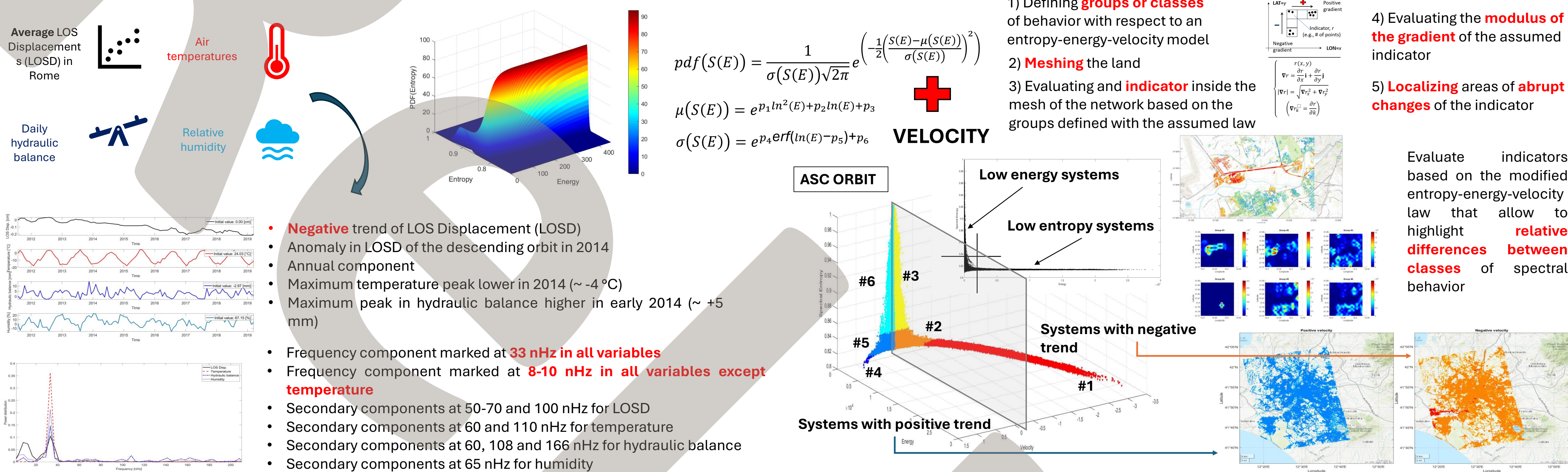# Task 6.1, 6.2, 6.3:
Integrazione di approcci e dati eterogenei per il monitoraggio strutturale a diverse scale di osservazione
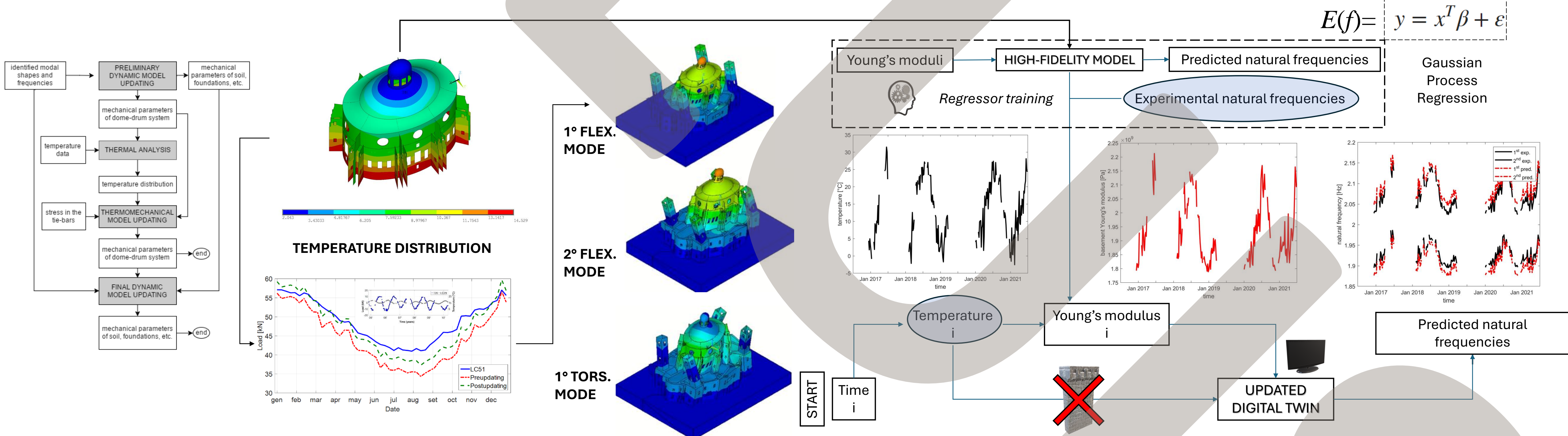
UR7

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Task 6.1

$$pdf(S(E)) = \frac{1}{\sigma(S(E))\sqrt{2\pi}} e^{\left(-\frac{1}{2}\left(\frac{S(E)-\mu(S(E))}{\sigma(S(E))}\right)^2\right)}$$

$$\mu(S(E)) = e^{p_1 ln^2(E) + p_2 ln(E) + p_3}$$

$$\sigma(S(E)) = e^{p_4 erf(ln(E)-p_5)+p_6}$$

VELOCITY

1) Defining **groups or classes** of behavior with respect to an entropy-energy-velocity model
2) **Meshing** the land
3) Evaluating and **indicator** inside the mesh of the network based on the groups defined with the assumed law

4) Evaluating the **modulus of the gradient** of the assumed indicator
5) **Localizing** areas of **abrupt changes** of the indicator

Evaluate indicators based on the modified entropy-energy-velocity law that allow to highlight **relative differences between classes** of spectral behavior

ASC ORBIT

- **Negative** trend of LOS Displacement (LOSD)
- Anomaly in LOSD of the descending orbit in 2014
- Annual component
- Maximum temperature peak lower in 2014 (~ -4 °C)
- Maximum peak in hydraulic balance higher in early 2014 (~ +5 mm)

- Frequency component marked at **33 nHz in all variables**
- Frequency component marked at **8-10 nHz in all variables except temperature**
- Secondary components at 50-70 and 100 nHz for LOSD
- Secondary components at 60 and 110 nHz for temperature
- Secondary components at 60, 108 and 166 nHz for hydraulic balance
- Secondary components at 65 nHz for humidity

Task 6.2

$$E(f) = \quad y = x^T\beta + \varepsilon$$

1° FLEX. MODE

2° FLEX. MODE

1° TORS. MODE

TEMPERATURE DISTRIBUTION

Young's moduli → **HIGH-FIDELITY MODEL** → Predicted natural frequencies

Regressor training → Experimental natural frequencies

Gaussian Process Regression

START → Time i → Temperature i → Young's modulus i → UPDATED DIGITAL TWIN → Predicted natural frequencies

Task 6.3

INTEGRATED STRUCTURAL HEALTH MONITORING MODEL

Experimental frequency, the residual between the model and experimental frequency, the mean of soil settlement, and the standard deviation of soil settlement can be **combined** into a single monitoring model using a **normalized elliptical equation via a stochastic oscillator**. This approach **correlates structural anomalies with soil** anomalies. The digital twin can **generate data** on these behaviors, which can be provided to a **classifier** to assess **how anomalies correlate** as experimental data is collected.

$$p_{norm} = \frac{p - p_{min}}{p_{max} - p_{min}} \quad \begin{cases} l_x = p_{norm,1} + p_{norm,3}\cos(\vartheta) \\ l_y = p_{norm,2} + p_{norm,4}\sin(\vartheta) \end{cases}$$

MONIOTORING METHODOLOGY

- The process begins with structural health monitoring, collecting data such as **InSAR displacement**, **temperature**, and **natural frequency** to estimate the material behavior of the structure.
- A **high-fidelity model** predicts the natural frequencies of the structure, comparing them with experimental ones. The **residual difference** is used to update the digital twin, which generates a predicted displacement field **calibrated using InSAR data**.
- If InSAR displacements are not provided over the structure, foundation settlement is calculated through data interpolation. The soil-structure's response is then statistically analyzed (**mean and standard deviation**), and the results are fed back into the monitoring system, closing the loop for optimization and calibration.