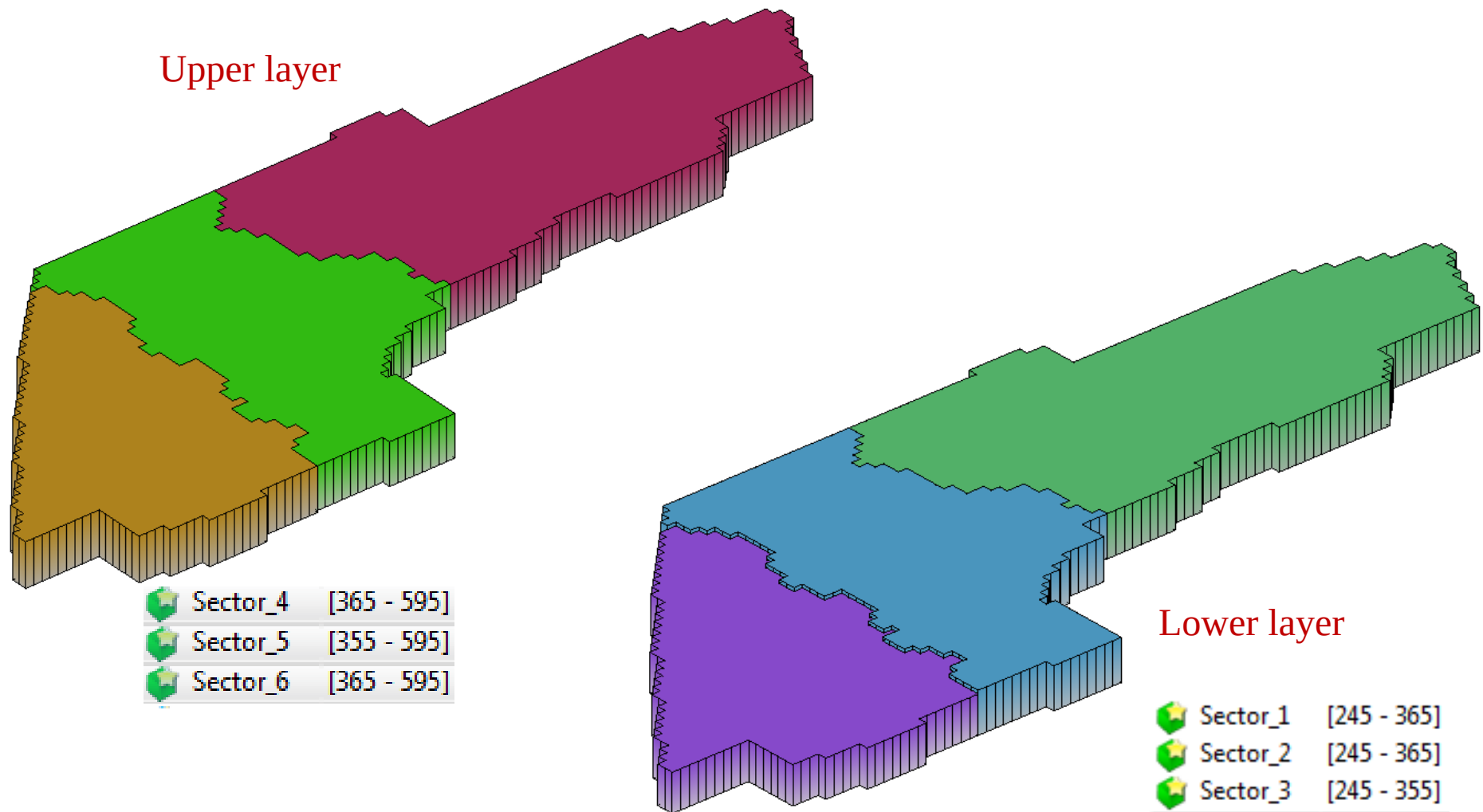
Parameters of operational criteria
 Workload/Load Imbalance allowed (%) : 20
 Reentries allowed (%) : 3
 Shortcrossing allowed (%) : 5
 Min time in sector (sec) : 120
 Minimum distance of conflicts to boundary (NM): 10

Criteria weight (Proportion [0..1])
 Workload/Load distribution : 0.4
 Coordinations (Flow cuts) : 0.3
 Entry conflicts : 0.2
 Reentries : 0.2
 Shortcrossing : 0.4
 Balconies : 0.1
 Overload (COBOS) : 0.1
 Optimized Nb of sectors (COBOS) : 0.1

Results obtained with ASTAAC

- for Maastricht/Amsterdam Airspace (EDYYDUTA)
- for 12/07/2014 11h-13h (peak hours)
- proportion coefficients of the objective function:
Scenario 1: $a_1 = 0.5, a_2 = 0.3, a_3 = a_5 = 0.25, a_4 = 0.4, a_6 = 0.1$.
Scenario 2: $a_1 = 0.2, a_2 = 0.6, a_3 = a_5 = 0.25, a_4 = 0.5, a_6 = 0.1$.

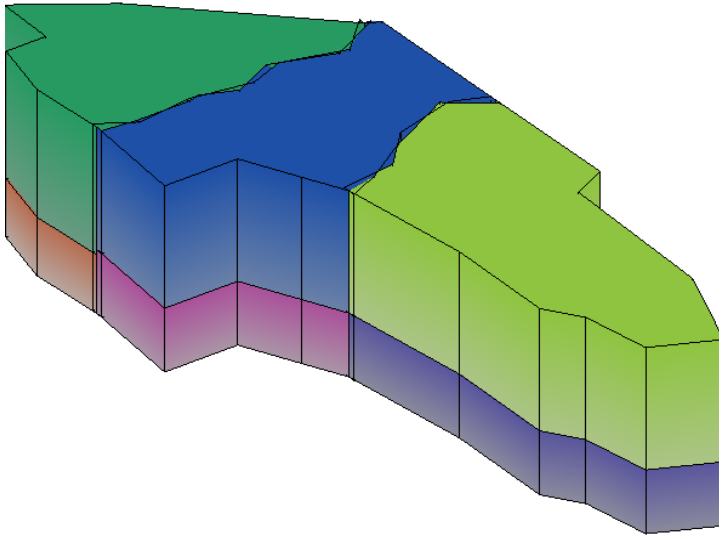
Results: Scenario 1



Traffic data: for 12/07/2014 11h-13h for Maastricht/Amsterdam Airspace (EDYYDUTA).

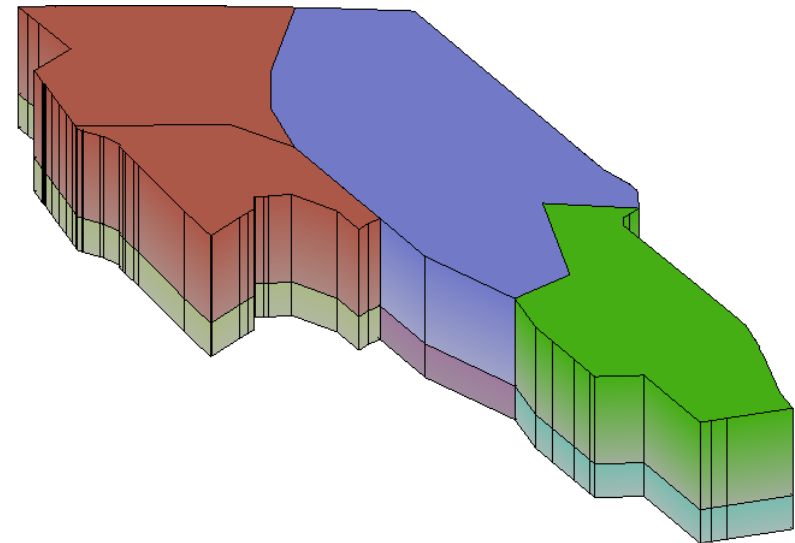
Results: Scenario 1

Scenario 1



sector	workload	short-cross	e-conflicts	re-entr
0	4273	4	0	0
1	4058	3	1	0
2	3642	3	0	0
3	3695	1	0	0
4	3923	3	0	0
5	4426	4	0	0

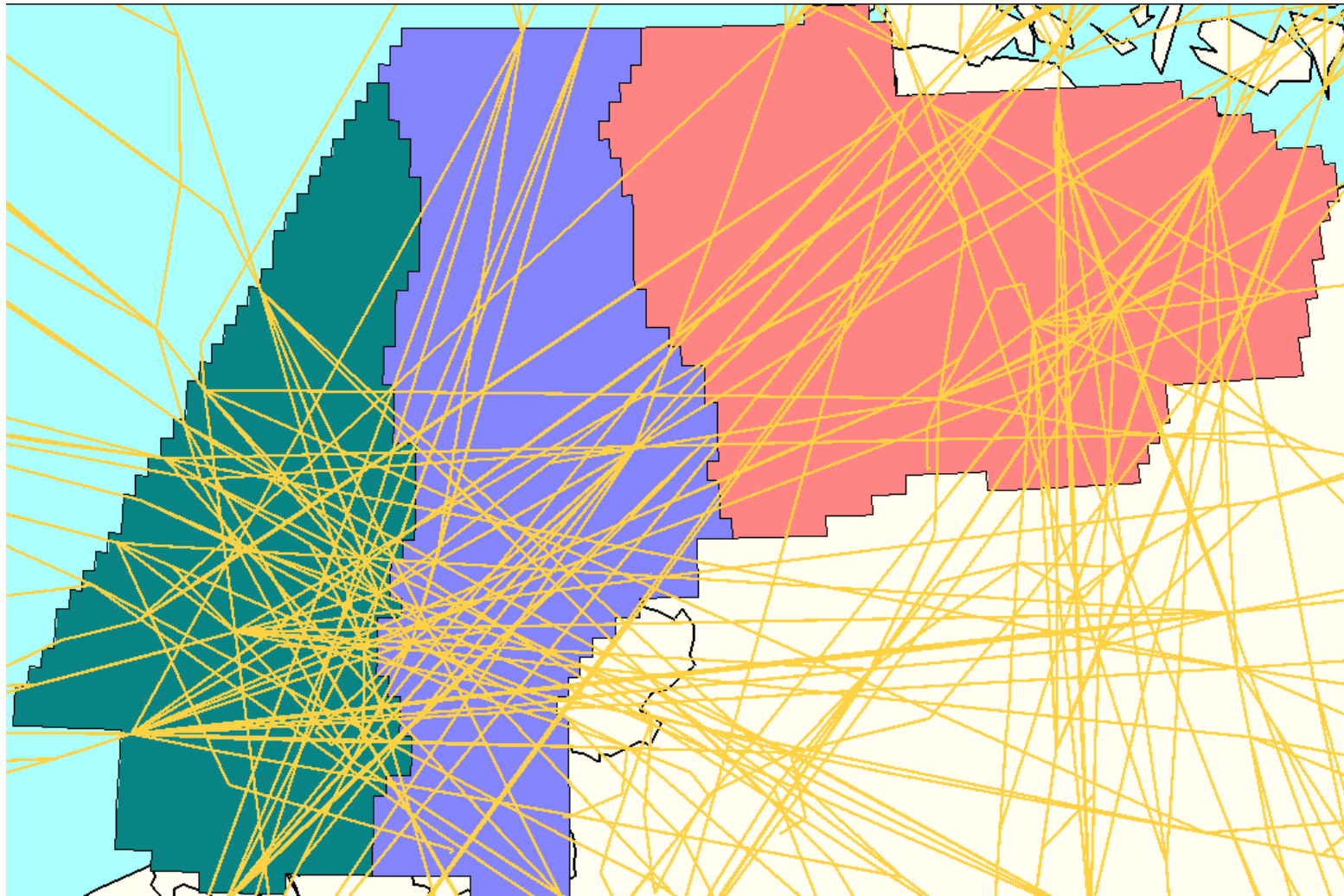
Original/Reference Scenario



sector	workload	short-cross	e-conflicts	re-entr
0	3008	0	0	0
1	993	4	0	0
2	5663	4	0	0
3	1928	2	1	1
4	8493	1	0	3
5	3140	6	0	2

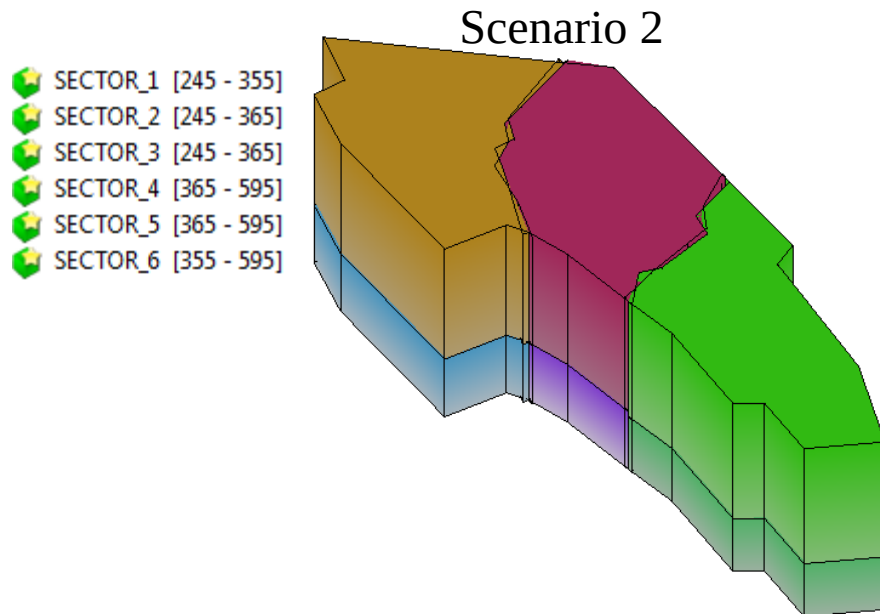
Traffic data: for 12/07/2014 11h-13h

Results: Scenario 1

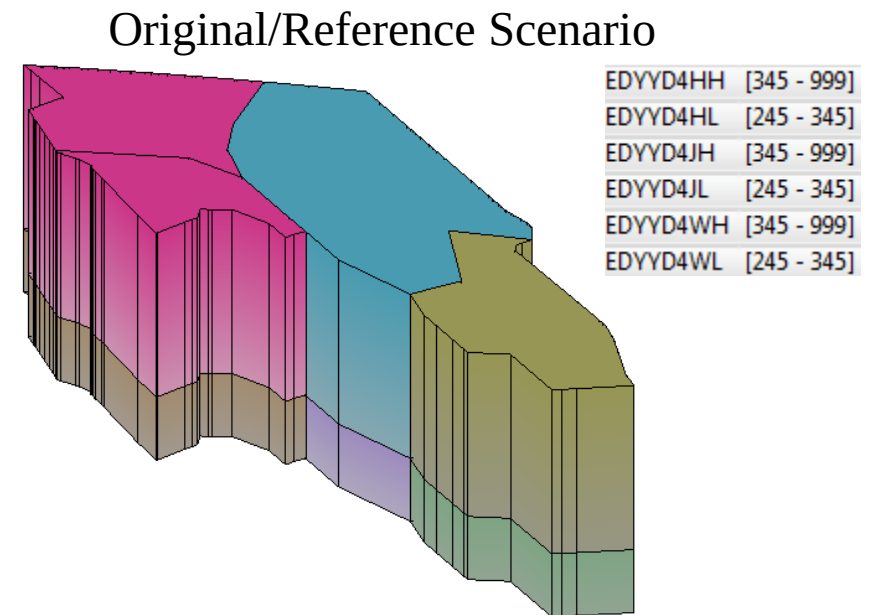


Traffic data: for 12/07/2014 11h-13h

Results: Scenario 2



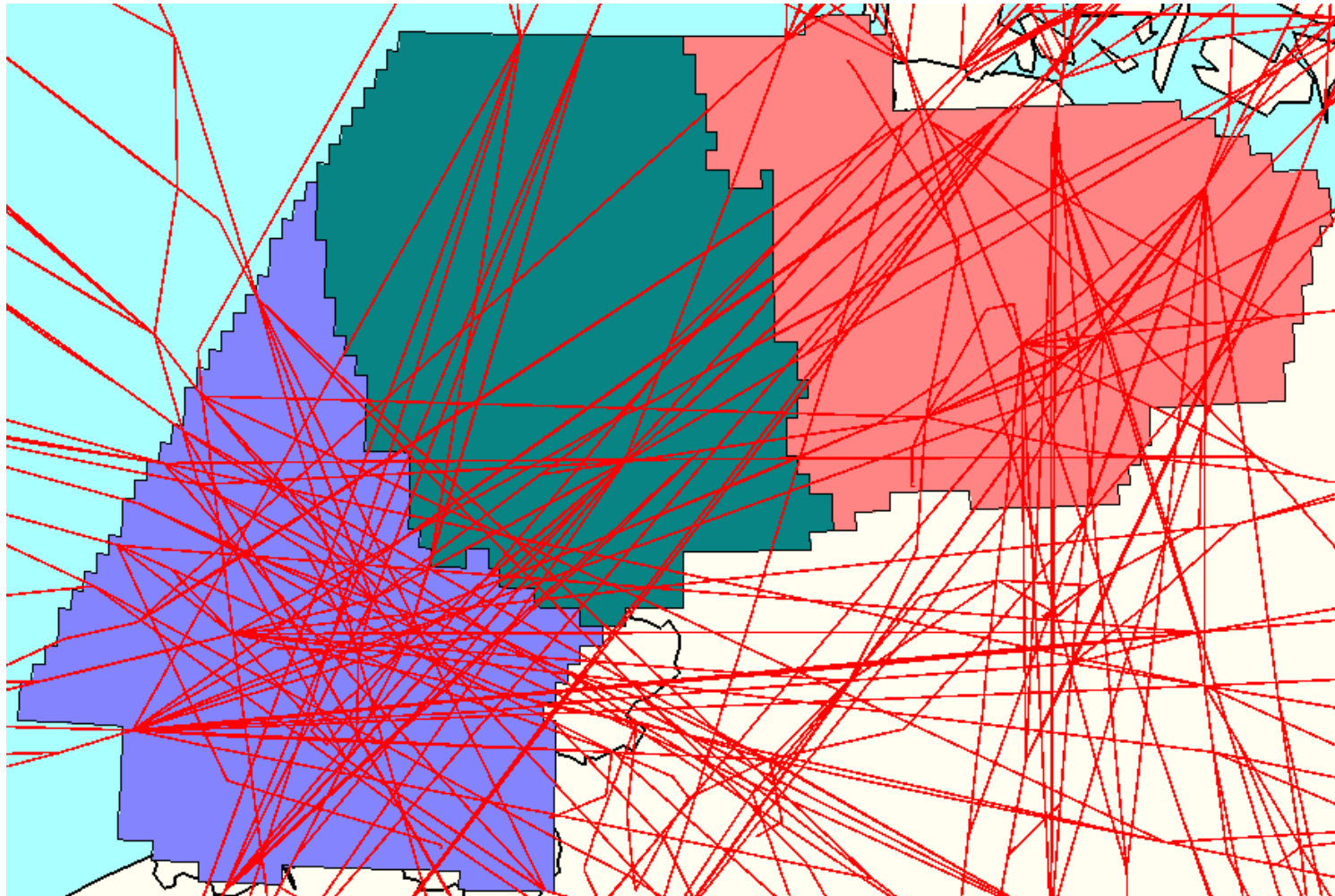
sector	workload	short-cross	e-conflicts	re-entr
0	2817	3	0	0
1	6116	2	0	1
2	3183	3	1	0
3	3327	1	0	0
4	5073	1	0	0
5	3501	2	0	0



sector	workload	short-cross	e-conflicts	re-entr
0	3008	0	0	0
1	993	4	0	0
2	5663	4	0	0
3	1928	2	1	1
4	8493	1	0	3
5	3140	6	0	2

Traffic data: for 12/07/2014 11h-13h for Maastricht/Amsterdam Airspace (EDYYDUTA).

Results: Scenario 2



Traffic data: for 12/07/2014 11h-13h

Conclusions

- Proposed sector design algorithm is able to provide very satisfying design regrading workload balancing and sectors shape.
- Proposed algorithm is flexible and can be calibrated according to different preferences.
- Next step includes adding new complexity metric for the workload evaluation.
- Algorithm can be adapted for Dynamic Sector Configurations.

Thank you for your attention.