HERACLES NEWSLETTER

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HERACLES

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CASE STUDIES

GUBBIO, ITALY:

3. Town Walls
4. Consoli Palace

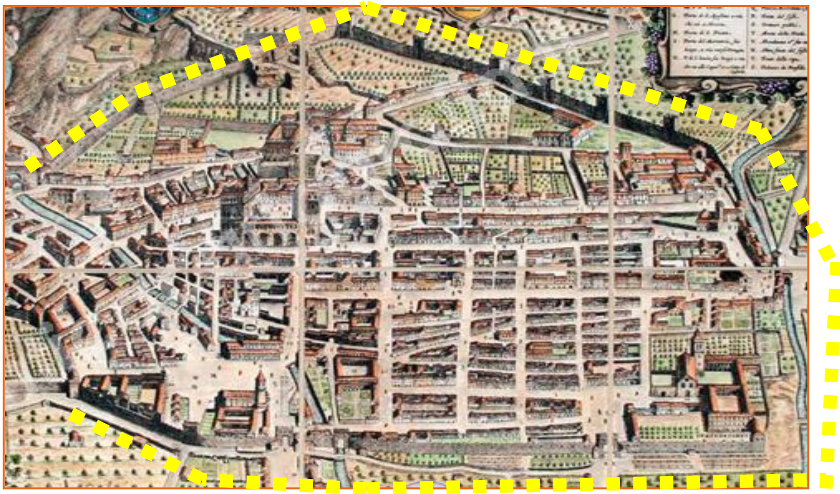
CRETE, GREECE:

1. Minoan Knossos Palace
2. Venetian coastal fortress of Koules

THE TEST-BEDS

GUBBIO: TOWN WALLS AND CONSOLI PALACE

In **Gubbio,** HERACLES is focused on two main test-beds: the Town Walls and the Consoli Palace.



In the past, the **town Walls** had the function of protecting the city against invasions, sieges and enemies raids. They represent a cyclopic structure formed over 2 millennia, continuously modified through elevations, renovations, expansions, reinforcements, modifications and demolitions too. They have a length of 2,85 kilometers, a maximum height of 12 meters, a thickness variable from 0,5 to 3 meters and variable sections. In fact, while in most parts the walls are a monolithic structure, in other parts (such as in some of the test bed zones), they have a multi-level hollow core section. All those parts were built within 1302[1], and some minor expansion were made until 1338.

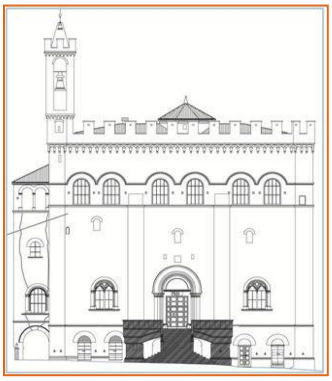
[1] A.Luongo "Gubbio nel trecento", 2014 – pag. 41

Nowadays, climate change is a threat for the preservation of the Walls. They mainly suffer from heavyl rains and humidity characterizing the soil surrounding the area, closely connected with the mountain natural zone. The heavy rains increase the push on the Walls in two ways: the first one is through the washout producing and transporting rubbles, the second one through the increase of the aquifer level. In the last decades many catastrophic episodes occurred, especially in the northern side of the town, such as collapses of medieval terracing (integrated parts of the town Walls or previous walls itself), and a 300 cubic-meters chasm opened in the *Duomo* garden.

Also the material constituting the Walls suffer of an increasing deterioration due to climate change effects, coupled with pollution, too. An important issue is the gradual degradation of the mortar binding the walls. The mortar has the function to make spatially uniform the stresses through the joints between the stones.

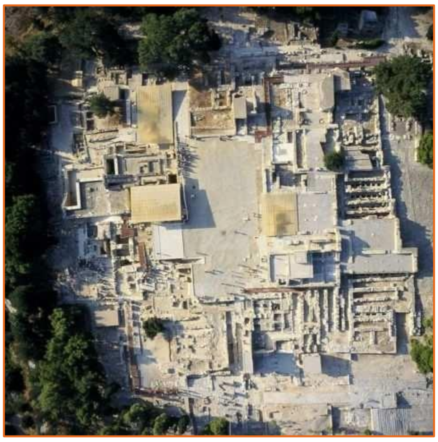
The **Consoli Palace**, is the second test-bed of Gubbio and is located in the monumental center of the city. It was built in the XIV century, during a period of demographic growth that occurred in Gubbio, as in other major centers of Central Italy. This demographic growth leaded to a downward expansion of the urban core with the re-occupation of the outer town walls spaces and new built areas. This demographic expansion of the popular classes led to the achievement of a new urban shape underlined both by the reconstruction of the main churches and by the completion of the new Town wall circuit.

From an architectural point of view, the Palace has a rectangular shape, and a very articulated distribution of volumes divided into 9 levels. The main façade of the Palace overlooking the square is made of ashlar stone and it stands for over 44 meters up to the top of bell tower. This façade has two mullioned windows positioned on the two sides of the Gothic style portal, decorated with a XVI-century fresco in the lunette.



The volumes of the two buildings constituting the Palace were conceived as a unique complex and complementary to the interposed empty space related to the square. In fact, the façades and the plans can be both inscribed in a single rectangular perimeter and form a prism with 4 equal faces organized according to a precise modular logic, based on the Golden ratio. The façade of the Consoli Palace is divided by a series of sketches and frames that clearly define horizontal and vertical scans. It can be verified that the determination of the facade dimensions and proportions is based on the "golden rectangle", a geometric figure whose proportional laws are multiples of the golden ratio, concept always appreciated in classical antiquity, rediscovered in the late Middle Ages and propagated later during Renaissance.

HERAKLION: SEA-FORTRESS OF KOULES AND PALACE OF KNOSSOS



The **Palace of Knossos Heraklion** is one of the Greek test-beds of HERACLES. It is the largest of the Cretan palaces, covering an area of 22000 sqm. The city around it was built on the top and on the slopes of the hill of Kefala, where the River Kairatos meets the small Vlychia stream. The first palace was built circa 1900 BC, following the leveling and landscaping of the hill.

There were entrances on every side, the most official being the Southwest and the North Entrance. The West Wing contained shrines, official halls and extensive storage areas, while the East Wing housed the royal apartments. There were also workshops, storerooms and other areas serving a variety of functions to north and south.

The Palace of Knossos was the only palace to remain in use after the destruction of 1450 BC, when the Mycenaeans settled Crete. Following the final destruction of 1380 BC, large parts of the Palace were reoccupied and remodeled, mainly as private houses. The first excavations at Knossos were carried out in 1878 by a merchant and antiquarian from Heraklion, Minos Kalokairinos, who discovered part of the West Wing of the Palace. Systematic excavations began in March 1900 under Sir Arthur Evans, then Curator of the Ashmolean Museum in Oxford. Two years later, the excavation of the Palace was almost complete. Over the following years there were supplementary excavations, which were completed in 1930-31.

After the Second World War, extensive restoration work was carried out on the Palace by the Directors of the Heraklion Archaeological Museum N. Platon and S. Alexiou. This work was limited to the conservation of the ancient masonry, the restoration of the floors and the protection of certain areas with roofing. During the nineties the Ministry of Culture, recognizing the problems that the monument was facing, took measures for its preservation and restoration. Under the authority of the Ephorate of Antiquities a great part of the concrete slabs of Evans' restoration of the Palace was conserved, and paths for the visitors were developed, which reduced the wear of the monument and gave the visitors a more complete view of it. In 2000 – 2008 a conservation project of the Palace was included in the 3rd C.S.F (Community Structural Funds). For its protection and restoration a NSRF (National Strategic Reference Framework) Project begun in 2010 and finished in 2015.

The other Greek test-bed is **the Venetian Sea-Fortress in Heraklion** is one of the Greek test-beds of HERACLES. It is an important monument for the city of Heraklion. It is situated at the edge of the NW breakwater of the Venetian harbour.

It is made of large limestones which come partly from the Hellenistic fortifications of the city. The shape of the fortress is roughly quadrangular, with a semi-circle bastion at the SE side. On the western, southern and north-eastern façades, the marble emblem of Venice (i.e. the lion of St. Marco) was embedded. On the ground floor, to the left of the main corridor, there are barrel-vaulted rooms which hosted barracks, warehouses, prison cells and water-tanks. Light and air came into the rooms through the roof. All around the building there were openings for the cannons. The surrounding walls ended up in a straight parapet, protecting the inner corridor. The battlements were added during the Ottoman occupation period.

Nowadays, the binding mortar of the masonry has been badly weathered and the balusters, although recent restored, were almost ready to collapse. Salt black hard crusts were covering part of the walls, sea and rain water were entering from the broken skylights at the roof of the galleries. All the iron elements used in the monument were heavily corroded.

During the first decade of 2000, the Greek Ministry of Culture, anticipating the problems that the monument was facing, decided to take new measures for its protection and safeguarding. Under the direction of the Ephorate of Antiquities a National Strategic Reference Framework Project concerning the Restoration and Conservation of the Venetian Fortress (Koules), took place (2011-2016). In the conservation program the main concern was related to the static and reinforcement aspects of the monument.

In order to achieve the desired result, previous interventions to masonries, both indoors and outdoors, have been removed, the lions relieves have been consolidated and preserved, and the old frames of the cannon openings at the ground floor have been replaced with stainless ones. Restoration works aimed to the cleaning and protection of the stone surfaces from hard salt crusts and biodeterioration signs, where it was possible without losses of the material. In addition, the three lions emblems on the façades of the monument were cleaned and consolidated in order to achieve compactness.

ONGOING ACTIVITIES OF THE PROJECT

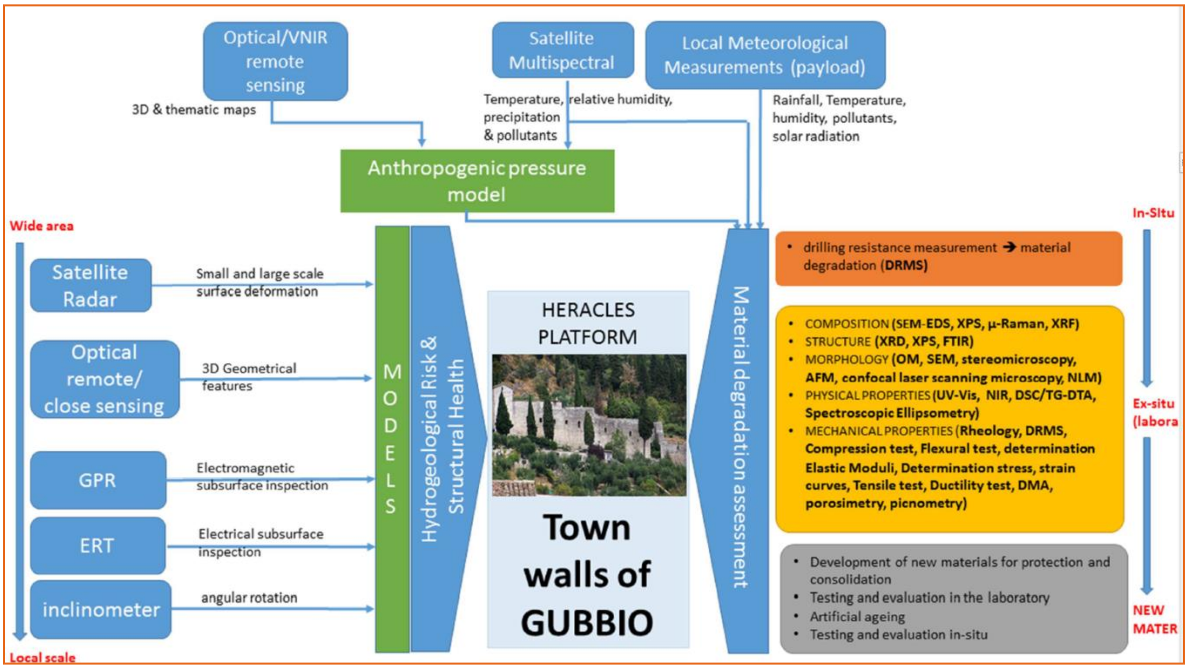
In Gubbio, the Town Walls are made in stone masonry (mainly limestone) and mortar.
The part of the urban walls exposed to the maximum risk is located on the slopes of Ingino Mountain in N/NE direction. The area nowadays is mostly interested by olive plantations, while in the past was also used by wood-cutters and farmers. The area inside the Walls was used as military bastions (such as the "Cassero") until the XVI Century, after which it has been used mostly for farming uses.
From historic information, i.e., pictures and paintings, it was possible to point out how the forestation, currently visible outside the walls, is very recent and has arisen only just after the World War II. In fact, in the past, only few trees and bushes were present and unable to stop sediments and surface flows.
The first scenario concernoing the Gubbio Town Walls is related to the hydrogeological risk, due to:

- Atmospheric moisture change and intense rainfall and related floods
- Damages derived by faulty or inadequate water disposal systems after an extreme event
- Subsoil instability, such as: ground heave, subsidence, landslide.

The second scenario is the material degradation mainly deriving from the following risks/hazard:

- Erosion of inorganic materials due to flood waters;
- Temperature changes coupled with wind (rain driven by wind can penetrate moisture into porous materials weakening them; combined with ice can create cracks in stones and mortars);
- Climate and pollution acting together.

A systematic protocol was developed to face these problems, as summarised by the following figure:



According to this protocol, the activities related to monitoring and analysing the Town Walls are the following:

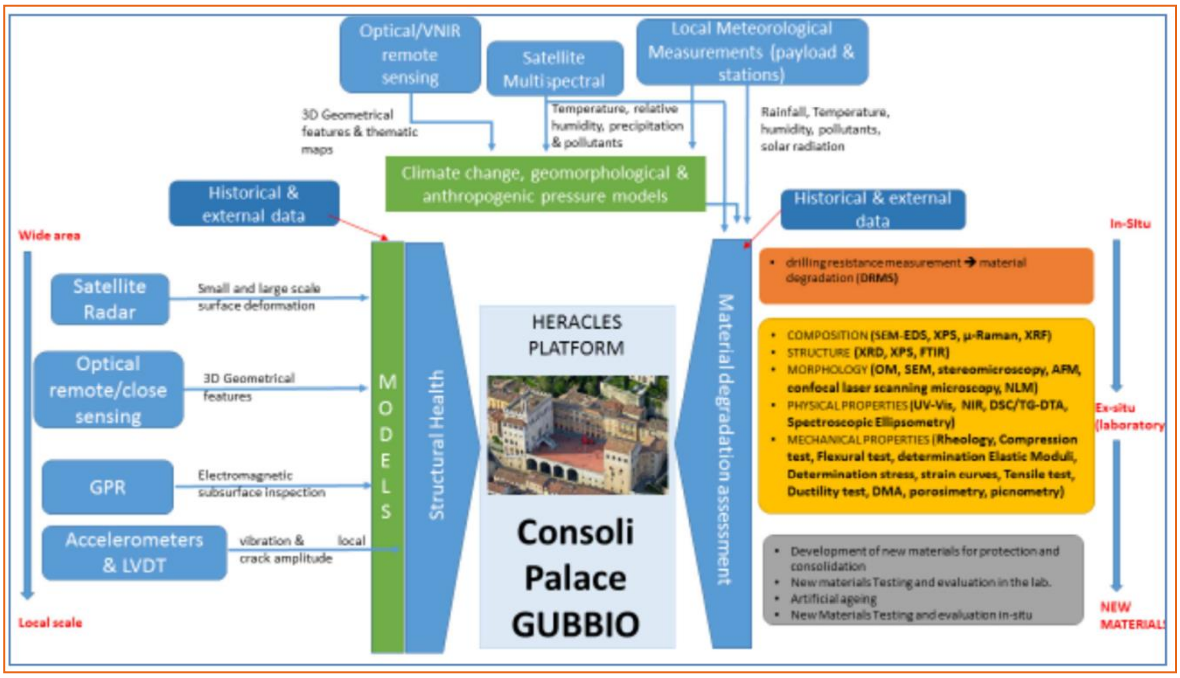
1. Spaceborne radar COSMO-SKYMED (data acquired by Spaceborne Synthetic Aperture Data (SAR) with multi-temporal differential interferometric techniques aimed at carrying out environmental monitoring at regional scale at high resolution. These techniques are able to perform an accurate 3D reconstruction (point clouds) of single building and infrastructures as well as to measure with millimetre/centimetre accuracy the superficial deformation of the observed objects by allowing the study of the stability of each single built structure and of the surrounding elements);
2. Multispectral Sensors (the collection of reflected, emitted, or backscattered energy from an object or area of interest in multiple bands of the electromagnetic spectrum. Combining spatial and temporal resolution features, multispectral sensors provide meteo-climatic and air quality measurements for the characterization of local scale meteorological conditions and climate change effects with a potential impact CH structures);
3. Drone geometrical survey (photogrammetric acquisition of photograms: final output of this survey is the 3D reconstruction of those parts of walls, in a very detailed and accurate representation);
4. GPR georadar (a portable radar instrumentation designed to perform subsurface investigations, i.e. to detect and localize buried or hidden targets.
5. ERT (Electrical Resistivity Tomography is an electromagnetic sensing technique useful to characterize areas of complex geology. It provides 2D and 3D images of subsurface targets/structures in terms of electrical measurements made at the surface. ERT allows to obtain high resolution images of the resistivity subsurface patterns, detecting and imaging shallow subsurface targets characterized by conductive properties that are very different from the ones of the host medium.)
6. Weather monitoring station network (The network of microclimate monitoring sensors currently installed in the area of the city of Gubbio is managed and operated by a local public environmental authority: A.R.P.A. Umbria. It is composed by five monitoring stations located at ground level, nearby and inside the city centre).
7. Drone measurement of climatic parameters (portable environmental payload device for the monitoring of local microclimate variables). It monitors microclimate parameters in time and space with a dedicated georeferenced payload made up of miniaturized environmental sensors also

equipped by visible and infrared cameras to detect superficial temperature [°C] of the surrounding environment.

8. TH3-Thermal-Humidity sensor data logging system (Rugged, waterproof temperature and relative humidity loggers with built-in sensors, able to monitors temperatures and relative humidity. Data collected by these systems are used to validate numerical microclimate models.)
9. Infrared Thermography (a thermographic camera detects specific inner structural diseases and dis-homogeneity).
10. Inclinometers (used for the static monitoring of the out-of-plane rocking of specific portions of the Town walls)
11. Drilling Resistance Measurements System – DRMS (drilling the materials with special diamond type drilling bits, the system can measure continuously: Penetration force, Actual drill position, Rotational speed and Penetration rate)
12. Physico-chemical characterization of Stone and Mortar samples (through techniques for the physical, chemical, morphological, mechanical and thermo-physical characterization of mortars, binders and stones. It allows to verify the wheathering state of the materials, assessing their degradation phenomena.

The **Consoli Palace**, built between 1332 and 1349, has a rectangular shape and a very articulated distribution of volumes divided into 9 levels. Several restorations were made after the 1982 and 1984 earthquakes and completed in the first half of the '90s. During these restorations, the façades were completely cleaned by the accumulations of dirt. After only thirty years, however, smog, concretions and localized phenomena of black patina are again clearly visible.

The first risk scenario is linked to atmospheric moisture change, intense rainfall and flooding. Main risks are related to the consequent variation of the aquifer level that could induce foundation settlement.
The second scenario is due to climate, wind and pollution acting together.The most frequent events that are consequences of temperature change are diurnal, seasonal, extreme events (i.e. heat waves, snow loading), changes in freeze-thaw cycles and ice storms, and the frost increase. All these factors induce damages inside stone and/or mortars undergoing wet-frozen cycles inside material before drying. Wind-driven rain can penetrate moisture into porous materials weakening them and combined with ice can create cracks in stones and mortars, inducing structural instability.
A systematic protocol was developed to face these problems, as summarised by the following figure:



In particular, the monitoring system includes all the sensors set for Town Walls (see # 1-12 above) with the exception of inclinometers (#10). The structural behavior of the building will be checked instead by means of:

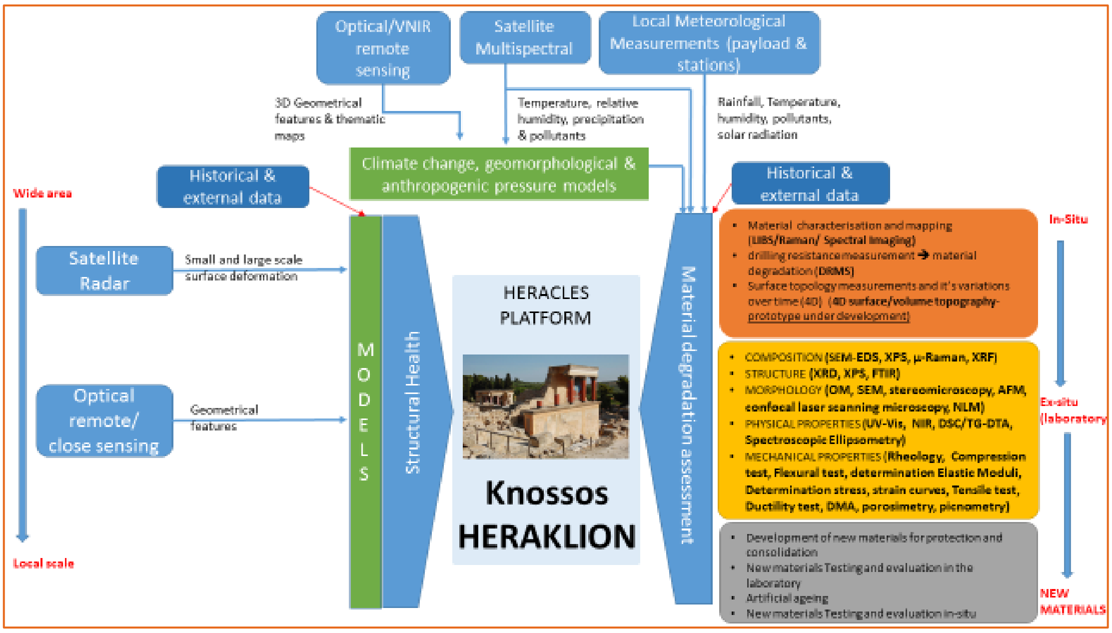
- Accelerometers (Three high-sensitivity uni-axialaccelerometers placed on the roof of Consoli Palace, fixed on two corners of the perimetral walls for the detection of the three rigid motion degrees of the roof in its plane. The sensors are connected through cables to an acquisition system placed below the roof.)
- LVDT (Two linear variable differential transformer placed in "noble" plan and in Consoli chamber. They monitors the mutual displacements of the sides of the same wall divided by a crack).

In the following picture is shown the Systemic protocol flow view for Gubbio Consoli Palace

All the sensors above described are now installed ad monitoring, with the exception of inclinometers and DRMS that are planned for spring 2018.

In Greece, KNOSSOS Palace: generally, the damage to the monument is associated with external factors connected to the environmental conditions of the area and to the history of the Palace, as well as to endogenous factors arising from the structure of the foundations and the characteristics of the building material themselves. Significant degradation effects for the masonries are concerned with the cracks affecting both the ancient and the restored masonry. Problems are related to: reinforced concrete used by Evans; Mineral Gypsum Decay and Degradation; Detachment process affecting laminated stones (most of sedimentary rocks, some metamorphic rocks); Exfoliation: detachment of multiple thin stone layers; disintegration; erosion; encrustation; disintegration; water infiltrations; issues related to pollution.

A systematic protocol was developed to face these problems, as summarised by the following figure:



The following sensors/analysis were installed/carried on:

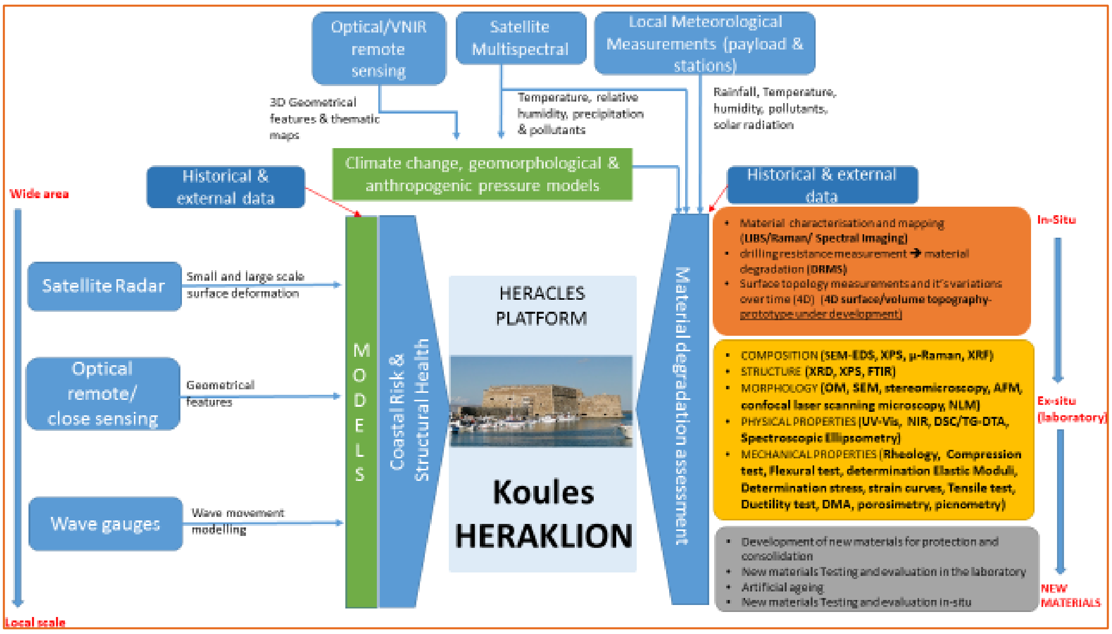
1. Geometrical
   - #1.1 Spaceborne radar COSMO-SKYMED

- #1.2 UAV-Drone geometrical survey
- #1.3 Terrestrial Laser Scanner

2. Environmental
   - #2.1a Weather monitoring: local station NETWORK
   - #2.1b Weather monitoring: public station NETWORK
   - #2.2 Drone measurement of climatic parameters (portable environmental payload device for the monitoring of local microclimate variables)
   - #2.3a Temperature-Relative Humidity (RH) sensor data logging system (portable)
   - #2.3b Temperature-Relative Humidity (RH) sensor data logging system (fixed)
   - #2.4 Infrared Thermography
   - #2.5 Multispectral remote sensors
   - #2.6 Physico-chemical characterization of stones, gypsum, concrete and mortar samples (through techniques for the physical, chemical, morphological, mechanical and thermo-physical characterization of mortars, binders and stones. It allows to verify the wheathering state of the materials, assessing their degradation phenomena.

The other Greek test-bed, the Koules fortress is representing all the coastal monuments present in Europe that face the risk of hazards from climatic changes, such as significant impact from the sea (as sea level is rising, increasing intensity of extreme weather phenomena combined with the air and land associated hazards, raised salinity accelerating corrosion and deterioration of materials and structures, *etc.*). Such hazards affect the monument integrity through time, leaving signs, unfortunately irreversible. Due to its severe preservation state, hazards and risks have been considered. Main issues are related to: **the black deposits** accumulated on the surfaces and due to intense environmental pollution; **bio-degradation** due to the biological activity on the surface, linked to the increasing levels of moisture, the air pollution and the temperature cycle variations; **efflorescence salts**; **white salt accumulations**, probably due to water infiltration through the masonry. Furthermore, the Koules fortress, is vulnerable to sea flooding, waves and salty northern winds, which several times become very severe, reaching the scale of 9 to 10 or even 11 in the Beaufort climax/scale; high waves are literally covering it. That means that waves during rough sea may cause the displacement of breakwater blocks with the consequent damage to the monument surface. In addition to the blocks, sand is transferred out from sea and upon the fortress masonry provoking a sandblasting effect. Furthermore, sea water is a mean of dispersion of soluble salts (mainly chlorides, secondary sulphates) producing an increased and well-known effect on construction material decay.

A systematic protocol was developed to face these problems, as summarised by the following figure:



The following sensors/analysis were installed and carried on:

1. Geometrical
   - #1.1 Spaceborne radar COSMO-SKYMED
   - #1.2 UAV-Drone geometrical survey
   - #1.3 Terrestrial Laser Scanner
2. Environmental
   - #2.1a Weather monitoring: local station NETWORK
   - #2.1b Weather monitoring: public station NETWORK
   - #2.2 Oceanographic sensors
   - #2.3 Drone measurement of climatic parameters (portable environmental payload device for the monitoring of local microclimate variables)
   - #2.4a Temperature-Relative Humidity (RH) sensor data logging system (portable)
   - #2.4b Temperature-Relative Humidity (RH) sensor data logging system (fixed)
   - #2.5 Infrared Thermography
   - #2.6 Multispectral remote sensors
   - #2.7 Physico-chemical characterization of stones, gypsum, concrete and mortar samples (through techniques for the physical, chemical, morphological, mechanical and thermo-physical characterization of mortars, binders and stones. It allows to verify the wheathering state of the materials, assessing their degradation phenomena.

PRESENTATION OF THE PROJECT

1. FORUM FOR NEXT GENERATION RESEARCHERS (STRASBOURG, FR – 18/11/17)

The Forum for Next Generation Researchers took place in the frame of the 6th World Materials Summit. The aim of this Summit is to bring together industry, university, and government representatives to discuss global issues and solutions, and in particular how materials research and engineering can contribute to mitigate these issues.

The HERACLES project was presented by coordinator G. Padeletti (CNR) on the first day to more than 30 international students and 20 international researchers

2. NATURAL THREATS AND CRITICAL INFRASTRUCTURES: RESEARCH, DEVELOPMENT AND MANAGEMENT OF EMERGENCIES (ROME, IT – 30/11/17)

During this workshop organized by the AIIC (Associazione Italiana Infrastrutture Critiche), Guido Mariotta (Leonardo) presented the project through a presentation entitled “Resilience and protection of cultural heritage against the effects of climate change: the HERACLES project”

3. US ARMY VISIT TO FORTH TEAM (HERAKLION, GR, 14/12/17)

HERACLES was disseminated on the occasion of the visit of the U.S. ARMY RDECOM (Sandra Gomez, http://www.rdecom.army.mil/itcatlantic/) in the Forth facilities in Heraklion, GR, on 14/12/2017. During the visit, HERACLES was discussed and presented.

4. INTERNATIONAL CONFERENCE "SAFEGUARDING CULTURAL HERITAGE FROM NATURAL AND MAN-MADE DISASTERS"- JOINT COMMUNICATION EVENT IN THE FRAMEWORK OF INTERREG CENTRAL EUROPE PROTRECHT2SAVE AND CONTRACT EAC-2016-0248)

An overview of the HERACLES project and its strong points were presented by CNR and SISTEMA.

5. 4TH HERACLES VIRTUAL COURSES

On December 20th, 2017, Prof. Maria Paula Diogo and Prof. Paula Urze, from the social component of Uninova, organized the fourth course “Socioeconomic factors in risk analysis” from Lisbon, PT.

For the video, see: http://www.heracles-project.eu/virtual-course-socioeconomic-factors-risk-analysis

FUTURE EVENTS

1. HERACLES VIRTUAL COURSES

The fifth Virtual Course is the next to be held. It’ll be entitled “Satelite and airbornes sensing techniques for surveillance and monitoring at territory and site scales” and will be given by e-Geos and CNR.

Information about the date and the procedure to follow the course will be provided on the HERACLES website. As a reminder, no registration is required.