

Antelope User Group meeting
DPC– via Vitorchiano 2-4 - Rome – Italy
May 18th to 20th , 2016

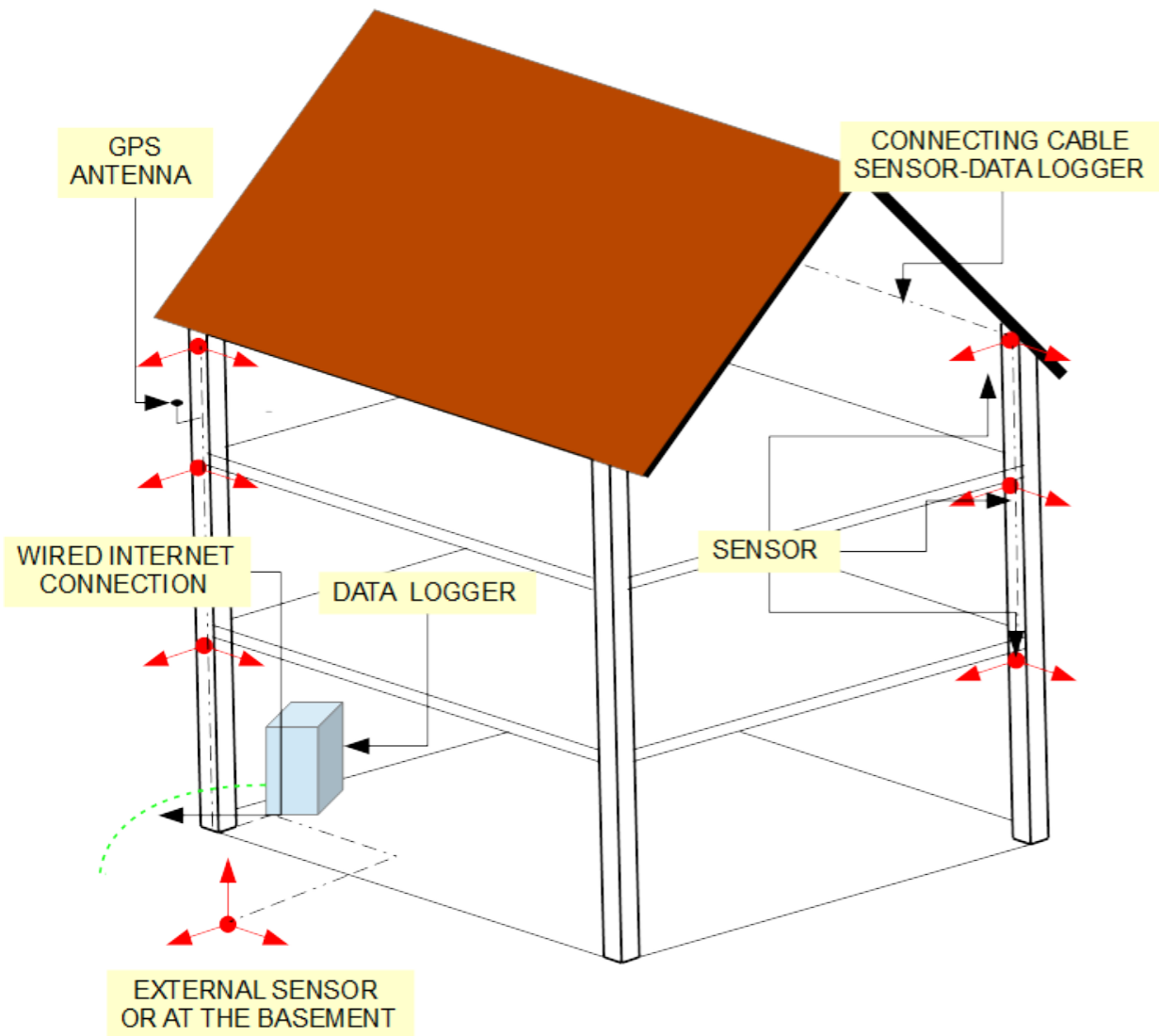
The data processing methodology for the Seismic Observatory of Structures (OSS)

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DPC - Ufficio Rischio Sismico e Vulcanico

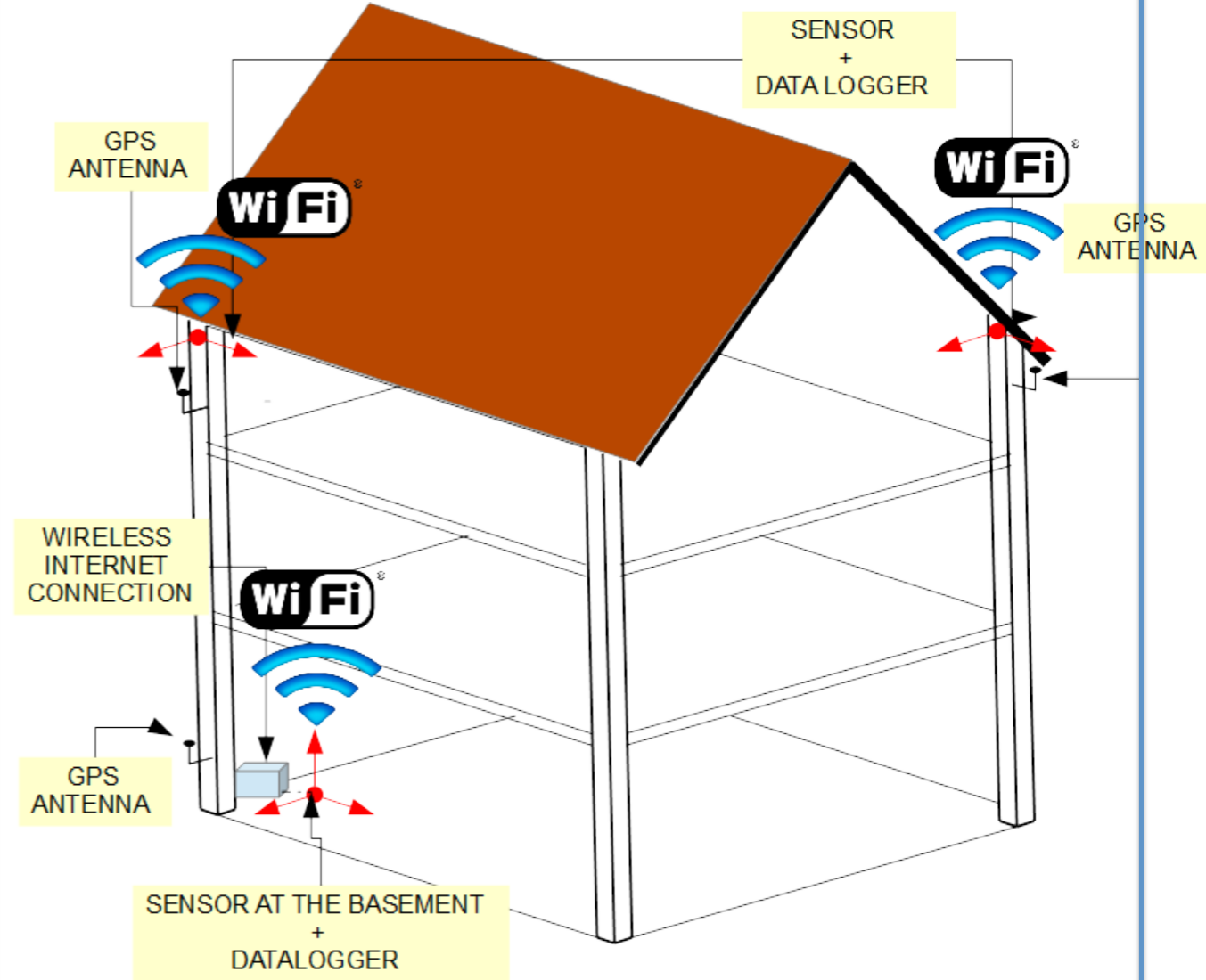


PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

REGULAR SYSTEM



SIMPLIFIED SYSTEM



1	2	3	4	5				
01BSP	52.191503	4.437122	1632-11-24	20.04.92	200			
3.8743931e-03	-8.4208961e-03	-2.4543166e-03	-1.2642465e-03	5.6984715e-04	-7.2909788e-03	4.5393888e-05		
			2e-02	1.3075165e-02	2.7256368e-03	5.5629192e-03	-5.4485236e-03	
			9e-03	-7.0927009e-03	3.6888095e-03	-7.6397307e-03	1.4763563e-02	
			0e-04	-2.3740677e-03	4.7733740e-03	-2.8840886e-03	-2.6538937e-02	
-6.1524317e-03					2.1934384e-02	6.7433474e-03	4.0792846e-03	
-8.0011416e-04					9.9033149e-03	2.5938775e-03	-5.0230192e-03	
-5.1193688e-03					3.5239656e-03	-1.4513076e-04	5.6955206e-03	
2.5128608e-03	1.1745325e-02	1.3518000e-02	1.0604001e-02	3.7312762e-03	2.8215008e-03	7.4488088e-03		
1.3413209e-02	-4.4472550e-03	-4.4018000e-03	1.0604001e-02	3.4016340e-03	-1.2487075e-02	-1.3497211e-02		
1.1483816e-02	-1.5367450e-02	6.9918000e-03	1.0604001e-02	5.2637182e-03	-1.1566966e-02	-4.4760717e-03		
8.4346570e-03	8.7818530e-03	1.1895218e-02	-4.4550068e-03	8.9594336e-03	-4.0243450e-03	-3.8927556e-03		
5.3316086e-04	4.0949641e-03	-1.1469688e-02	8.1000000e-03	2.1934384e-02	2e-04	5.4530746e-03		
2.5608789e-04	1.3006505e-03	-5.1248876e-03	-2.8000000e-03	5.6984715e-04	5e-03	-1.0030253e-02		
1.0316055e-03	1.0396552e-02	1.6591833e-02	1.1000000e-02	1.1000000e-02	1e-02	1.7867002e-02		
2.0520973e-02	2.6477959e-03	2.5463687e-04	-1.2967042e-03	2.0520973e-02	1e-04	1.5000001e-04		
1.5777538e-02	1.1154310e-02	-1.7512771e-03	6.0841853e-03	1.5777538e-02	7e-03	1.5000001e-04		
-1.6523360e-02	8.7424354e-03	-3.4731337e-03	-6.3596745e-03	-1.6523360e-02	5e-04	1.5000001e-04		
-5.2322456e-03	-8.0463774e-03	5.1638285e-03	1.0850228e-02	4.9788496e-03	-4.8081883e-03	-2.3262332e-03		
-2.1691209e-03	-1.2393558e-02	-1.2114368e-02	2.7696255e-03	3.4091863e-03	8.6695957e-03	-4.1274587e-03		
9.8547843e-03	-1.2718203e-02	-7.0134576e-03	6.6418445e-03	5.0983160e-03	-1.6606248e-02	-7.2705851e-03		
5.2946441e-03	1.2869550e-02	2.7300299e-02	-1.2217335e-02	-1.6627345e-02	-1.4853159e-02	-6.7022325e-03		
-3.3841209e-03	-6.0912599e-04	1.2929575e-02	-2.5013692e-03	-4.3794712e-03	-1.2324700e-02	1.7286698e-03		
-4.2107481e-03	4.0477285e-03	-1.9389971e-03	1.3911031e-03	6.2697148e-03	-4.1175517e-03	1.1007231e-02		
-7.8600719e-03	-5.3657383e-03	-6.0281872e-03	9.1816957e-04	6.9126012e-03	8.6154316e-03	-1.9285540e-02		
-1.1608380e-03	7.8230579e-03	-2.8204376e-03	2.1401748e-02	1.5897284e-02	-1.9812361e-02	-1.2866881e-03		

1. Station short name

2. Geographic Coordinates

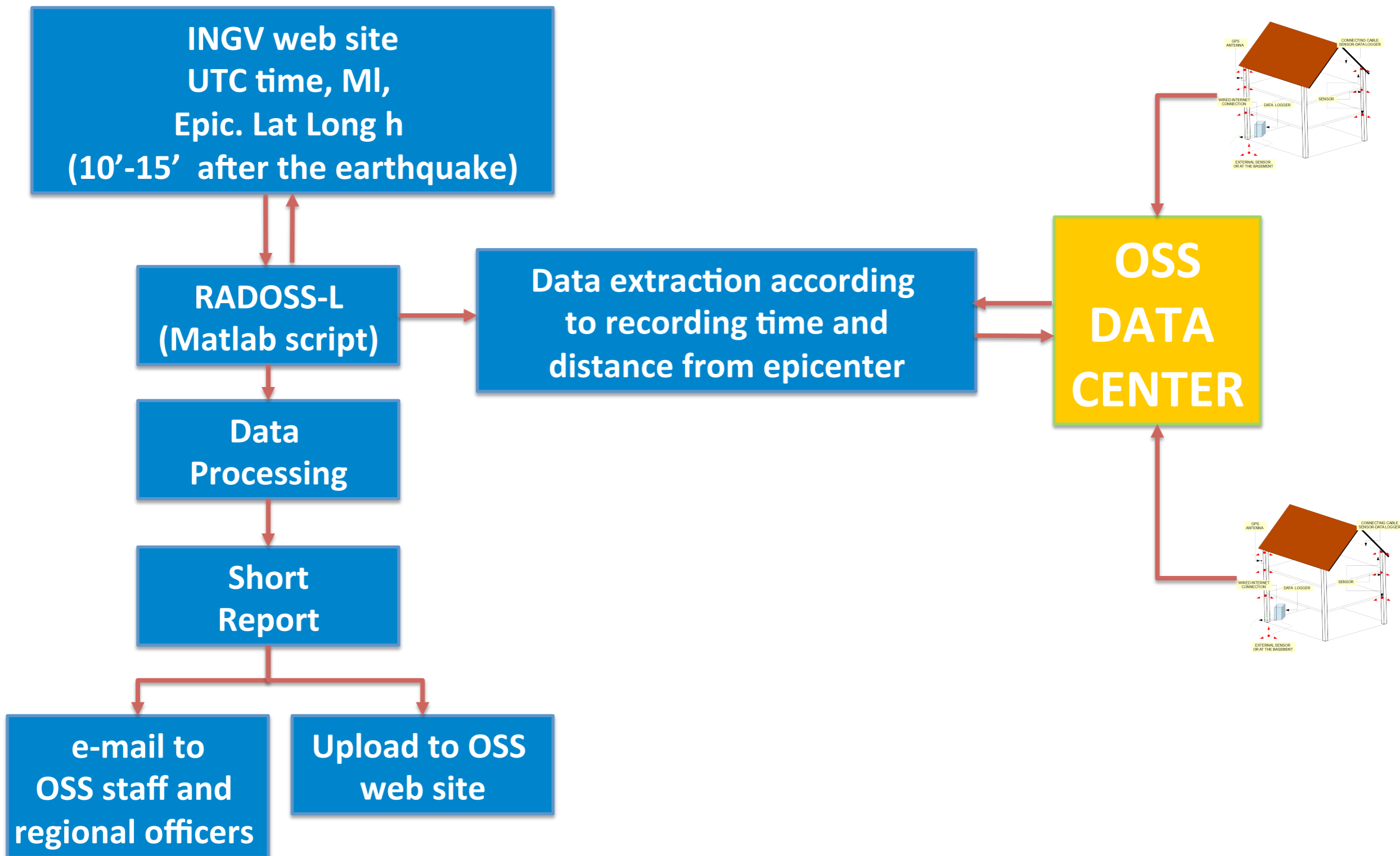
3. Trigger Date

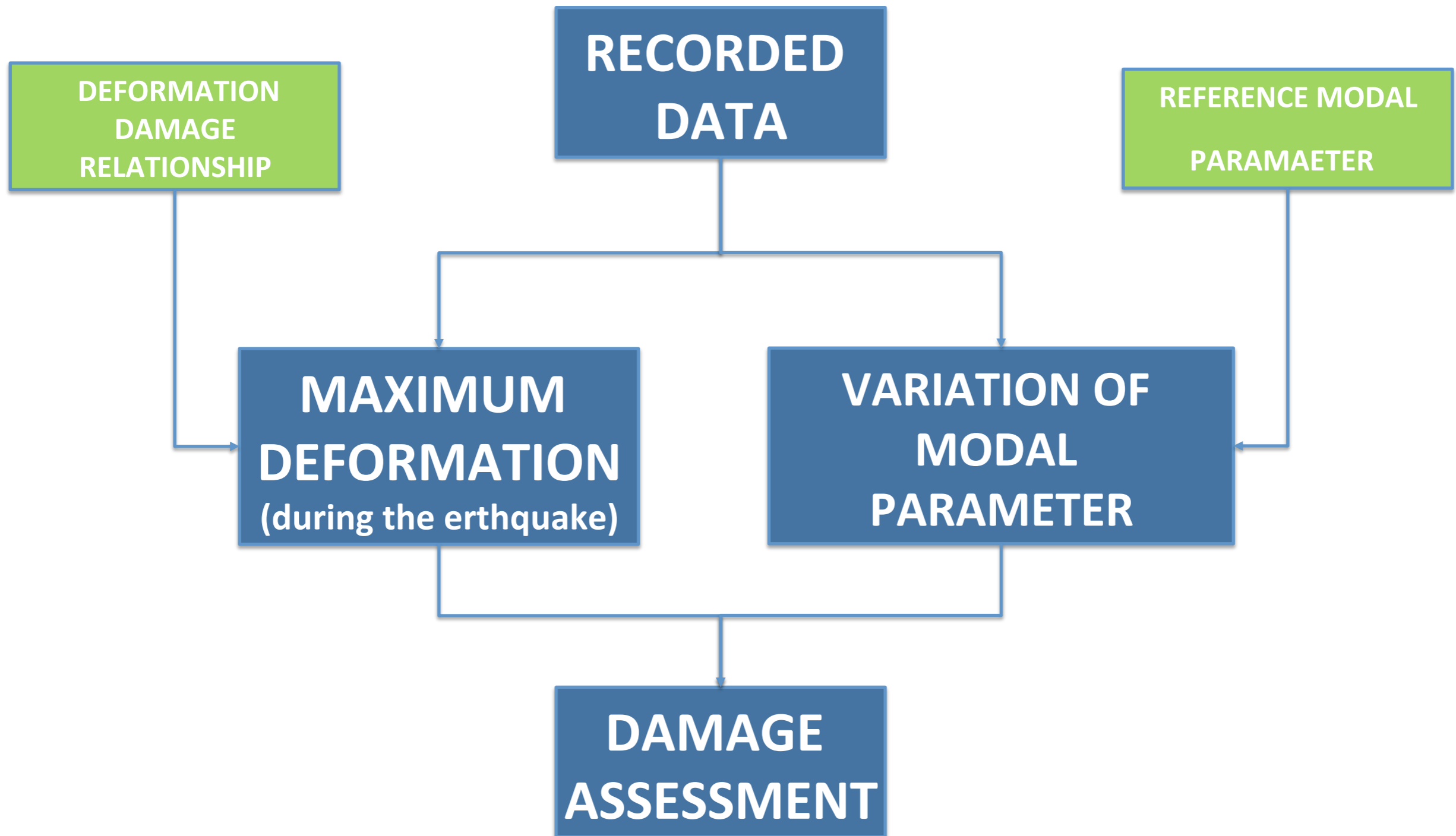
4. Trigger UTC Time

5. Sampling Frequency

6

6. Recorded physical signal



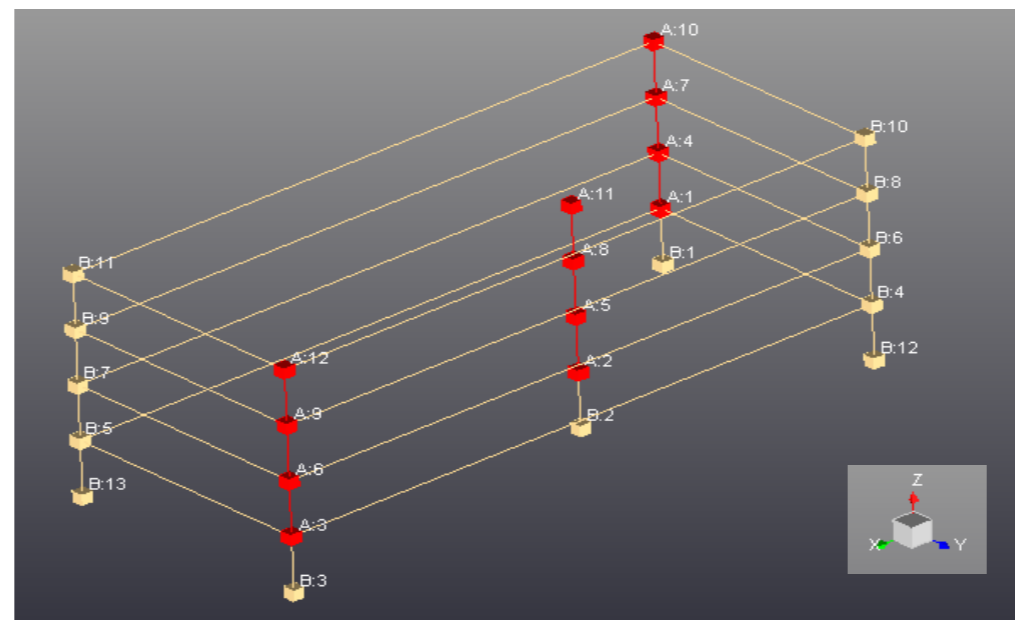




Hospital of Sanremo



sensors layout (red)



Channel vs dof

	Response DOF
1	A:1:+X
2	A:1:+Y
3	A:2:+Y
4	A:3:+X
5	A:3:+Y
6	A:4:+X
7	A:4:+Y
8	A:5:+Y
9	A:6:+X
10	A:6:+Y
11	A:7:+X
12	A:7:+Y
13	A:8:+Y
14	A:9:+X
15	A:9:+Y
16	A:10:+X
17	A:10:+Y
18	A:11:+Y
19	A:12:+X
20	A:12:+Y

Coordinates of the measurement points

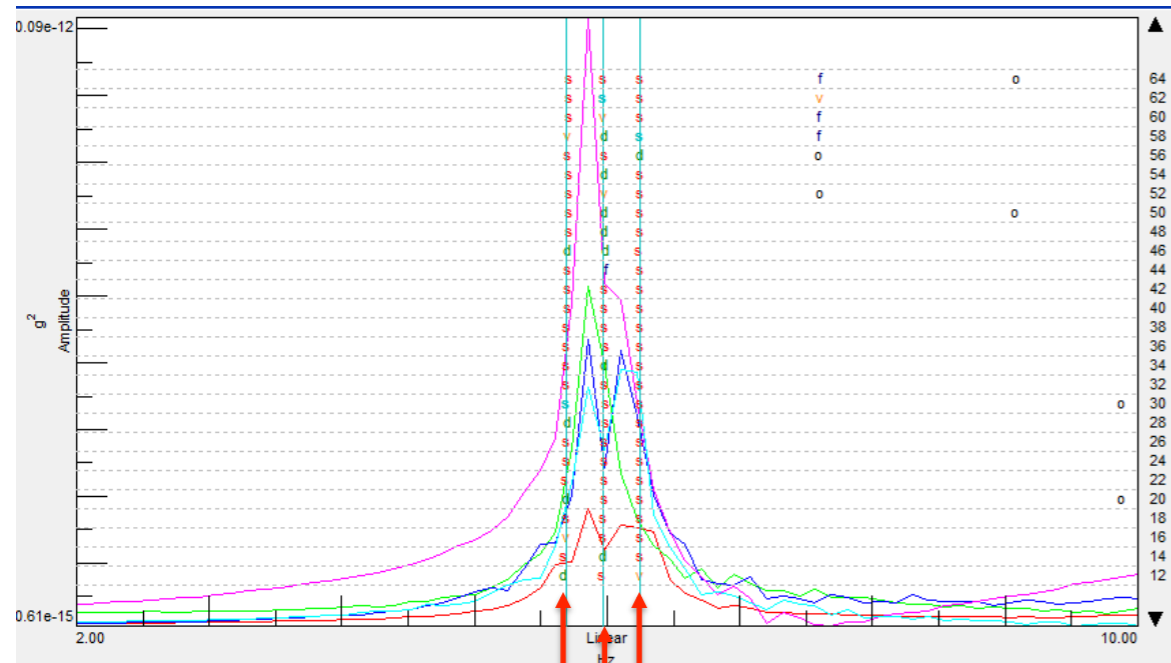
	Parent Comp...	Name	Full Name	X (m)	Y (m)	Z (m)	XY (°)	XZ (°)	YZ (°)
1	A	1	A:1	0.0000	0.0000	3.5000	0.0000	0.0000	0.0000
2	A	2	A:2	15.0000	11.0000	3.5000	0.0000	0.0000	0.0000
3	A	3	A:3	37.0000	15.2000	3.5000	0.0000	0.0000	0.0000
4	A	4	A:4	0.0000	0.0000	7.0000	0.0000	0.0000	0.0000
5	A	5	A:5	15.0000	11.0000	7.0000	0.0000	0.0000	0.0000
6	A	6	A:6	37.0000	15.2000	7.0000	0.0000	0.0000	0.0000
7	A	7	A:7	0.0000	0.0000	10.5000	0.0000	0.0000	0.0000
8	A	8	A:8	15.0000	11.0000	10.5000	0.0000	0.0000	0.0000
9	A	9	A:9	37.0000	15.2000	10.5000	0.0000	0.0000	0.0000
10	A	10	A:10	0.0000	0.0000	14.0000	0.0000	0.0000	0.0000
11	A	11	A:11	15.0000	11.0000	14.0000	0.0000	0.0000	0.0000
12	A	12	A:12	37.0000	15.2000	14.0000	0.0000	0.0000	0.0000
13	A		A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
14	A		A	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

ambient vibrations



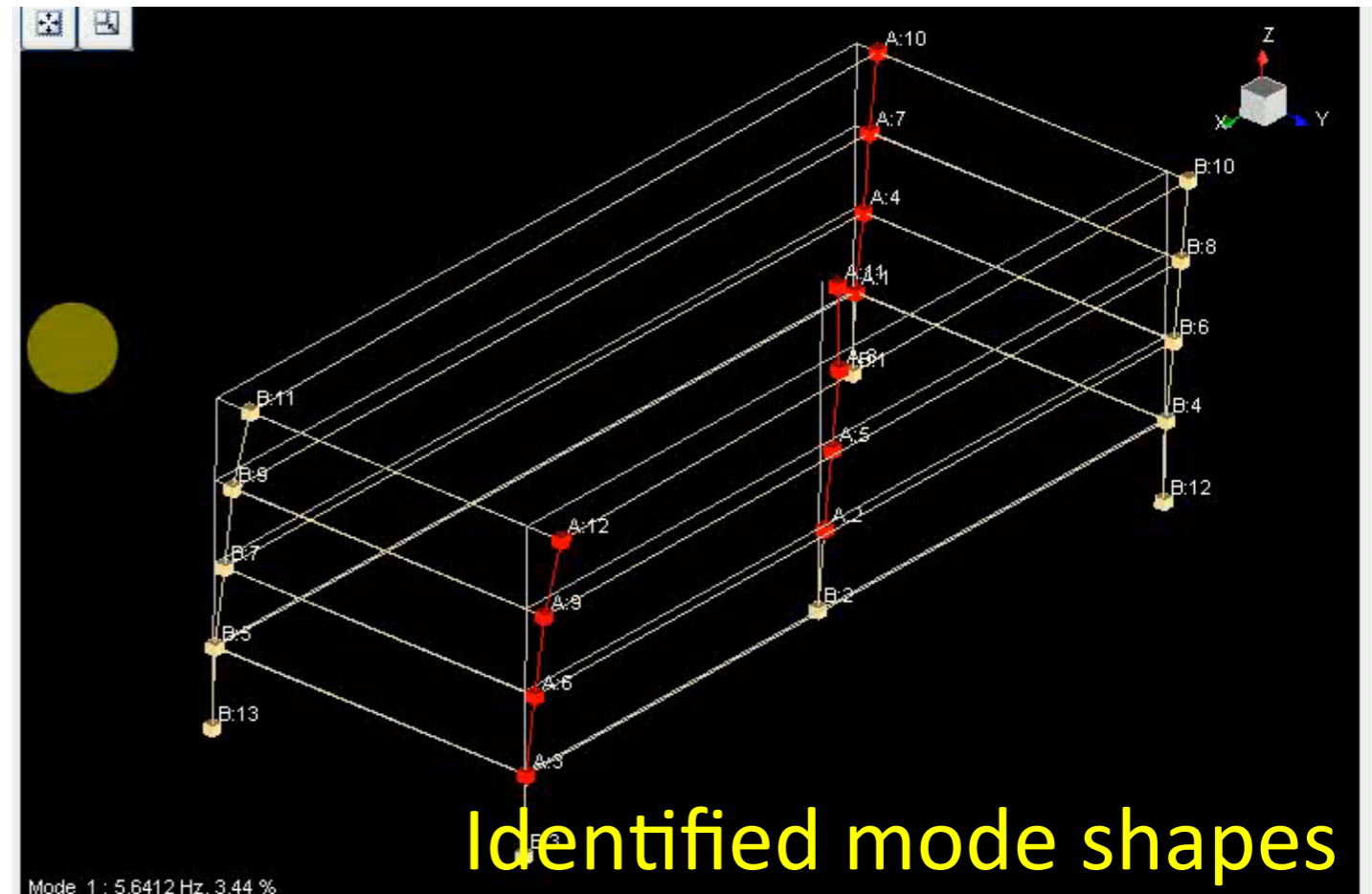
modal parameters

cross-spectra



stable poles

- Mode 1 : 5.696 Hz, 2.82 % s
- Mode 2 : 5.970 Hz, 1.89 % s
- Mode 3 : 6.249 Hz, 1.53 % s



Damage indexes based on modal parameter variation

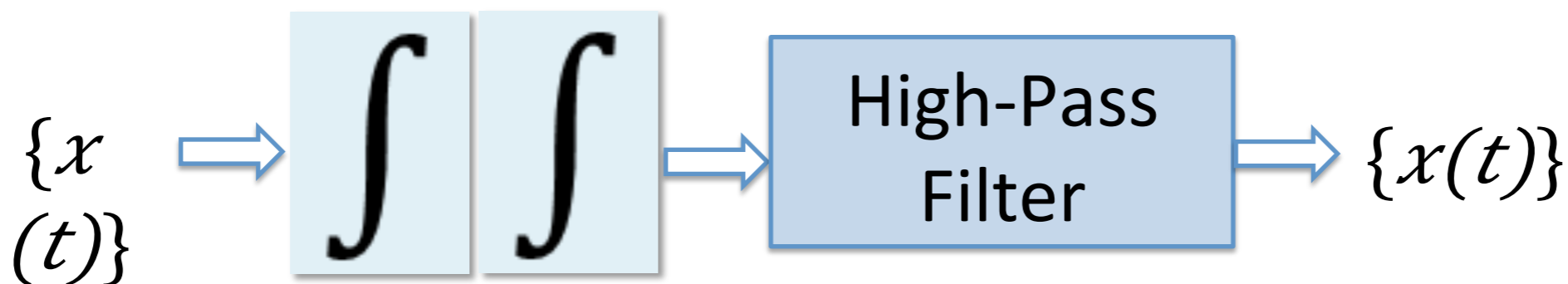
Percentage Frequency Change

$$\frac{\Delta f_k}{f_k} = \frac{f_k^d - f_k}{f_k}$$

Modal Assurance Criterion

$$MAC_k(\phi_k, \phi_k^d) = \frac{\langle \phi_k, \phi_k^d \rangle^2}{\langle \phi_k, \phi_k \rangle \langle \phi_k^d, \phi_k^d \rangle}$$

FROM ACCELERATION TO DEFORMATION



$$\{\epsilon(t)\} = [D]\{x(t)\}$$

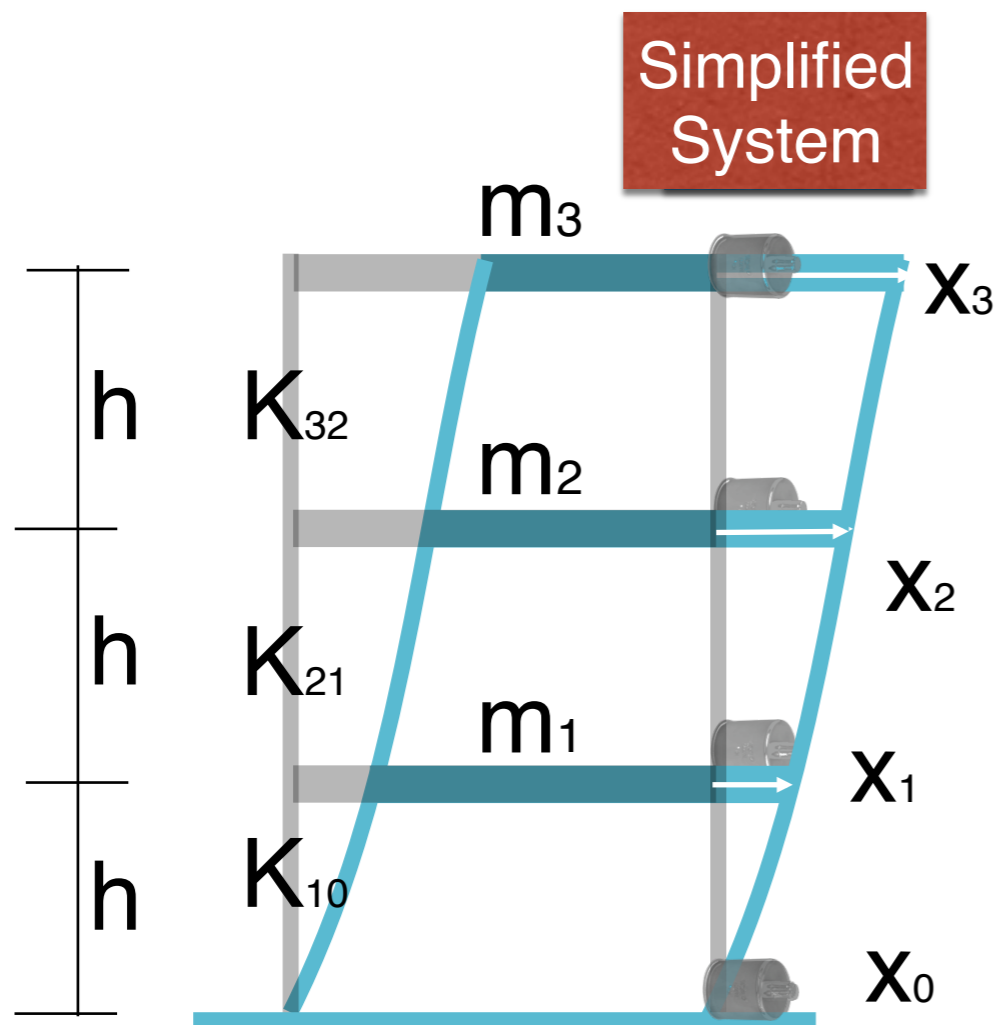
$\{x$ Acceletation $[LT^{-2}]$

$\{x(t)\}$ Displacement $[L]$

$[D]$ Kinematic compatibility matrix $[L^{-1}]$

$\{\epsilon(t)\}$ Deformation $[L^0]$

$$\{\epsilon(t)\} = [D]\{x(t)\}$$



Kinematic compatibility matrix

$$[D] = \begin{bmatrix} -1/h & 1/h & 0 & 0 \\ 0 & -1/h & 1/h & 0 \\ 0 & 0 & -1/h & 1/h \end{bmatrix}$$

Interstory drift


$$\epsilon_i = \delta_i = \frac{x_{i+1} - x_i}{h_i}$$

Damage parameter

detailed system: $\max(\delta_i) \quad i = 1, 2, 3$

simplified system: $\bar{\delta} = \frac{x_3 - x_0}{3h}$

<http://www.mot1.it/osdownload>

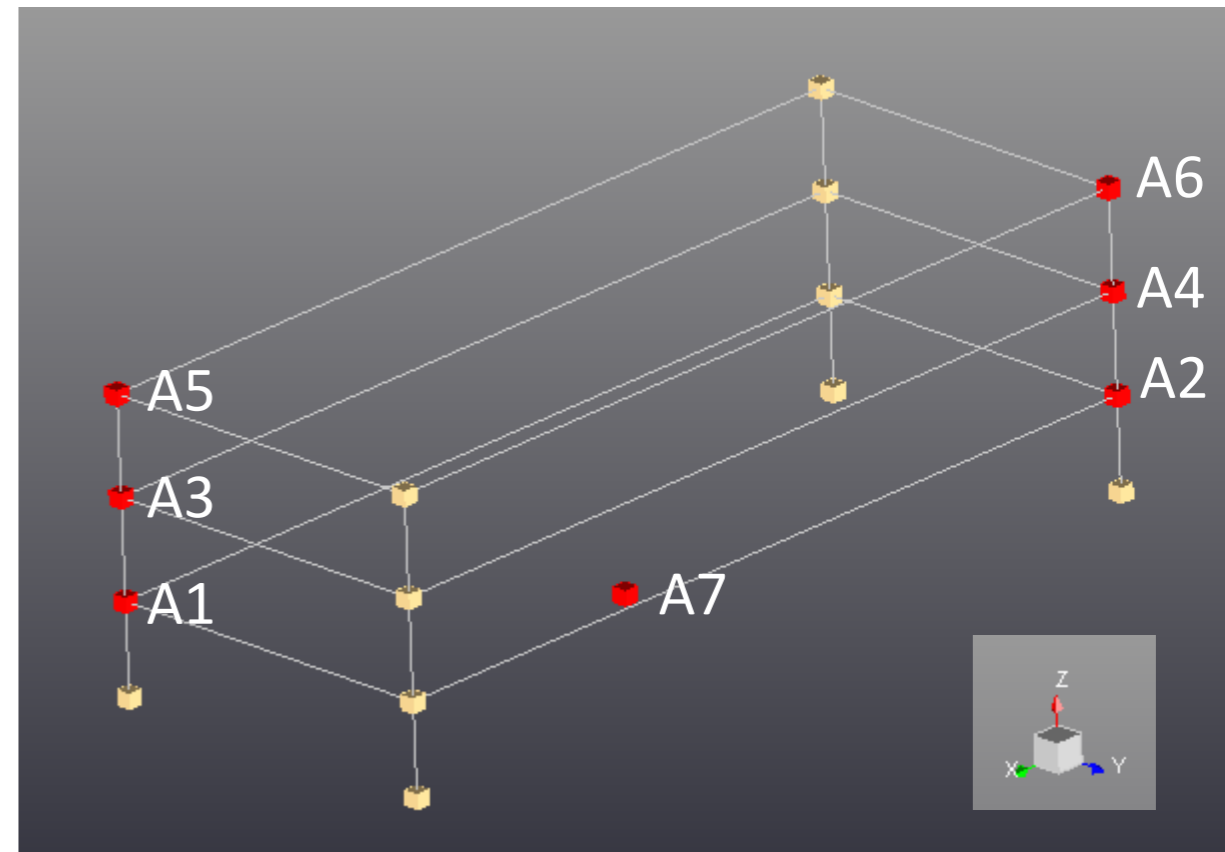
OSSERVATORIO SISMICO DELLE STRUTTURE (OSS download service) 

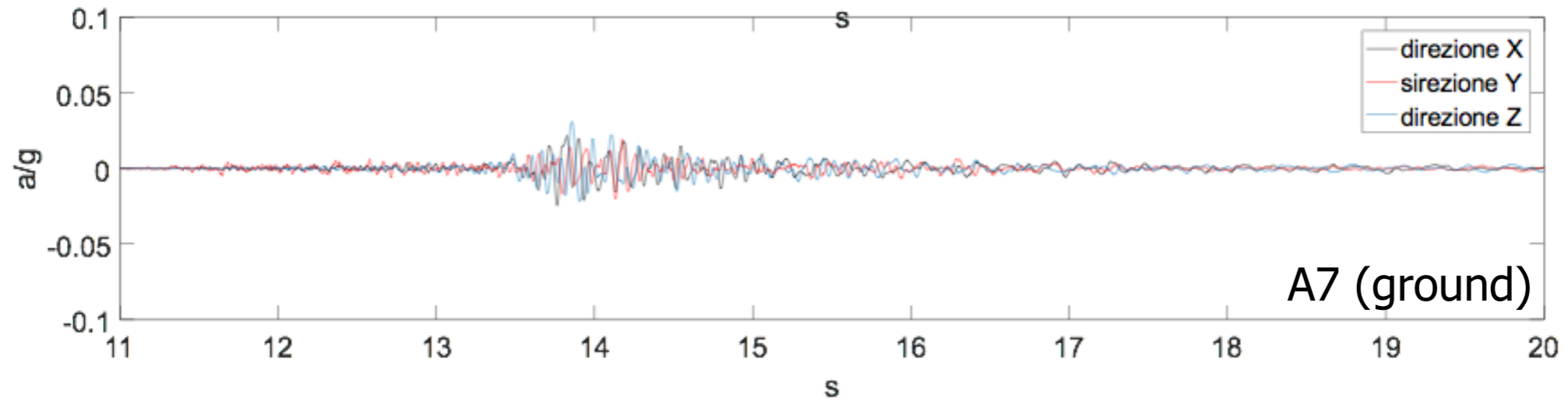
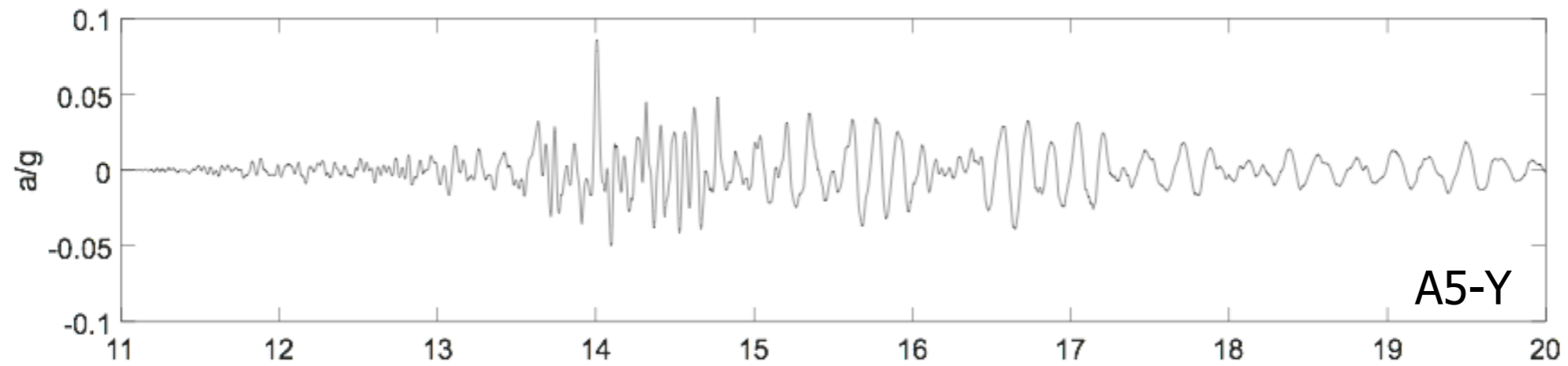
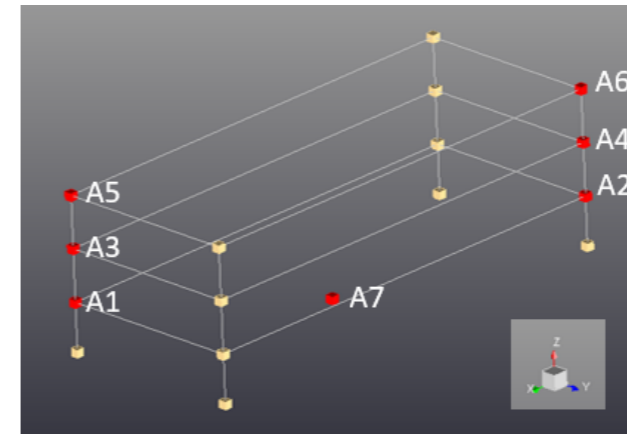
Elenco dei parametri - Tempo origine: 30/01/2015 00:45:49 - MI: 4.10 - Comune: 33015 Moggio Udinese, Province of Udine, Italy

Sigla	Nome Stazione	Lat(°)	Lon(°)	Tipologia	Città	Dist (Km)	PGA x (g)	PGA y (g)	PGA z (g)	PSA x (g)	PSA y (g)	Dmax (x1000)
BC060	Scuola Media 'G. F. da Tolmezzo'	46.4042	13.0133	Edificio in c.a.	Tolmezzo	10	0.0248	0.0206	0.0309	0.0388	0.0859	0.13
BC055	Casa dello Studente	46.2792	13.1394	Edificio in c.a.	Gemona	15	0.0048	0.0040	0.0033	0.0074	0.0104	0.01
BC059	Municipio e Teatro di Pontebba	46.5087	13.3071	Edificio in muratura	Pontebba	17	0.0032	0.0041	0.0027	0.0090	0.0137	0.03
BC057	Municipio di San Daniele del Friuli	46.1614	13.0158	Edificio in muratura	San daniele del friuli	30	0.0015	0.0014	0.0010	0.0060	0.0057	0.00
BC054	Centro Scolastico Forni di Sopra	46.4230	12.5833	Edificio in muratura	Forni di sopra	43	0.0052	0.0033	0.0026	0.0149	0.0146	0.05
BC056	Scuola Media 'G. Marconi'	46.1661	12.7072	Edificio in c.a.	Maniago	43	0.0012	0.0011	0.0009	0.0057	0.0065	0.01

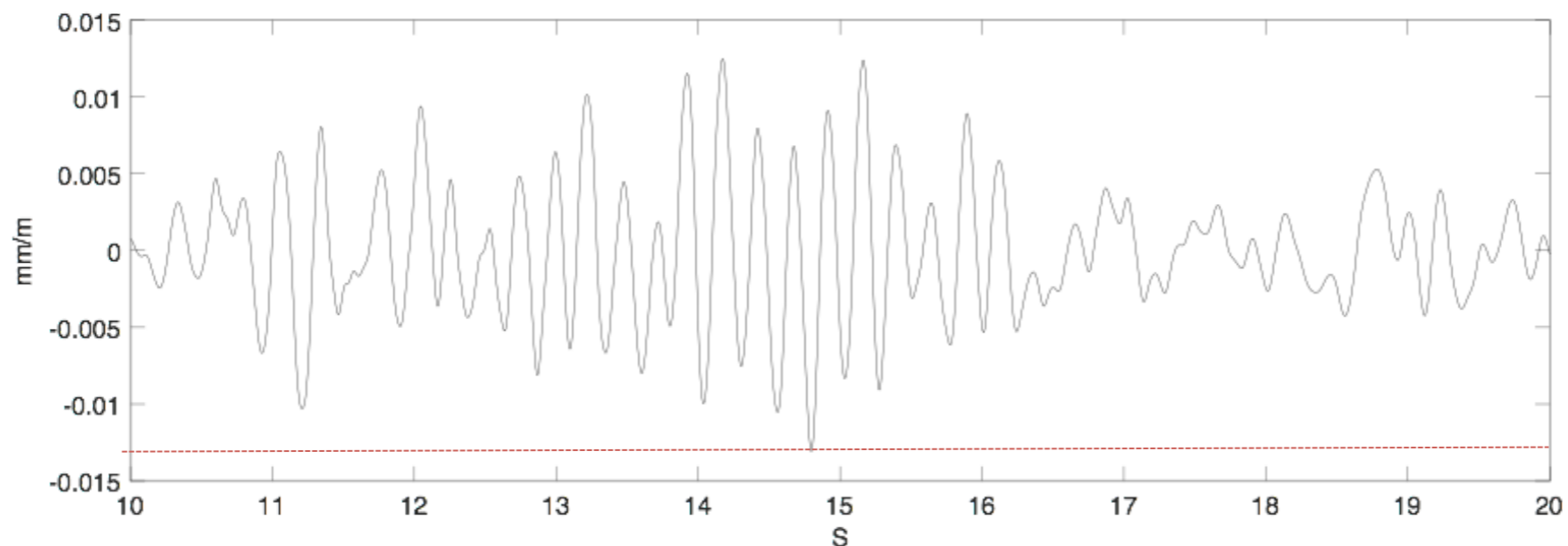


STRUCTURAL TYPOLOGY	R.C.
NUMBER OF FLOORS	3
NUMBER OF MEASURED ACC.	12
NUMBER OF DISP. TRASDUCER	2





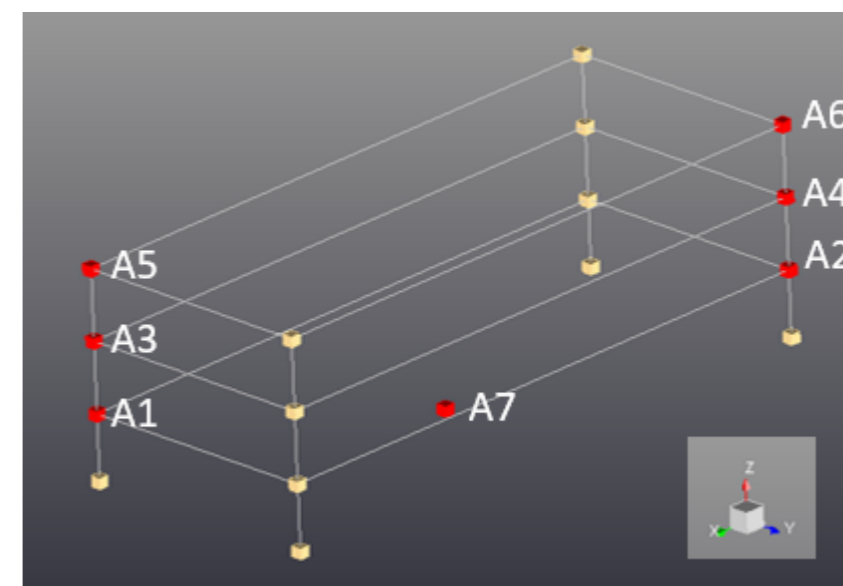
Drift Floor 3-2 A5-A3 Dir. X



$$D_{SLO} = 2 \times 10^{-3}$$

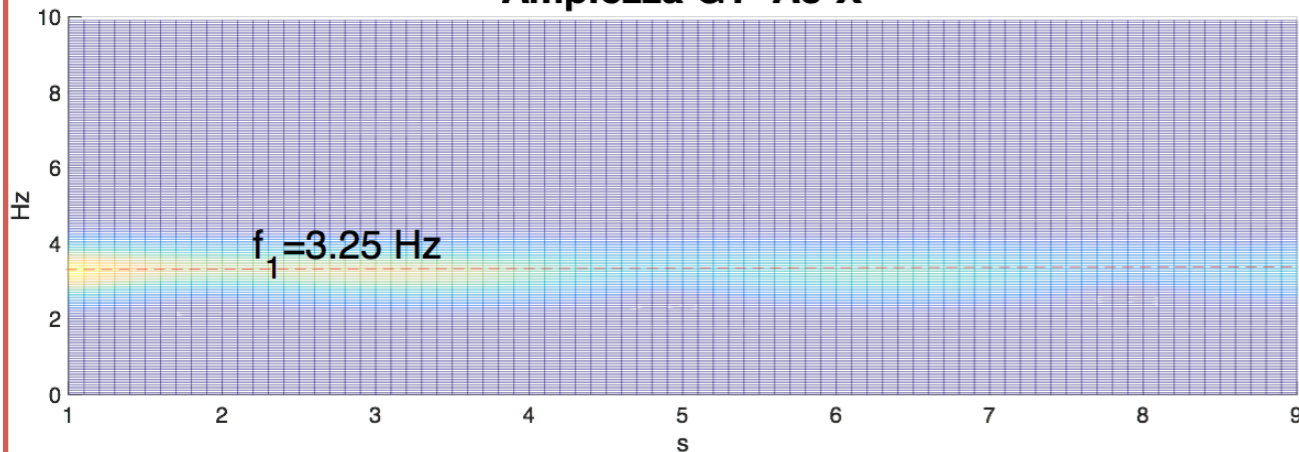
$$D_{max} \ll D_{SLO}$$

FLOOR	POINTS	DIRECTION	INTERSTORY DRIFT
1 - Ground	A1 - A7	X	0.11×10^{-3}
1 - Ground	A1 - A7	Y	0.10×10^{-3}
1 - Ground	A2 - A7	Y	0.09×10^{-3}
2 - 1	A3 - A1	X	0.06×10^{-3}
2 - 1	A3 - A1	Y	0.03×10^{-3}
2 - 1	A4 - A2	Y	0.02×10^{-3}
3 - 2	A5 - A3	X	0.13×10^{-3}
3 - 2	A5 - A3	Y	0.09×10^{-3}
3 - 2	A6 - A4	Y	0.13×10^{-3}

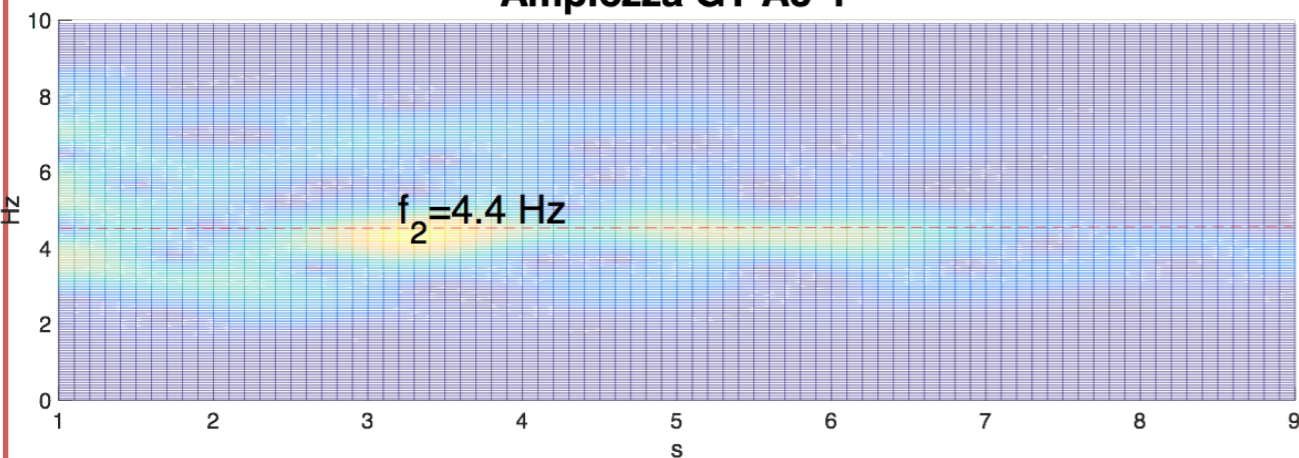


Earthquake

Ampiezza GT A5-X



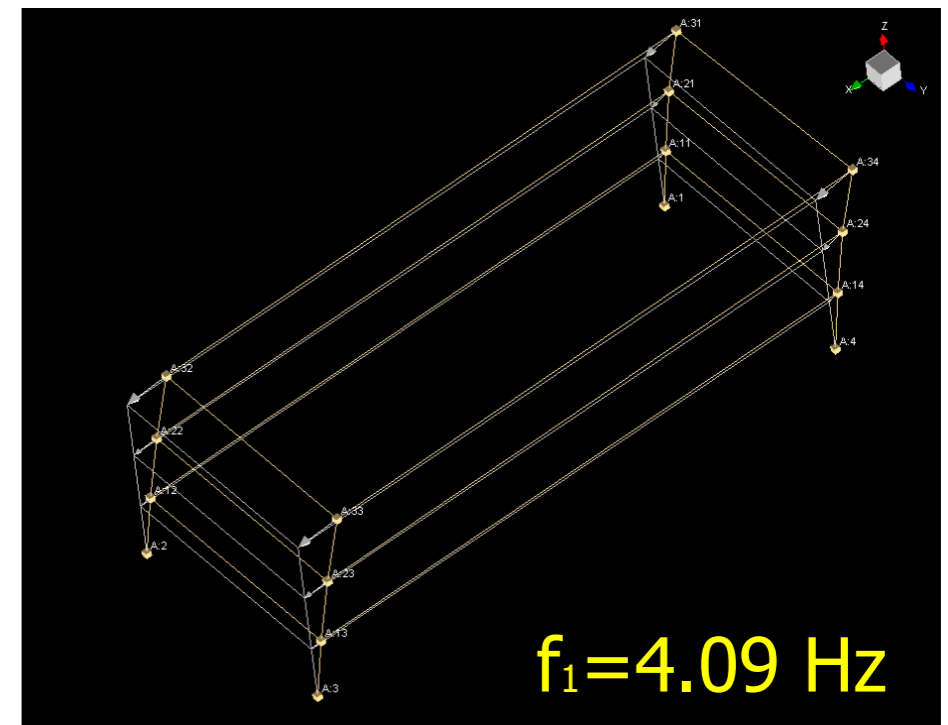
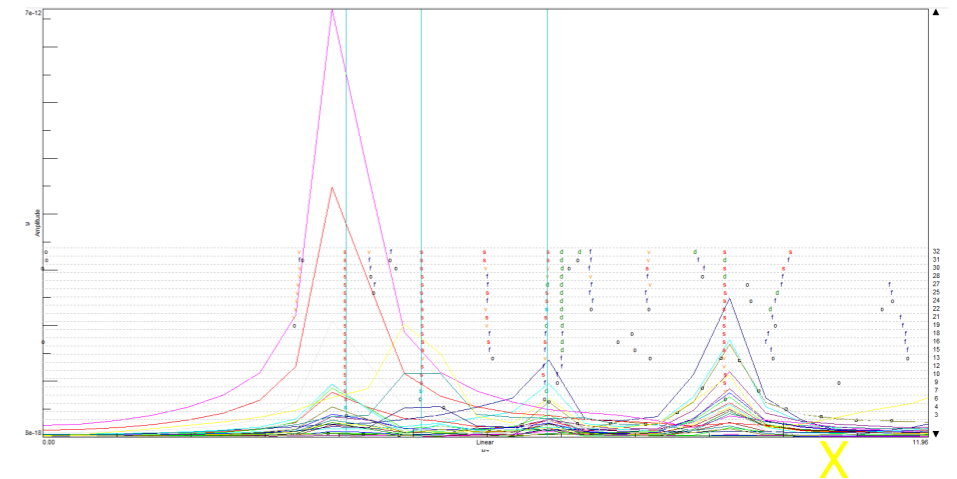
Ampiezza GT A5-Y



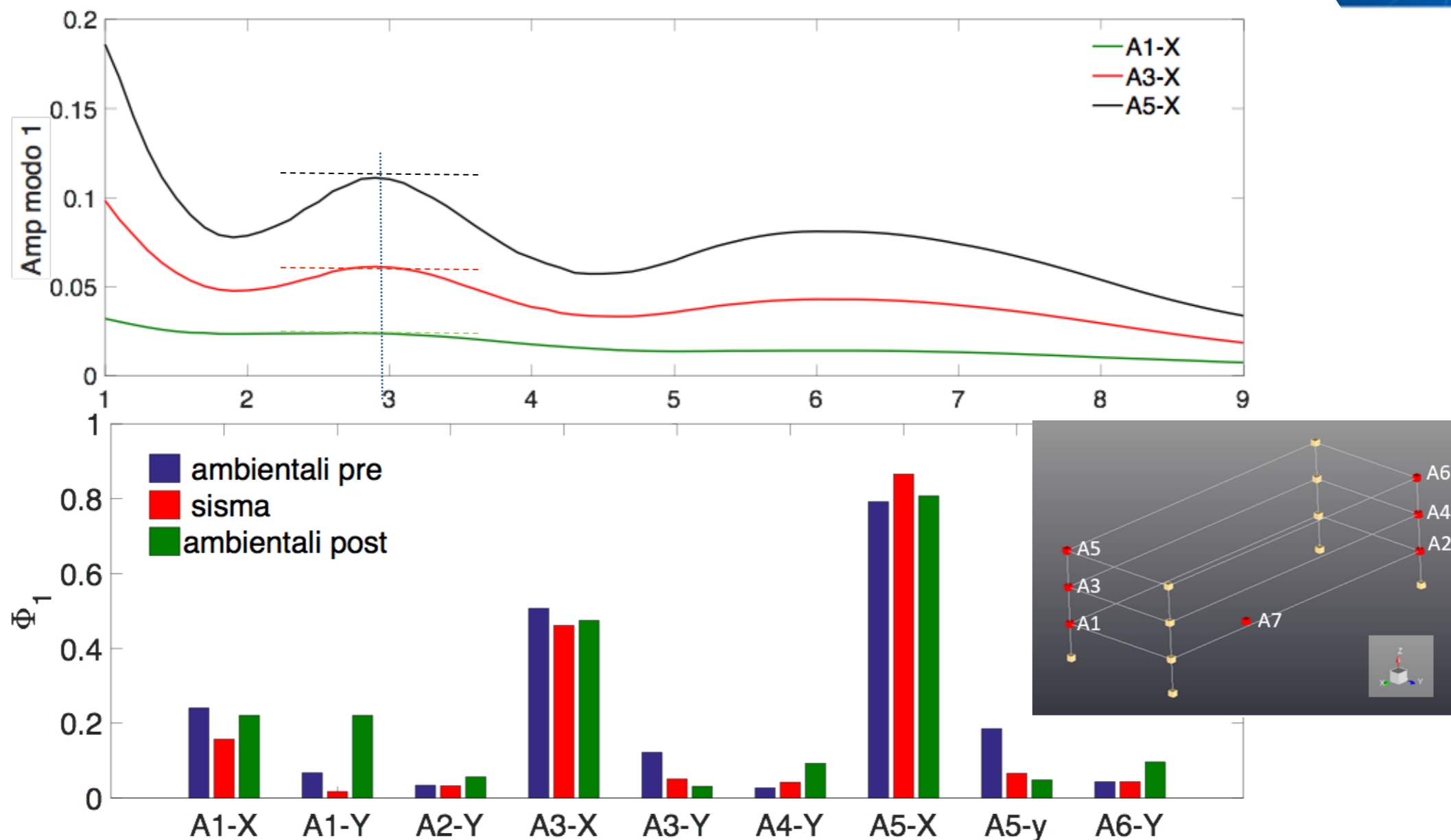
Freq. (Hz)	1	2	df 1 (%)	df 2 (%)
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Amb. pre	4.19	5.21	-	-
Earthquake	3.25	4.40	-20.0	-14.0
Amb. post	4.09	5.13	-2.4	-1.6

Ambient post



MODAL PARAMETER VARIATION



$MAC(\text{pre}, \text{sisma}) = 0.96$
 $MAC(\text{pre}, \text{post}) = 0.94$
 $MAC(\text{sisma}, \text{post}) = 0.94$

Thank you
for the
attention

the **Seismic Observatory of Structures (OSS)** records the dynamic response of **155 public structures** (147 buildings, 7 bridges and 1 dam):

schools 45%;

hospitals 18%;

town halls 20%;

other 17%;

with *reinforced concrete* (65%) or *masonry* (35%) structure.

Structures are chosen, that are representative of the public building stock and useful for emergency management.



Structures are monitored in order to assess both their **health state** and possible **earthquake damage**.

Every floor (buildings) or span (bridges) or section (dam) is monitored with **4÷6 accelerometers**, cable-connected with a **central unit** that converts to digital and records & transmits by **ADSL** triggered data to the **OSS server** in Rome, where data are processed, **maxima and a damage index** are computed, and (15-20' after the quake) data & results are **shared through e-mail reports** and a dedicated **website**.

