



An experience in high



productivity

lidar mapping

and

noise modelling

TRB Summer Meeting

Williamsburg, VA

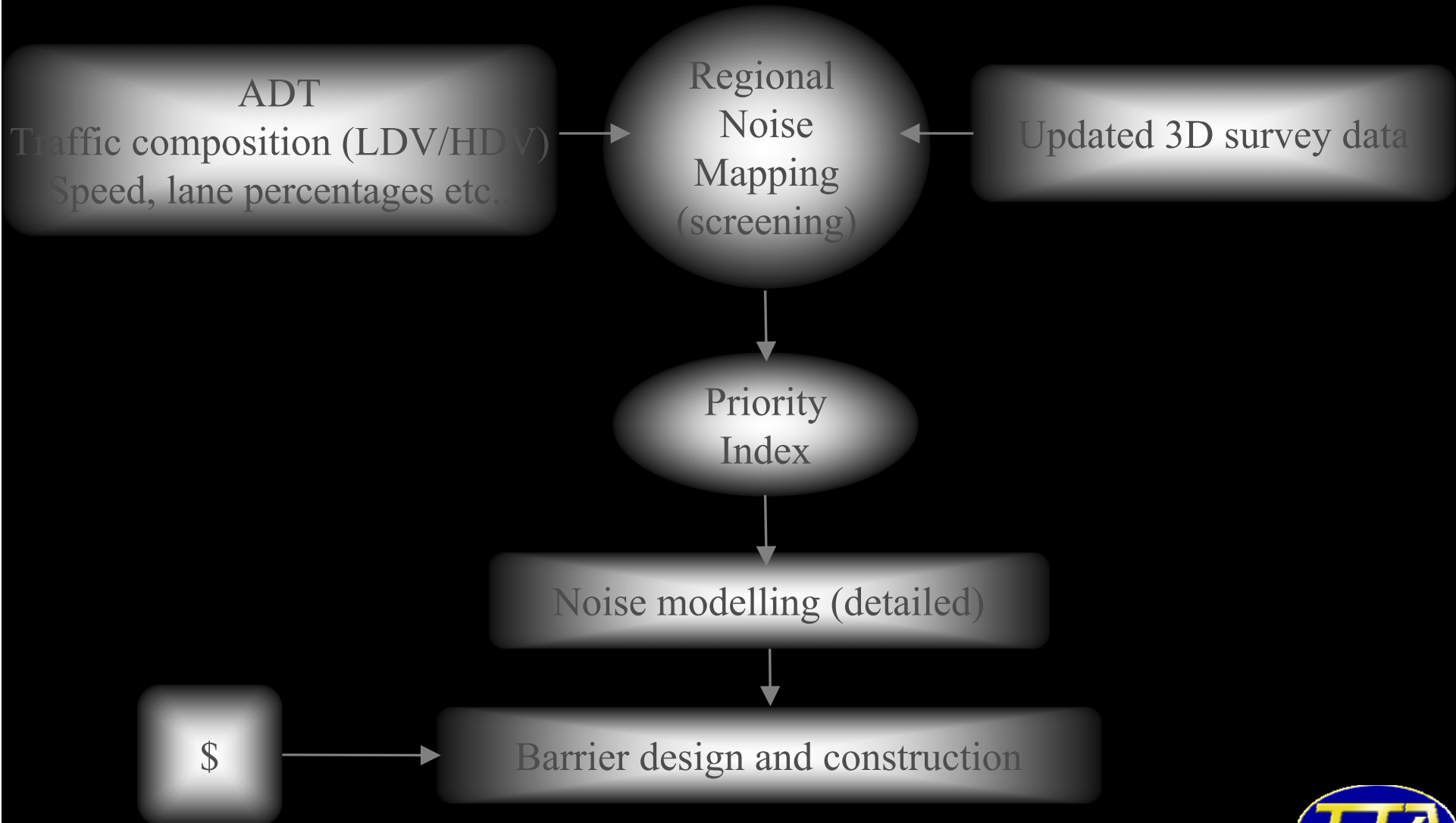
July 11, 2006

Presented by: Douglas Tommasi Crudeli



Noise mapping as a regulatory requirement (Italy)

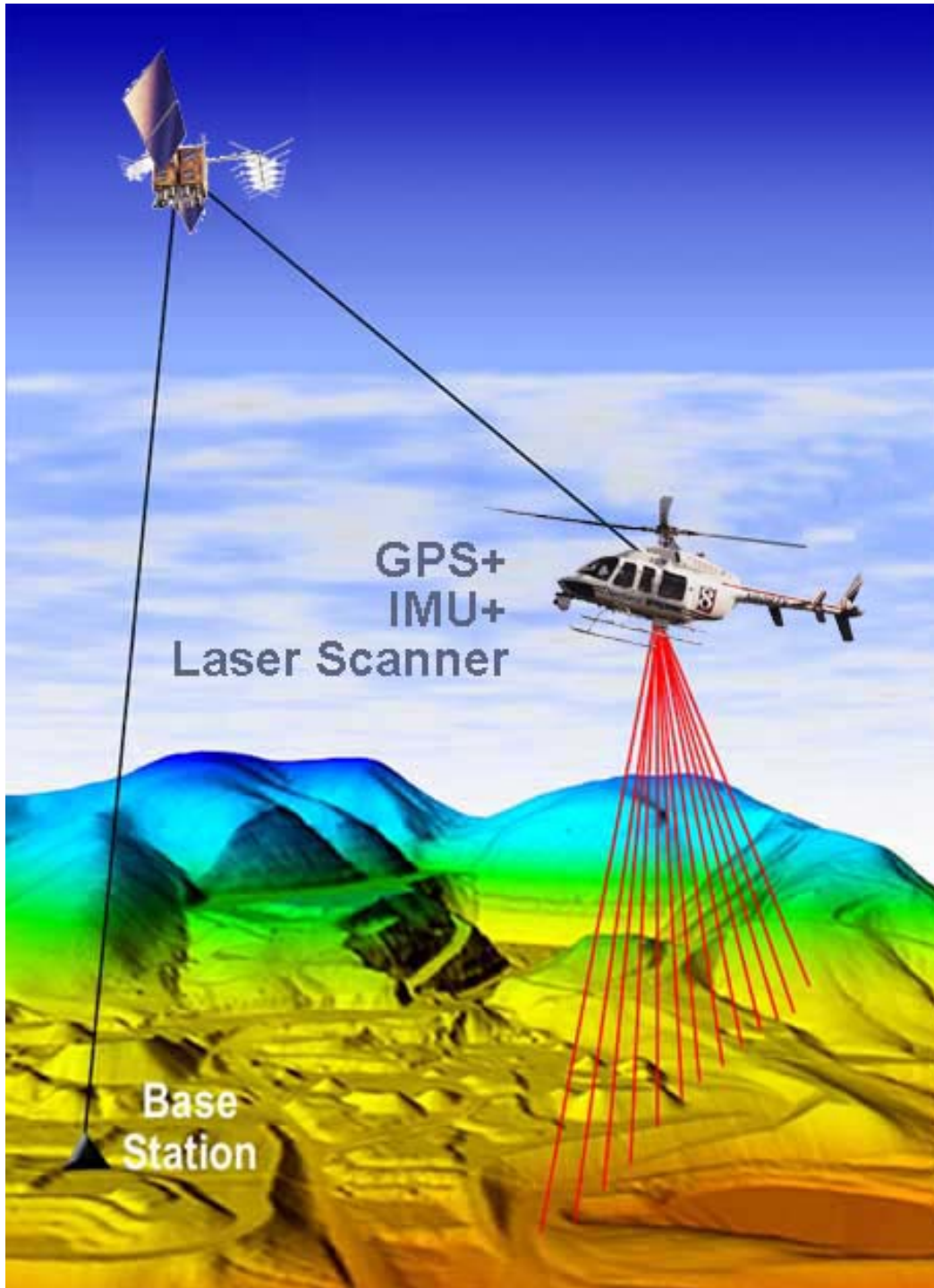
Needed data



Updated 3D survey Data

- Italy has a very dense population → practically every highway/freeway passes through many urban areas
- New buildings are erected even near existing highways → cartography is outdated already after a couple of years
- Building density in urban areas: up to 1.000 per square mile
- Available national data (like USGS in US) is outdated (>3years)
- Distances to be surveyed:
 - at least 820 ft per side from the roads
 - about 1800 ft overall
- Traditional survey too expensive and takes too long
- Aerial photogrammetry is very precise but takes long and is expensive
- An excellent compromise is a Lidar acquisition





Acquired data:

- Airborne laser ranger (distance)
- GPS (position)
- Inertial Unit (angles)

It is possible to obtain ground points directly in WGS84/UTM

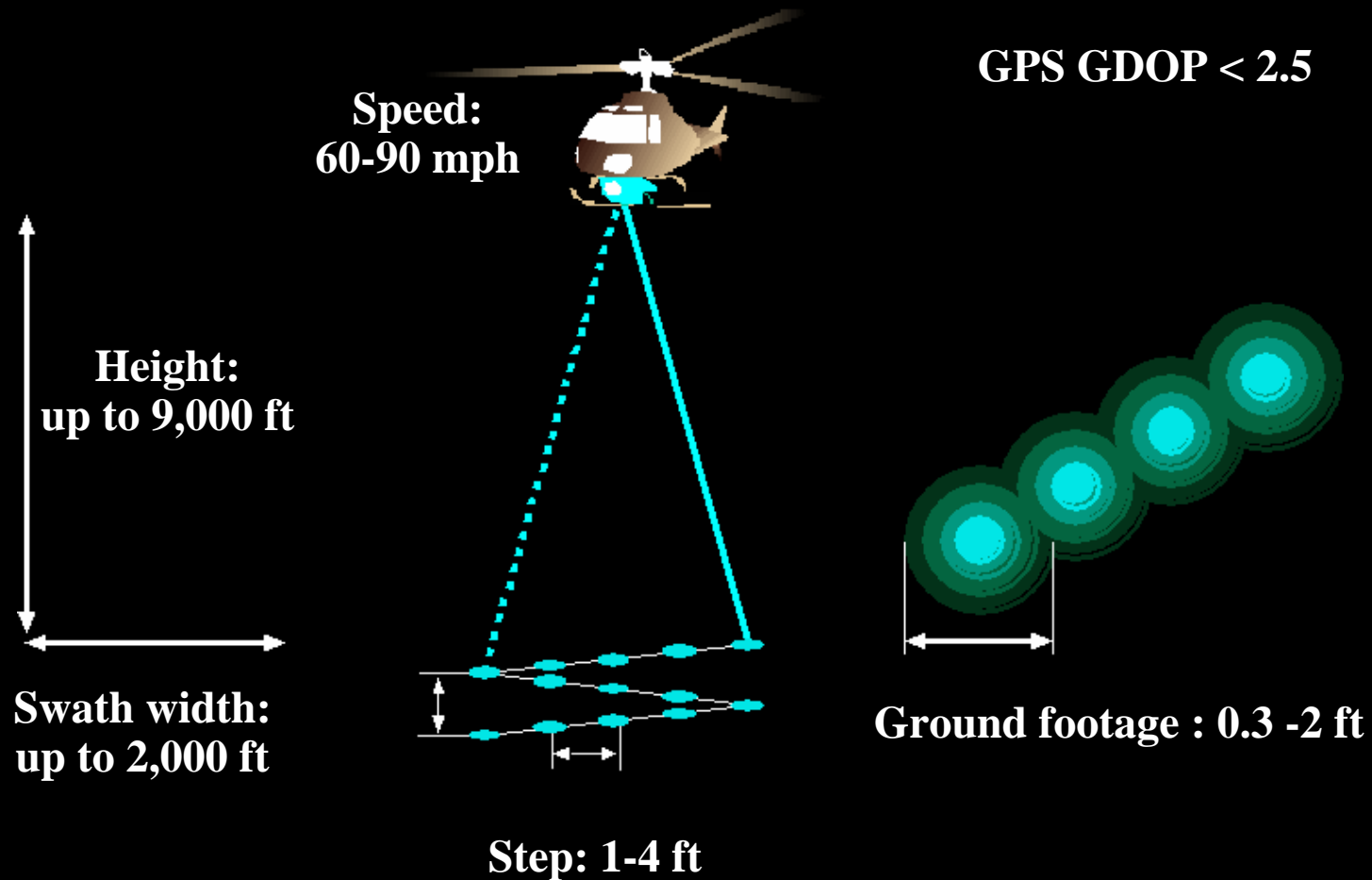


$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{\text{WGS84}} = \begin{bmatrix} \Delta x \\ \Delta y \\ \Delta z \end{bmatrix}_{\text{Antenna}} + R_{\text{WGS84}} R_E R_{\text{INS}} \left(\begin{bmatrix} \delta x \\ \delta y \\ \delta z \end{bmatrix} + R_A R_L \begin{bmatrix} 0 \\ 0 \\ -r \end{bmatrix} \right)$$



Lidar concepts

System specifications & typical performances

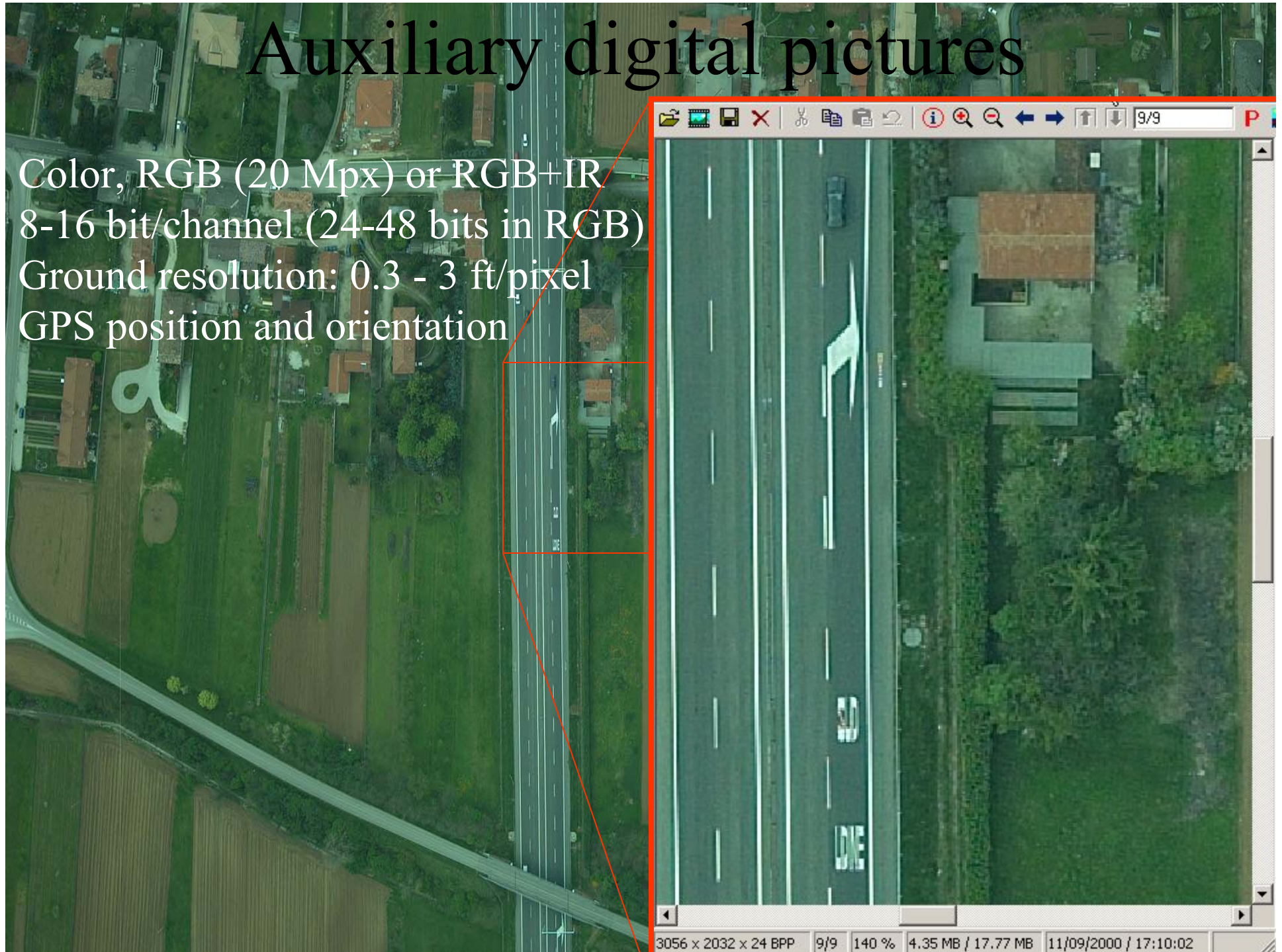


- Acquisition rate: up to 100,000 points per second
- Point density: 1 to 4+ pt/sqm (more points, higher costs)
- Point precision: 0.3-0.5 ft rms



Auxiliary digital pictures

Color, RGB (20 Mpx) or RGB+IR
8-16 bit/channel (24-48 bits in RGB)
Ground resolution: 0.3 - 3 ft/pixel
GPS position and orientation

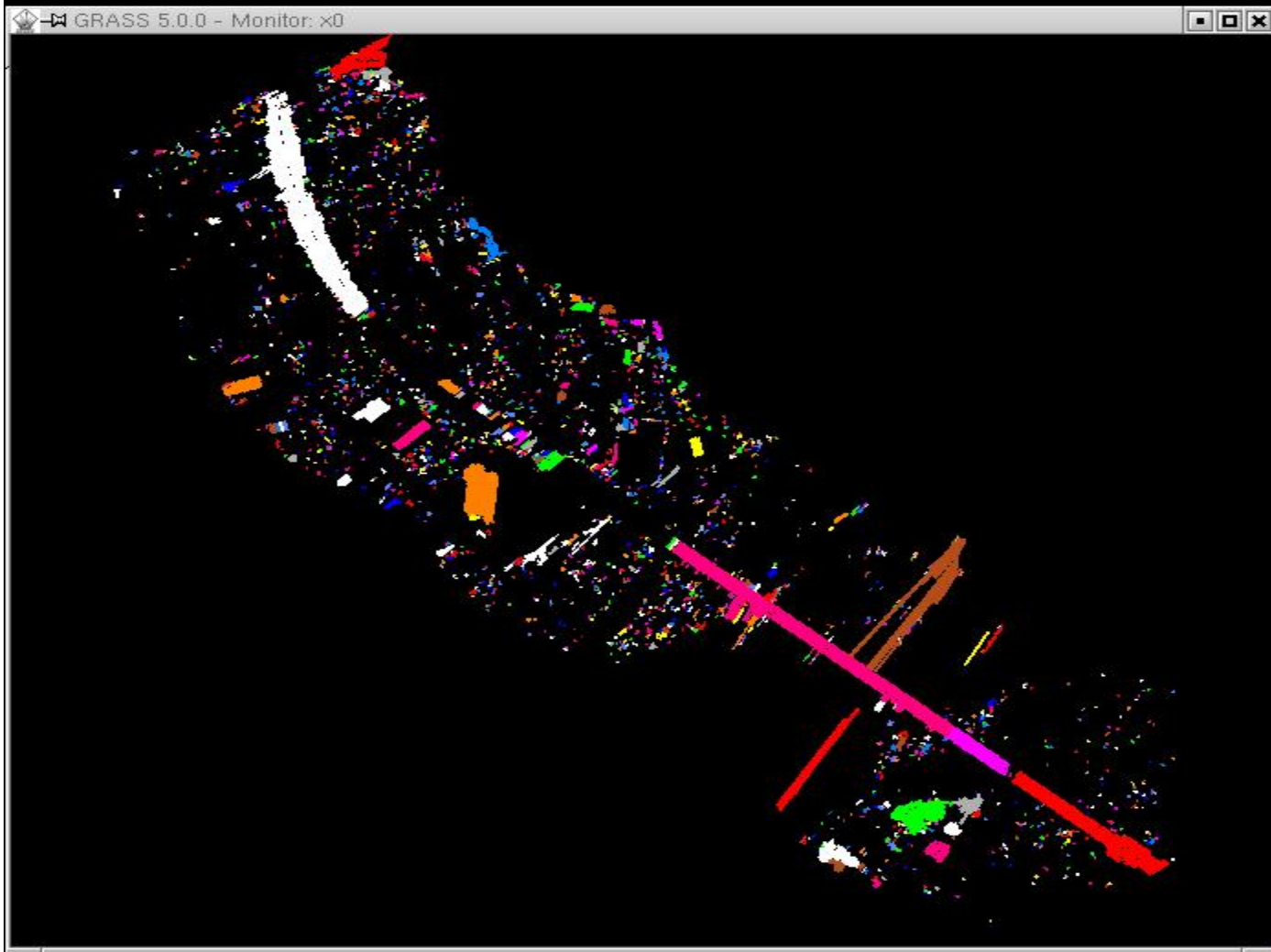


Raw data output

- About 1.5 mile
- About 2.5 million points



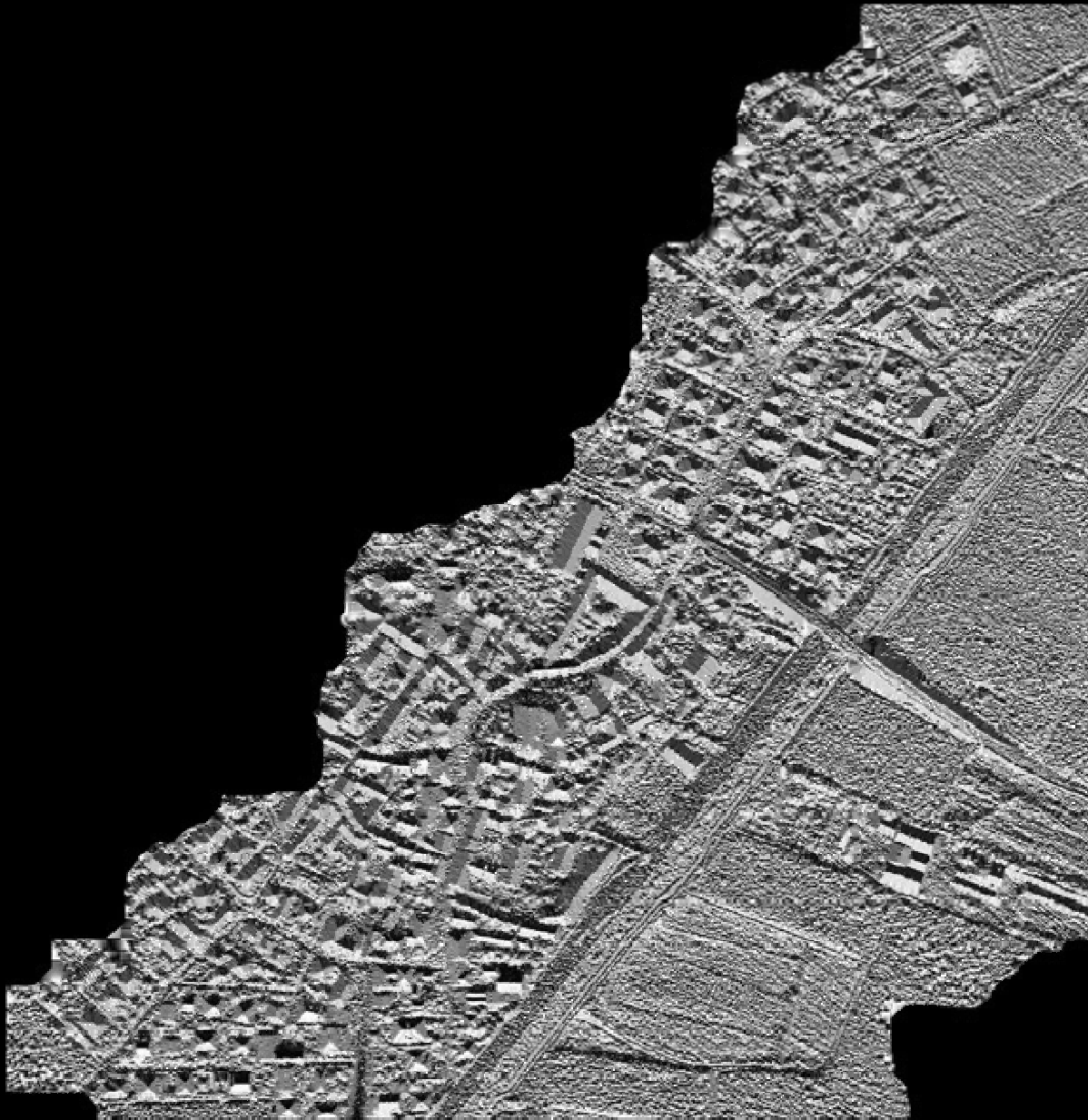
Object recognition



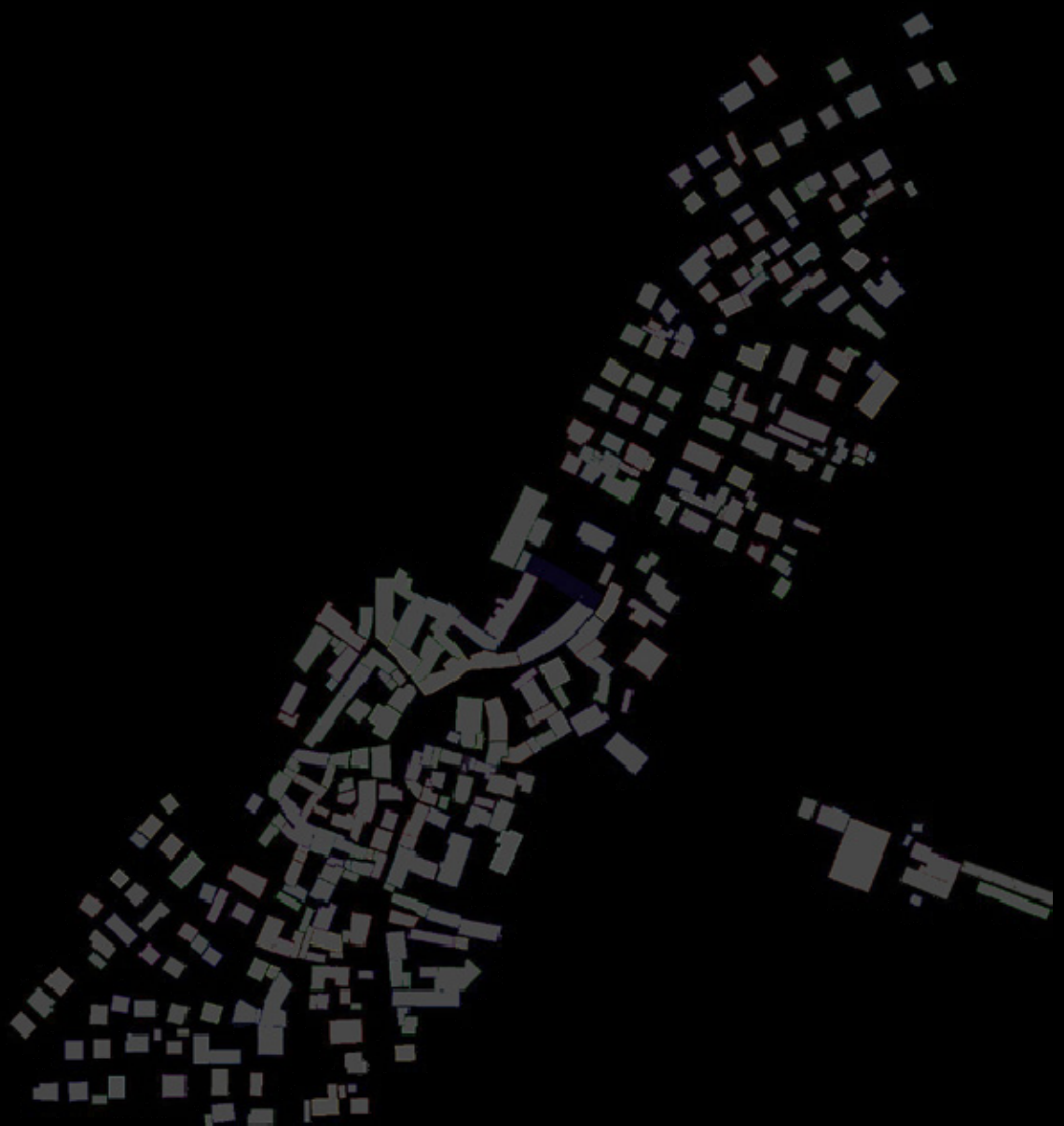
Edge detection

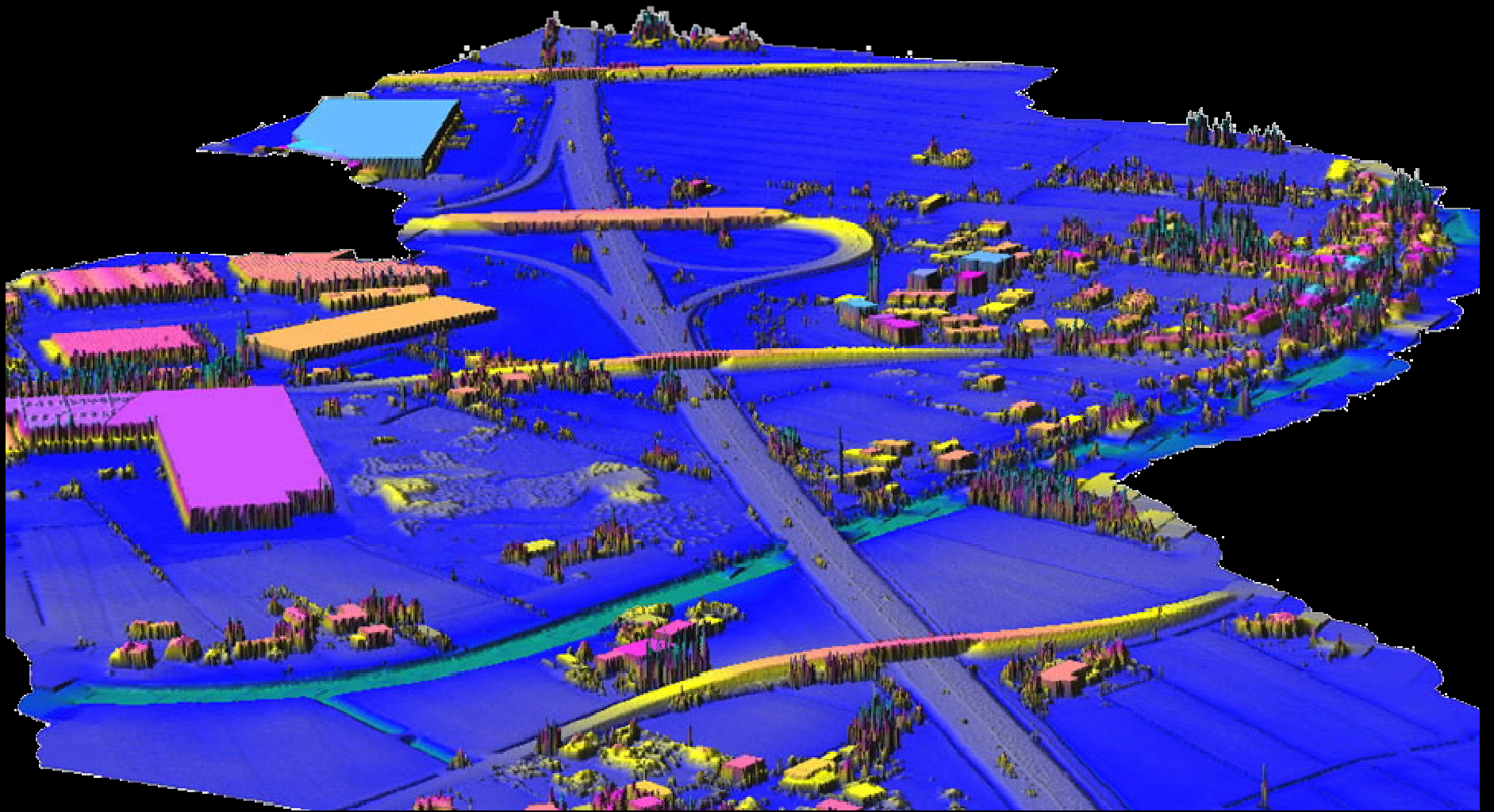


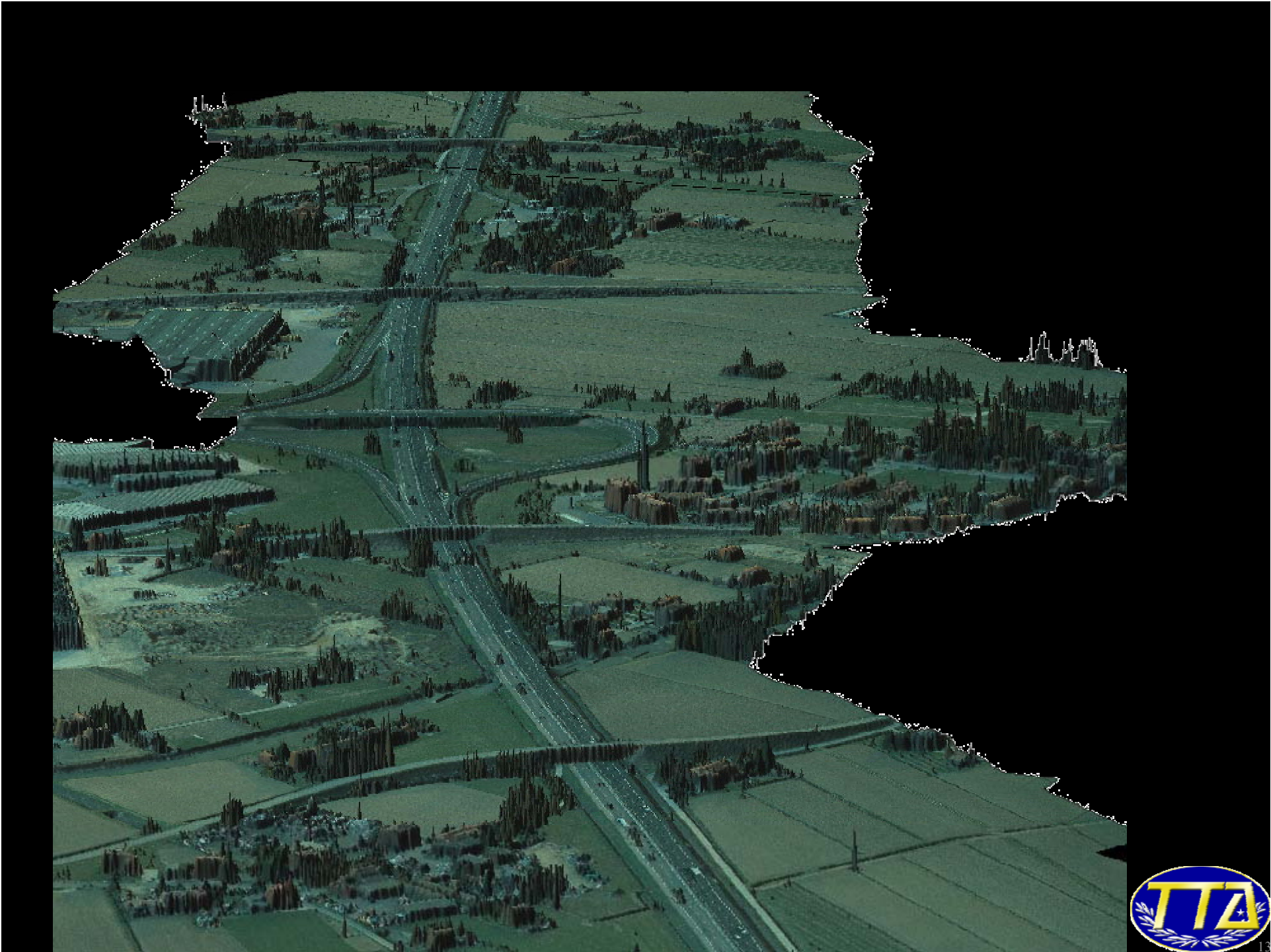
Aspects map

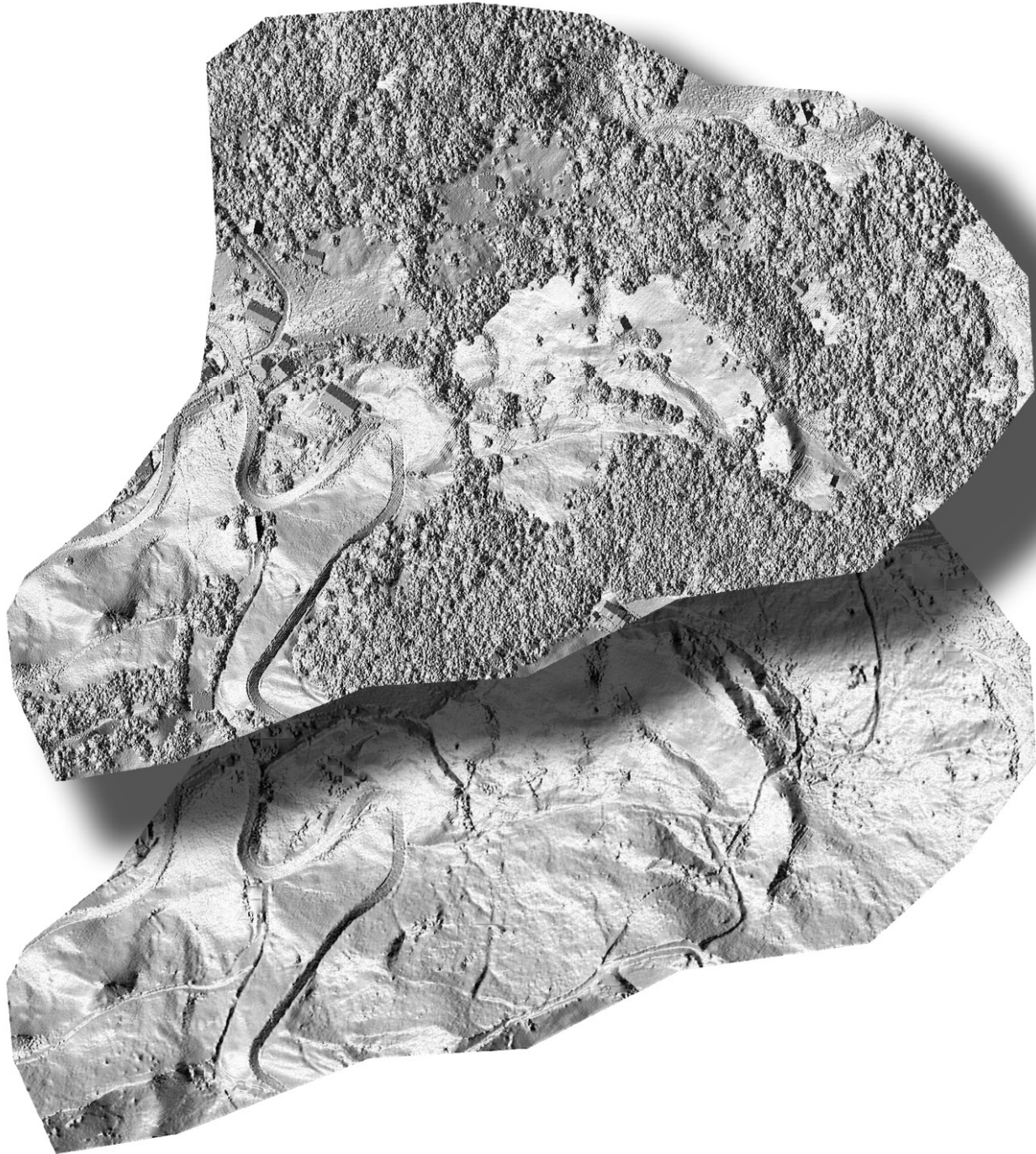


Building occupation

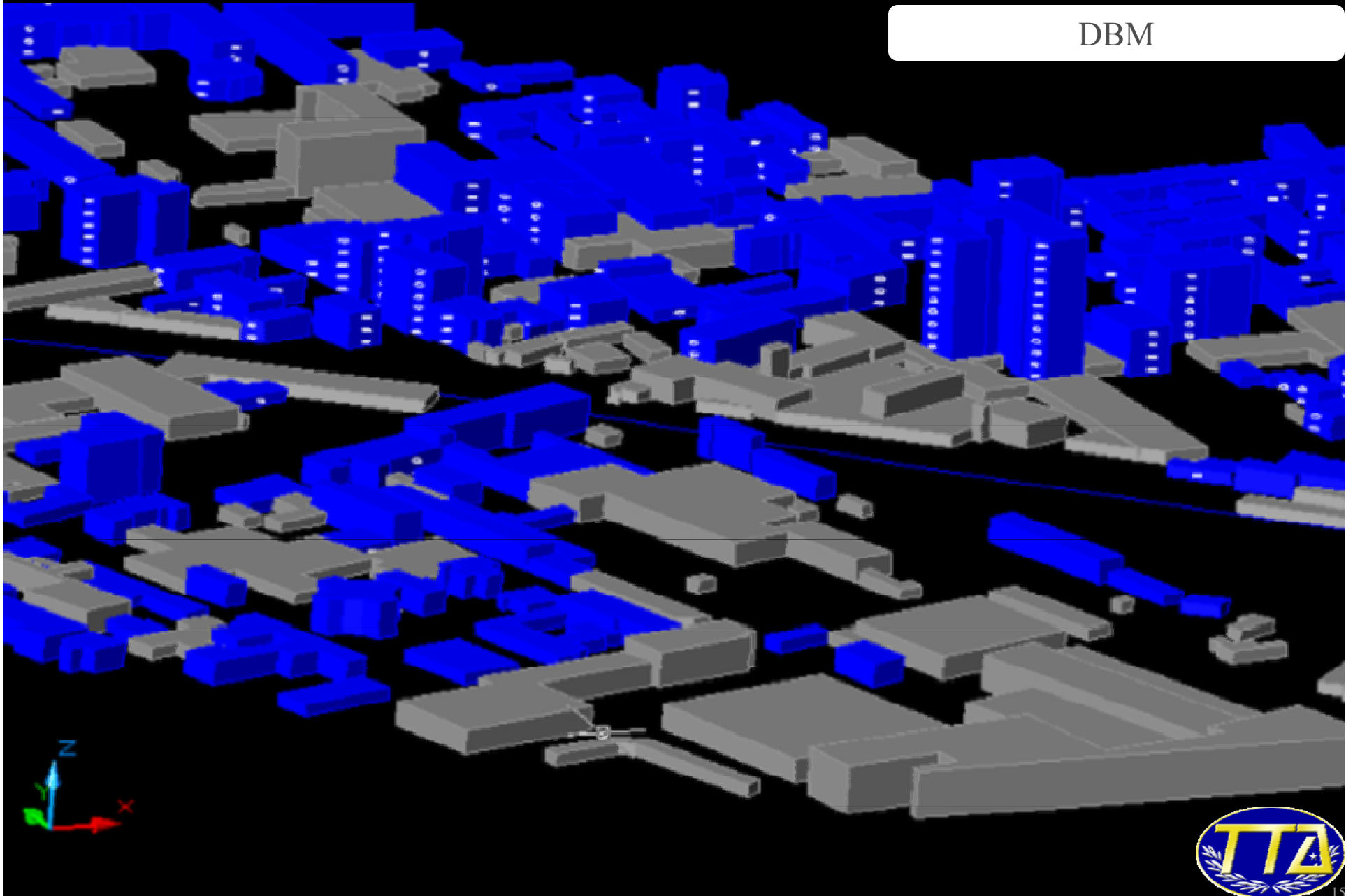




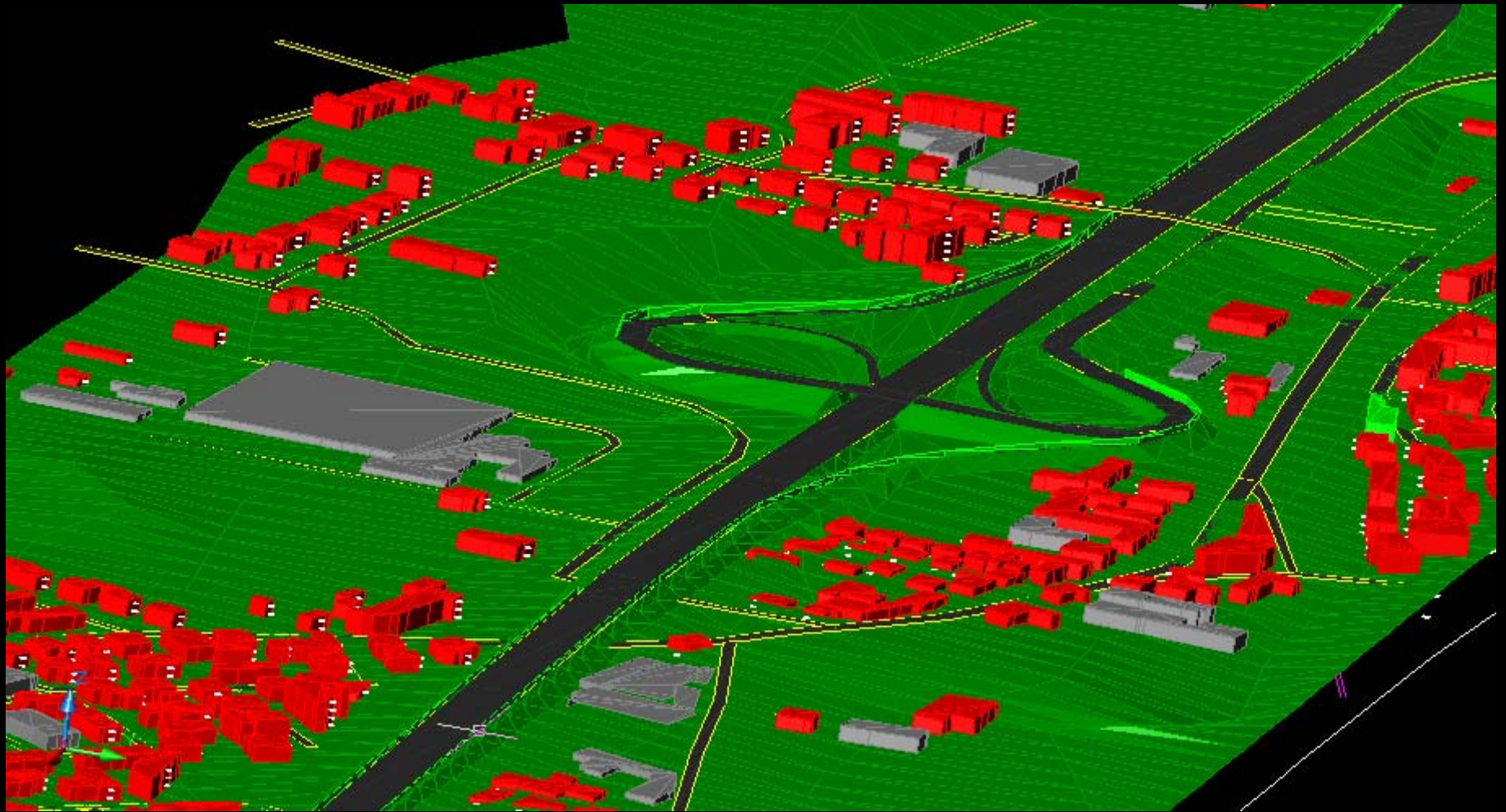




DBM



3D Output



Regulatory requirements

New roads

Road class	Width [ft]	Sensible receptors		Other receptors	
		Day [dBA]	Night [dBA]	Day [dBA]	Night [dBA]
A Toll highway	820	50	40	65	55
B Freeways	820	50	40	65	55
C Interstate - main	820	50	40	65	55
D Interstate - secondary	500	50	40	65	55
E Local - main	100	50	40	65	55
F Local	100	50	40	65	55

Width: always 1640 ft

Regulatory requirements

Existing roads

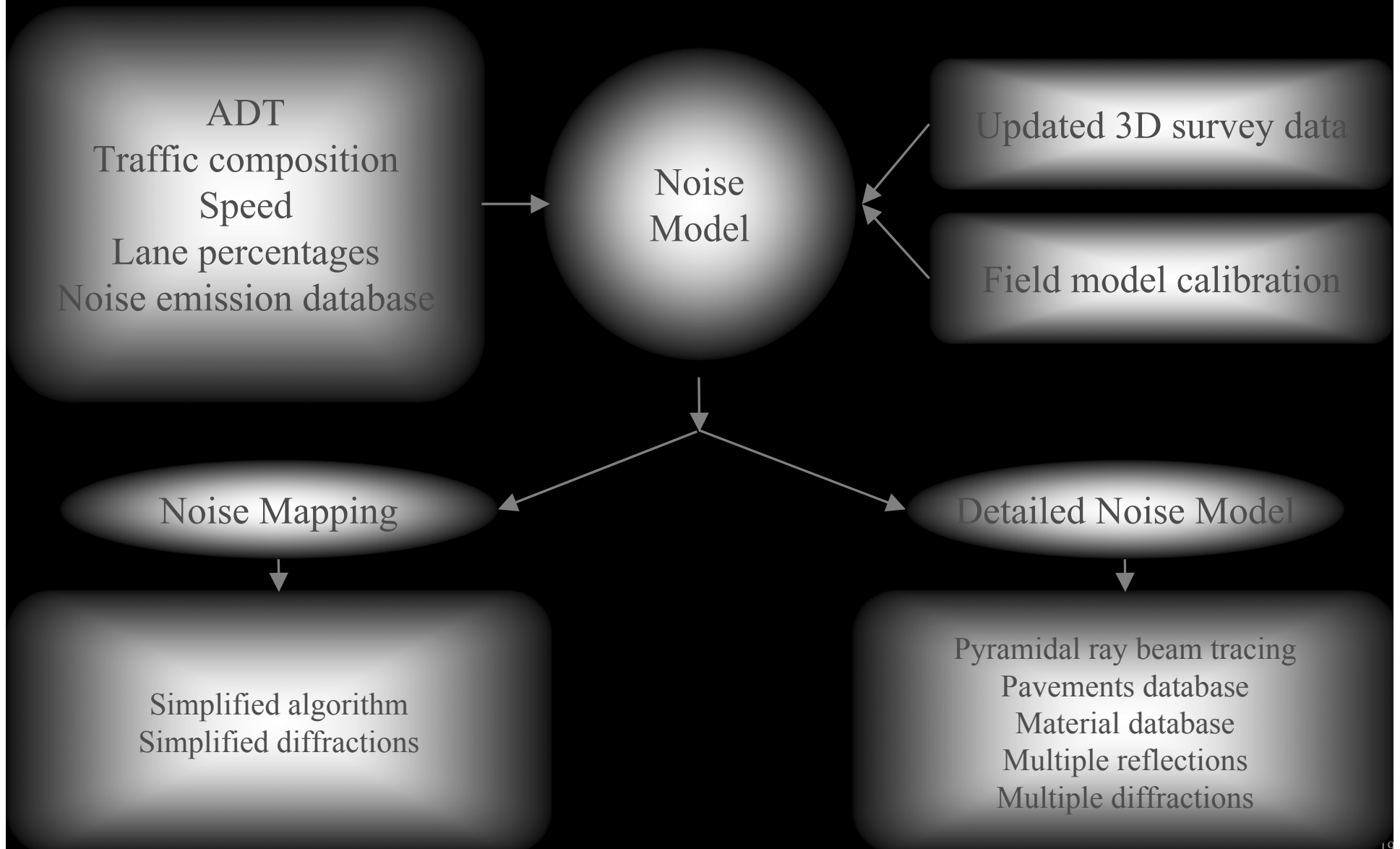
	Road class	Width [ft]	Sensible receptors		Other receptors	
			Day	Night	Day	Night
			[dBA]	[dBA]	[dBA]	[dBA]
A	Toll highway	280	50	40	70	60
		820			65	55
B	Freeways	280	50	40	70	60
		820			65	55
C	Interstate - main	280	50	40	70	60
		820			65	55
D	Interstate - secondary	280	50	40	70	60
		500			65	55
E	Local - main	100	50	40	65	55
F	Local	100	50	40	65	55

Width: always 1640 ft

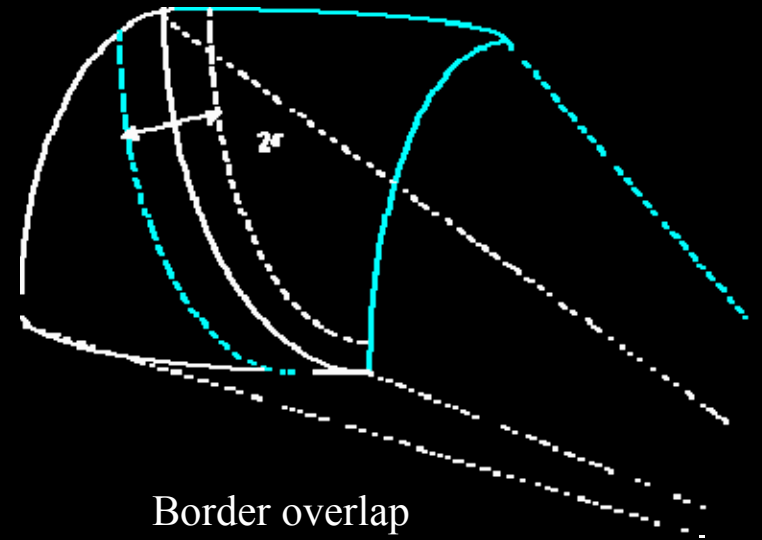
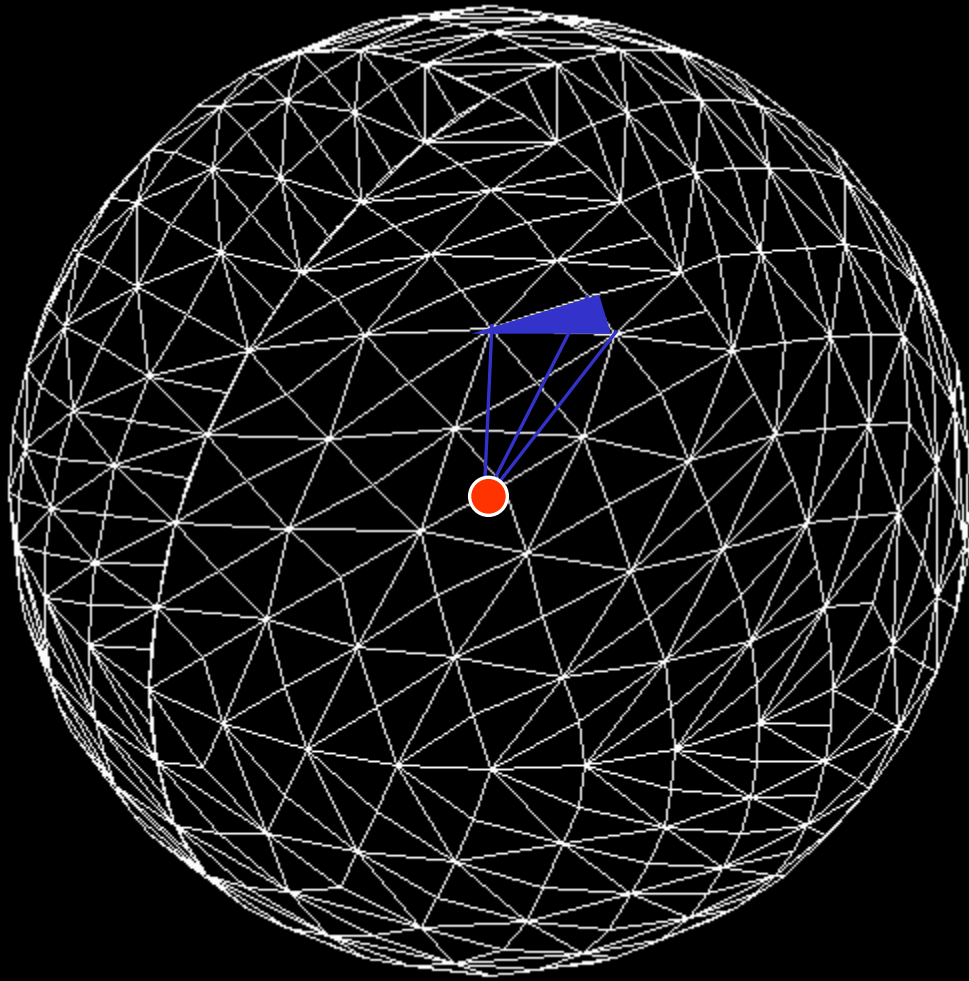


Noise modelling

Model Flowchart

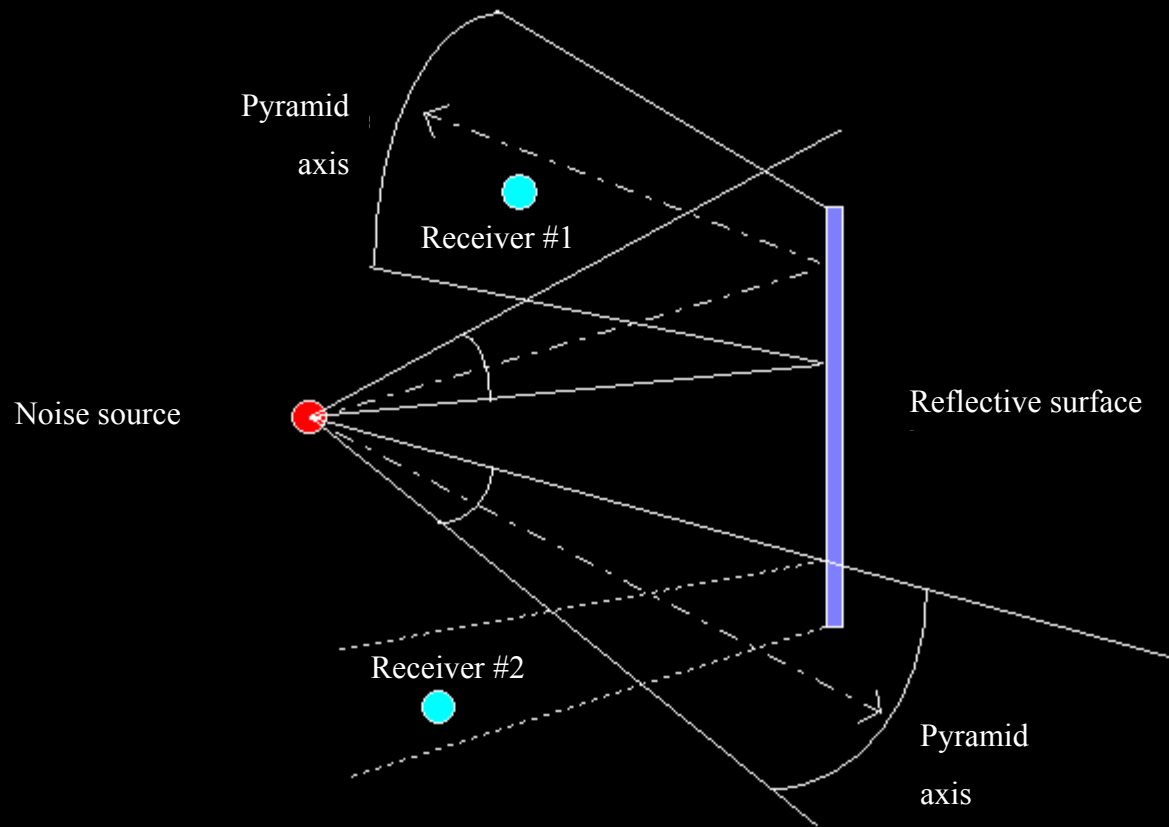


Noise sphere tassellation



Border overlap

Example



Editazione dati traffico ferroviario
 Editazione dati traffico stradale

Selezione Tratto Stradale
 Tratto n. Nome:

Leq,7.5m (G/M)
 Fisso Calcola

Proprietà
 Tipo di Pavimentazione

Pendenza [% + | -]

hmed edifici lato Sinistro

hmed edifici lato Destro

Data input

Traffico diurno comp

N.autovetture [V1]

N.camion 2 assi [V2]

N.camion 3 assi [V3]

N.TIR [V4]

N.motocicli [V5]

Traffico notturno con

N.autovetture [V1]

N.camion 2 assi [V2]

N.camion 3 assi [V3]

N.TIR [V4]

N.motocicli [V5]

Cat.A - Autostrada

Cat.C - Extraurb. se

Cat.E - Urbana quar

Material Manager 1.4 - Ramsete.mat

α R

N.	Frequency (Hz)	Color	31.5	63	125	250	500	1k	2k	4k	8k	16k
0	Nessuno	800000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	intonaco calce (s.r.)	008000	0.03	0.06	0.06	0.06	0.06	0.07	0.09	0.14	0.23	0.28
2	intonaco ruvido	808000	0.01	0.01	0.02	0.03	0.04	0.05	0.04	0.03	0.02	0.02
3	intonaco liscio	000080	0.01	0.02	0.02	0.02	0.03	0.04	0.04	0.03	0.02	0.02
4	int. calce fresco (T.R.)	800080	0.01	0.02	0.03	0.04						
5	int. calce maturo (T.R.)	008080	0.01	0.02	0.03	0.04						
6	int. calce degrad.(T.R.)	C0C0C0	0.03	0.05	0.06	0.07						
7	int. gesso liscio legno (P)	808080	0.02	0.03	0.04	0.05						
8	int. gesso liscio ferro	FF0000	0.01	0.01	0.02	0.03						
9	piastrelle stuccate (g)	00FF00	0.02	0.03	0.03	0.03						
10	legno di pino (C)	FFFF00	0.05	0.1	0.1	0.1						
11	legno verniciato (g)	0000FF	0.06	0.11	0.11	0.12						
12	legno compensato (C)	FF00FF	0.06	0.11	0.11	0.11						
13	pavimento legno poroso	400040	0.01	0.02	0.03	0.04						
14	pavimento legno duro	800000	0.05	0.09	0.09	0.1						
15	pavimento marmo (B)	008000	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.06
16	pavimento moquette (B)	808000	0.03	0.05	0.05	0.05	0.1	0.2	0.3	0.59	0.5	0.6
17	pavimento moquette (C)	000080	0.03	0.07	0.08	0.1	0.2	0.25	0.3	0.35	0.36	0.43
18	pavimento gomma (B)	800080	0.0	0.01	0.02	0.04	0.05	0.05	0.1	0.05	0.05	0.06
19	pavimento linoleum (m)	008080	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.05	0.06	0.07
20	pavimento in cemento (g)	C0C0C0	0.01	0.01	0.01	0.03	0.05	0.02	0.02	0.02	0.02	0.02
21	pavimento sughero cerato (C)	808080	0.02	0.03	0.04	0.03	0.05	0.11	0.07	0.02	0.01	0.01
22	tende velluto a 20 cm (C/B)	FF0000	0.01	0.03	0.08	0.29	0.44	0.5	0.4	0.35	0.28	0.34
23	tende velluto tese (C)	00FF00	0.01	0.02	0.05	0.12	0.35	0.45	0.38	0.36	0.36	0.43
24	Unita' ass.ti poltrona in cuoio (P)	FFFF00	0.08	0.16	0.2	0.25	0.29	0.31	0.29	0.25	0.22	0.26
25	tappezz. stoffa (B)	0000FF	0.01	0.02	0.03	0.04	0.11	0.17	0.24	0.35	0.42	0.5

DisiaPyr Launcher

C:\DISIA\CARTOGRA\PIPP0.RAY

Level:

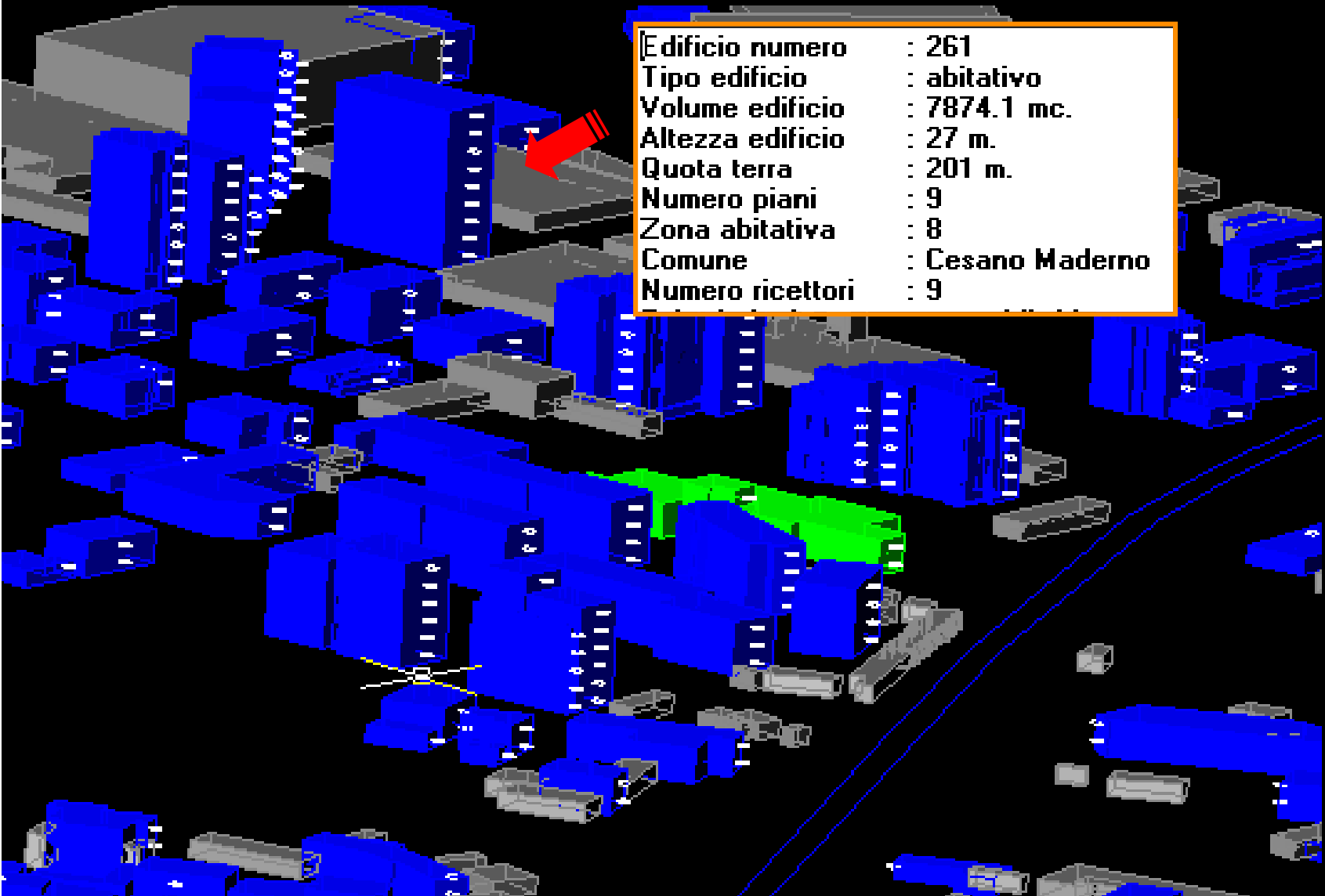
Time (s):

Humidity (%):

LOD: 2^N



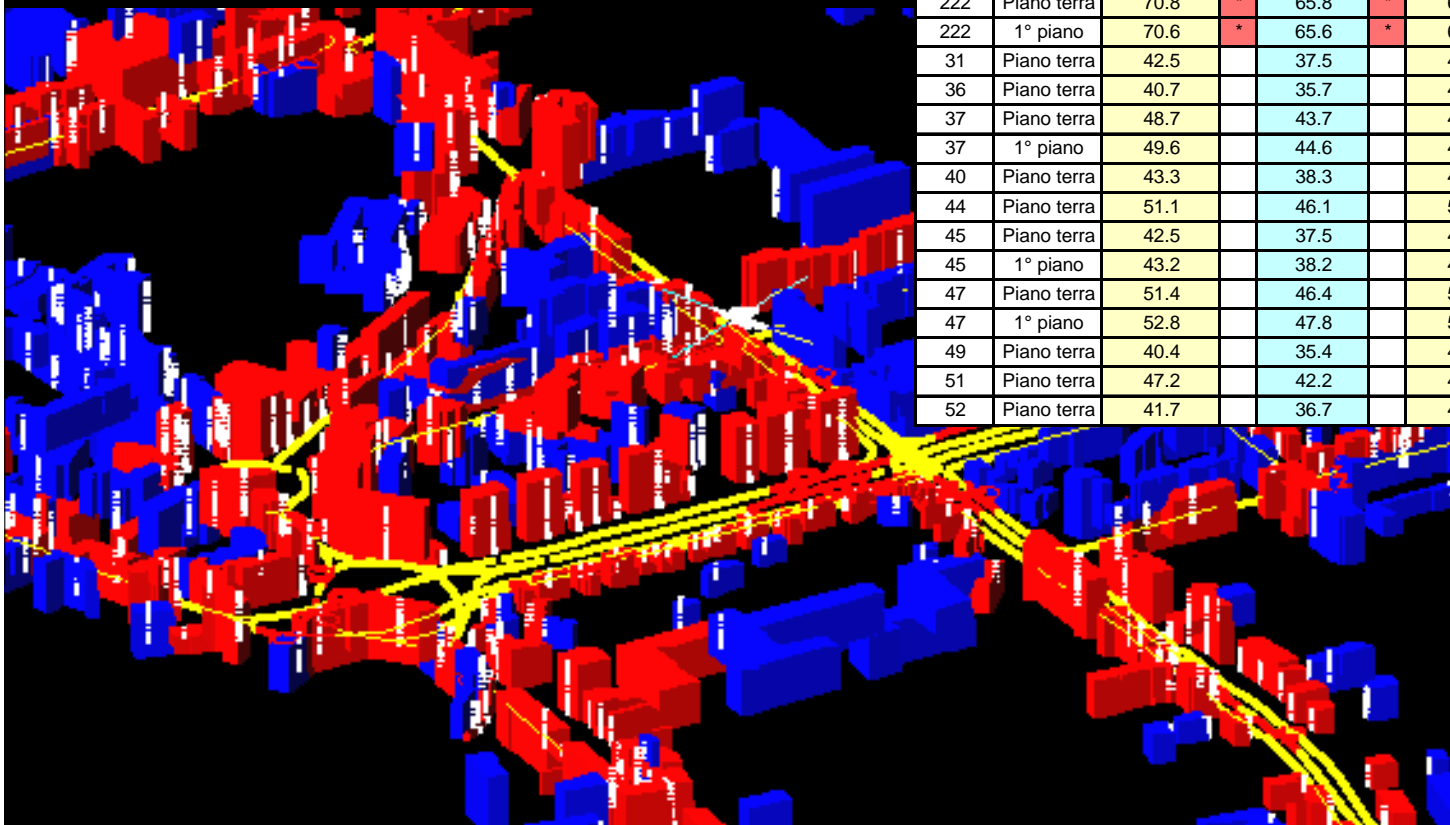
3D Data & associated database

A 3D perspective view of a city model where buildings are represented as blue rectangular blocks. A red arrow points from a specific building to a white data popup box with a black border. The popup box contains a list of attributes for that building. The rest of the city model is visible in the background, showing a dense urban layout.

Edificio numero	: 261
Tipo edificio	: abitativo
Volume edificio	: 7874.1 mc.
Altezza edificio	: 27 m.
Quota terra	: 201 m.
Numero piani	: 9
Zona abitativa	: 8
Comune	: Cesano Maderno
Numero ricettori	: 9

Overexposed buildings

Casa n.	Piano n.	A] - Situazione attuale [dB(A)]			B] - Situazione post interventi di bonifica [dB(A)]			Efficacia interventi di bonifica acustica	
		day	night		day	night		day	night
174	2° piano	66.8	61.8	*	58.0	53.0		8.8	8.8
180	Piano terra	54.4	49.4		50.2	45.2		4.2	4.2
180	1° piano	54.8	49.8		51.2	46.2		3.6	3.6
182	Piano terra	66.2	61.2	*	56.1	51.1		10.1	10.1
182	1° piano	67.8	62.8	*	56.9	51.9		10.9	10.9
183	Piano terra	67.5	62.5	*	52.2	47.2		15.3	15.3
184	Piano terra	69.5	64.5	*	62.0	57.0		7.5	7.5
184	1° piano	69.6	64.6	*	63.0	58.0		6.6	6.6
192	Piano terra	62.4	57.4		48.3	43.3		14.1	14.1
201	Piano terra	77.8	72.8	*	69.5	64.5	*	8.3	8.3
210	Piano terra	60.4	55.4		48.3	43.3		12.1	12.1
210	1° piano	60.4	55.4		49.7	44.7		10.7	10.7
212	Piano terra	69.2	64.2	*	63.5	58.5		5.7	5.7
212	1° piano	69.0	64.0	*	65.4	59.6		3.6	4.4
214	Piano terra	61.7	56.7		49.6	44.6		12.1	12.1
214	1° piano	63.5	58.5		50.5	45.5		13.0	13.0
214	2° piano	63.9	58.9		51.7	46.7		12.2	12.2
222	Piano terra	70.8	65.8	*	61.2	56.2		9.6	9.6
222	1° piano	70.6	65.6	*	63.7	58.7		6.9	6.9
31	Piano terra	42.5	37.5		42.4	37.4		0.1	0.1
36	Piano terra	40.7	35.7		40.6	35.6		0.1	0.1
37	Piano terra	48.7	43.7		48.7	43.7		0.0	0.0
37	1° piano	49.6	44.6		49.6	44.6		0.0	0.0
40	Piano terra	43.3	38.3		43.2	38.2		0.1	0.1
44	Piano terra	51.1	46.1		51.1	46.1		0.0	0.0
45	Piano terra	42.5	37.5		42.4	37.4		0.1	0.1
45	1° piano	43.2	38.2		42.8	37.8		0.4	0.4
47	Piano terra	51.4	46.4		51.4	46.4		0.0	0.0
47	1° piano	52.8	47.8		52.8	47.8		0.0	0.0
49	Piano terra	40.4	35.4		40.3	35.3		0.1	0.1
51	Piano terra	47.2	42.2		47.1	42.1		0.1	0.1
52	Piano terra	41.7	36.7		41.7	36.7		0.0	0.0



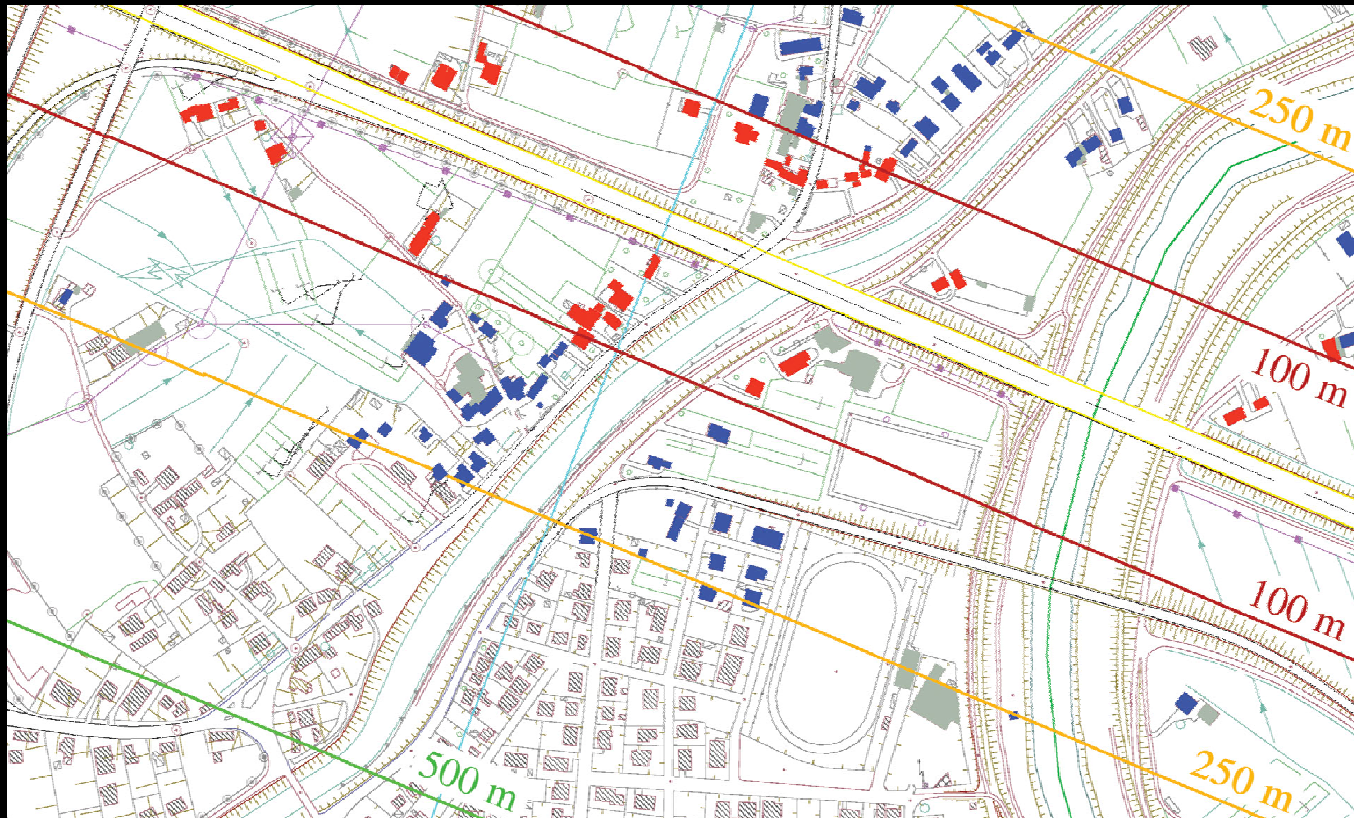
Definition

$$p = \sum_{i=1}^n R_i (L_i - L_i^*)$$

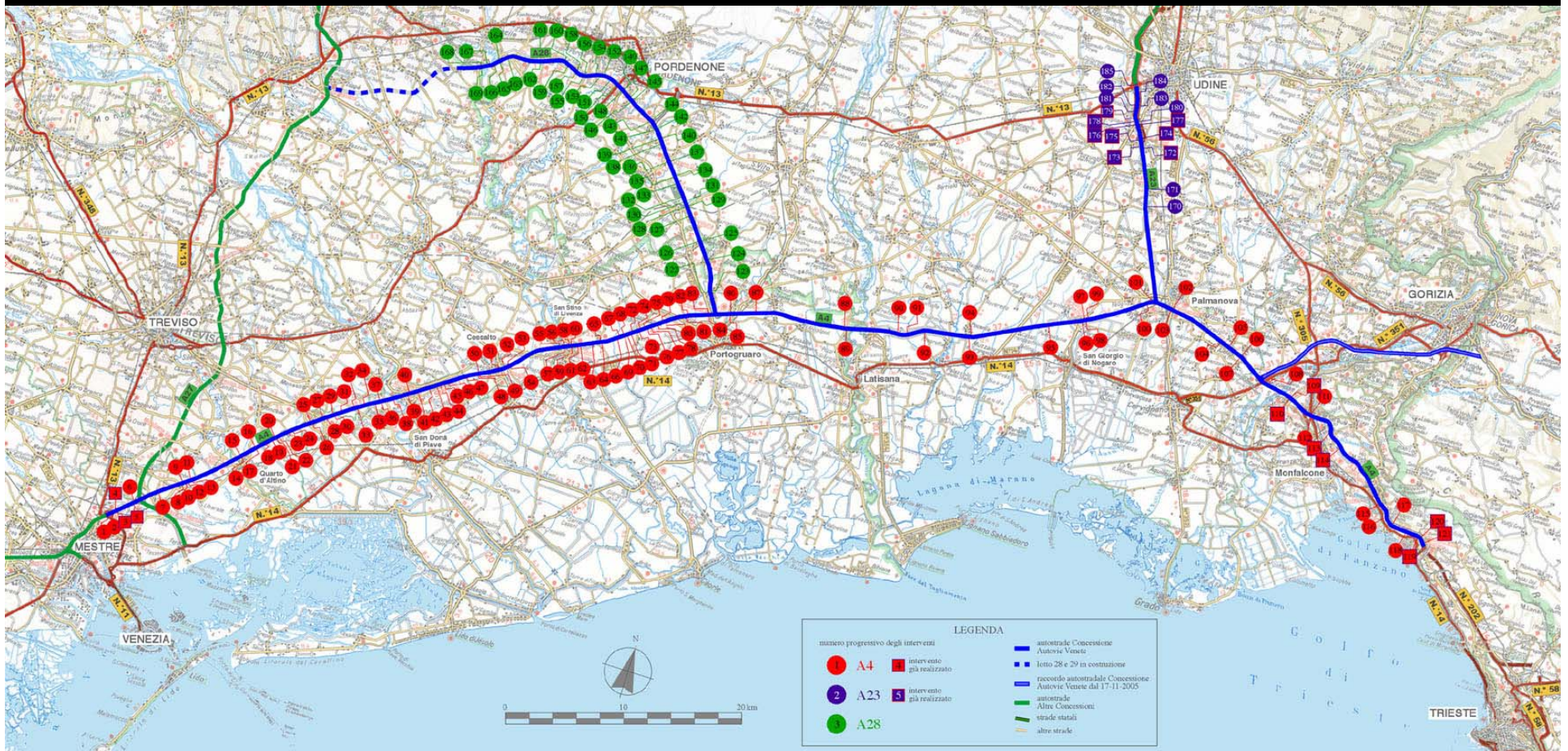
R_i: Exposed inhabitants

L_i: measured/calculated level

L_i*: regulatory limit



An Example Mapping



Conclusions

- Lidar survey for noise modelling: fast response, accurate data
- Delivery times, from scratch: first 100 mi in 1-2 months (depending on atmospheric conditions)
- Useful decision support for identifying –numerically- where to invest to maximize effects
- Regulatory complaint
-
- Effectively maximizes benefits for the population

Open issues....

How do we protect the **drivers**.....



..... from **shouting**???





THE END





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