

Project SHC – Space for Heritage Conservation

**Space Applications for
European Heritage Site Conservation**

**A “Space for Sustainability Award” Submission
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The present project proposal concerns the use of space based instruments and capabilities to develop tools, in a multidisciplinary setting, for managing and protecting European heritage sites (National monuments and historic structures) from various types of threats. For the purposes of this presentation, we will gather all man-made structures identified by National, European and International authorities as being historically or artistically significant under the umbrella of the term “National Monuments”, though many of them have an impact well beyond National borders. The presentation features an explanation for the importance of National monuments and other heritage sites, a description of their varied threats to which satellite applications may offer solutions and a brief plan for the pilot phase of the project. The plan is addressed to EU countries, plus non-EU ESA partners, such as Norway and Switzerland, but is also a useful platform to engage with partners outside Europe in a cooperative framework for the protection of global heritage sites. In some cases, the managing authorities for certain or all heritage sites in some countries are already making extensive use of satellite derived information for assessing threats and planning for protection, restoration or threat removal (or advocacy for it). However, the degree to which space applications are used varies from region to region, and it is a net gain for the whole of Europe that the heritage of its members benefits from a core standard of protection through the use of novel space application. The timing for such a project is right, since access to Earth Observation data was previously encumbered by unwieldy business and access models, high costs, lower quality and a lack of diversity in instruments. The project is in line with the European Space Agency’s efforts at promoting the use of the capabilities of its SENTINEL satellites throughout Europe, as a result of the GMES/Copernicus Programme. Having personally attended two of the yearly events dedicated to promoting awareness among entrepreneurs and the general public of the capabilities of the SENTINEL satellites and the unprecedented freedom of accessing their gathered data, the present project proposal emerged as a logical application possible only in the context of the rapidly changing field of Earth Observation. With the planned augmentation of the GMES/Copernicus programme through the addition of new SENTINEL satellites with other instruments, the project has the potential to evolve in its usability and its capacity to address real problems facing Civil Society and National Authorities in protecting the monuments of Europe.

National Monuments – a Critical Infrastructure

Critical infrastructures are defined as being assets and systems whose disruption or destruction would cause damage and hardship at societal level in the hosting state, with the risk of transmission to other infrastructures or even beyond national boundaries. The concept has been in development for decades throughout the world, but especially in the EU and the US. The EU even has a Programme for Critical Infrastructure Protection dedicated to safeguarding critical infrastructures of European systemic importance, while also enhancing the ability of Member States to protect the National critical infrastructures.



The 3.000 year history of European civilization, with its tumultuous and sinuous path to humanist and technological enlightenment, has littered the continent with numerous monuments of varying ages and levels of preservation. Every EU state and its partners has its share of ancient monuments, medieval cityscapes and iconic landmarks. These serve numerous functions, which warrant their labelling as a new kind of critical infrastructure:

- Monuments are a source of National identity, pride, morale and a sense of historical continuity of civilizations, achievements and values;
- Monuments are a tourist attraction, drawing significant numbers of visitors to them and their surroundings, contributing immensely to European prosperity in a way that cannot be outsourced or diminished;
- Monuments are a repository of artefacts of cultural, historic and aesthetic worth, with inestimable value;
- Monuments are an object of scientific study, contributing to the knowledge of past events and societies;
- Monuments may even perform current functions, either housing an organization, including authorities, or performing a current and relevant ceremonial function.
- Their damage, destruction or disfigurement could cause irreparable harm to their host societies or even throughout Europe.

For these reasons and many more, they should be considered critical infrastructures.

Threats to European Heritage Sites

According to a seminal article by Iranian specialists Shoureshe Kanani and Hassan Zandi, summing up the various types of threats to the heritage of their homeland, there are numerous categories of destructive factors plaguing the conservation of National monuments and other historical structures:

- Natural factors with instant function, such as natural disasters (earthquake, lightning, fire, flood, drift and movement of earth);
- Natural factors with gradual function;
 - Physical factors (wind, sunlight, changes in moisture, changes in temperature, acid rain, air polluters);
 - Chemical and electrochemical factors found in nature;
 - Plant and animal based destructive factors;
 - Biological and microbiological factors;
- Social factors due to profiteering or negligence and mismanagement;
- Inherent and internal factors due to the weakness of techniques or lack of knowledge about the climate or available material;
- Complex factors, integrating all of the above.

The main threats addressed under this project proposal are the natural factors with gradual function, which are accommodating to a system where observations can be made over time and there is scope for assessing the situation, engaging the relevant authorities in a dialogue and, finally, developing a solution to manage and mitigate these threats and their damage.

The numerous ways in which just these factors affect the structural soundness, the conservation of architectural elements and the overall aesthetics of a National Monument are too numerous to list.

For instance, the seepage of groundwater or rainwater into the structures weakens them over time, causing sudden collapses, with dire consequences and well attested precedents. These effects are compounded by seasonal variations in temperature, as well as the interplay of other destructive factors. Many regions are characterized by a simultaneous exposure to environmental risk factors that often mutually strengthen each other. For instance, an earthquake may not outwardly damage a structure, but increase the chance for landslides or modify the physical characteristics of the ground underneath, accelerating sinking and promoting unanticipated structural stresses.

Another significant and universal threat is air pollution and acid, which affect limestone, marble, timber, carbon-steel, zinc, nickel and even plastic surfaces. The heavy air pollution in Athens has had a measurable effect on the marble of the Acropolis, and even newly developing places, such as India, have witnessed the accumulation of such pollution that the Taj Mahal has started to turn yellow from its original and famous pearly white colouring. Cologne Cathedral, Notre Dame, the Coliseum and Westminster Abbey have all been affected. Sometimes, the change of colour under the effect of the elements, such as the oxidization of copper, leading to a greenish tint in statues (most famously the Statue of Liberty) come to be seen as the natural state of the monument, however it is the responsibility of the host society to vigilantly monitor all possible sources of degradation and prevent them, wherever possible. One may argue that The European Union has had significant success with its environmental policy, which should lessen the frequency and severity of air and rain pollution and their impact on National Monuments. However, the degradation of Europe's monuments has accelerated, even after the amelioration of the peaks of pollution in the 1960s and 1970s. For instance, UK Sulphur dioxide (SO₂) emissions peaked in the 1960s but have since declined by over 80%. The emissions of other substances have similarly declined, even though global air currents may deposit pollution from other areas in more environmentally friendly places (this is known as wet deposition, as opposed to dry deposition, based on particles settling in proximity to their source). The explanation lies in studying the response of materials to exposure to various conditions.

Calcium carbonate, which is present in numerous building and faceting materials, dissolves in dilute sulphuric acid to form calcium sulphate:



The following explanation is taken from a specialty presentation on this phenomenon: "This has two effects. Firstly it causes the surface of the stone to break up; secondly, a black skin of gypsum (calcium sulphate) forms which blisters off exposing more stone. When the gypsum crystals form they can grow into the stone, and the process may continue for up to 50 years. This is known as the Memory Effect".

Submersion of parts of the building and foundations into acidified waters are also cited as factors. The various pollutants even accelerate their corrosive effects in presence of each other, and are encouraged by specific climates, temperatures, humidity and other factors.

Such factors are:

- The growth of plant matter and fungi;
- The mineralization or pulverization of soil, leading to acidic environments, formation of crystals on stones, or sandblasting effects;
- The mechanical effects of expanding tree roots and land movement.

In the case of Venice and many other places throughout the world, the whole city appears to be slowly sinking, while the geography of its lagoon leads to instances of flooding, water degradation and accumulation of pollutants.

Space Applications for Protecting European Heritage

While urban areas are, often, monitored for air pollution and other types of hazards, not all Monuments are located within such a jurisdiction. At the same time, certain risks are not adequately accounted for in day to day research on the ground. Space applications, especially in the realm of Earth Observation/Remote Sensing, are constantly increasing in diversity, sensitivity and accessibility in terms of costs and ease of distribution of information. Constant surveillance has produced a backlog of images and readings, some of which have entered the public domain, that enable the compilation of historical data series, which better aid conservation specialists in assessing the rate of damage and the subsequent improvements to the underlying conditions. It is this feedback that is of vital importance in conservation efforts and tailoring their response. Satellite surveillance can glean information such as the state of aquifers, the rate of sinking, the presence and preponderance of pollutants in air, water and soil, as well as their physical characteristics, the movement of the ground, the impact of events such as earthquakes, and even the anthropic threat of site vandalism and theft.

Project SHC envisions a partnership between the ESA and conservation specialists to establish a multidisciplinary team studying the intersection between space capabilities and conservation needs. By identifying the areas where Earth Observation yields a relevant insight into the threats facing a particular heritage site, National and European authorities, as well as the local specialists, are empowered with new tools for site conservation, protection and restoration.

The potential beneficiaries are in the thousands, throughout the European Union and beyond. The project can establish a standard of approaching conservation through the lens of space applications that is relevant for efforts in any part of the world, depending on the availability and provision conditions for space-based services. In the EU, the efforts under the GMES/Copernicus programme have created an underlying opportunity to research and establish such a system of protection with minimal costs.

The core of the project consists of the following components, over a two year period:

1. Setting up a multidisciplinary team of GIS specialists from the ESA and selected partners, along with conservation experts, to develop the space capabilities into *products* and *tools* for conservation efforts. The dialogue between these two groups matches the macro vision of space imaging with the specific knowledge of conservation needs. The end result of a 20 man team working for one year is a document of reference on the applicability of space capabilities to conservation efforts, along with methodologies for placing relevant information in the hands of beneficiaries.

The estimated costs are:

- Manpower costs: EUR 4.000 times 20 members times 12 months = EUR 4.000 times 240 man-months = EUR 960.000
- Costs of four working meetings at EUR 35.000 per meeting = EUR 140.000
- Costs of editing and publishing = EUR 30.000

2. Identifying five European sites on which to test the new methodologies and assess the enhancement of the conservationists' knowledge and efforts. The beneficiaries will be assisted in obtaining the current and historical data for the relevant threats and they will, in turn, integrate it into their processes – soliciting government funds, approving major work, arguing for changes in the underlying conditions (better environmental protection) and appealing to the public with regards to the threats facing the monuments, backed by hard data. This stage should last another year, and the five selected sites should be as varied as possible – urban and rural sites, ancient and medieval, ruined or in use, solitary or collective (like a section of a city).

The estimated costs are:

- Manpower costs: EUR 4.000 times 20 members times 12 months = EUR 4.000 times 240 man-months = EUR 960.000
- Costs of two working meetings for each of the 5 sites, attended by a sub-team of the core group, at EUR 10.000 each = EUR 100.000
- Costs of editing and drafting reports on the effectiveness of the tests = EUR 50.000
- The cost of the National collaborators for each site would be the responsibility of their respective organizations

3. The results are gathered and published, along with the documents of reference. To save costs on dissemination and awareness building, a segment on National Monument protection can be included in the GMES/Copernicus yearly conferences in many countries on the benefits and opportunities of the programme's resulting hardware and business model.

The estimated costs are null, as the initial awareness campaign would take place during already scheduled and budgeted events. If a special event is desired in Brussels or another European Capital, with large participation, including from outside Europe (150-200 people total), the costs could reach EUR 200.000.

4. Further events may be organized, with a focus on conservation, especially in countries whose resources and knowledge in this field may lag behind the most advanced EU states in the field of space capabilities usage. This stage is beyond the scope of the pilot project, but events could be organized by the beneficiary states, with European authorities covering transport and accommodation for a small team of "evangelists" for each event, composed of a conservation expert and a space applications expert. In time, a network linking conservation authorities to the ESA and other specialist organizations could be formed, to help update the documents of reference, to disseminate the new state of the art in the field, and to address issues of common interest in conservation.

Conclusion

The proposal lays out a plan for a cost-effective, multidisciplinary, novel and scalable approach towards conservation of European heritage through the use of space capabilities. Its cost over two years is projected at EUR 2.440.000 and includes 20 full time staff, five test sites, a number of work meetings, general and specialized deliverables, as well as some dissemination and awareness raising activities. Care has been taken to emphasize the compatibility of the proposal with the existing ESA efforts at raising awareness of the capabilities of the SENTINEL satellites in the GMES/Copernicus Programme, which feature diverse capabilities and an unprecedented degree of freedom of access and processing of collected information. To this end, some of the promotion activities for the project have been folded into the yearly GMES/Copernicus conferences in Member States. In the long run, it is possible to even form a network of conservationists and imaging specialists, to help disseminate new tools and maintain their technological edge. The project also serves as a basis for cooperation with partners from beyond Europe, who have just as much interest in learning how to protect their own heritage.

Protecting European heritage sites is a critical responsibility for the European Union and for its Member States. The number of threats and vulnerabilities associated with these sites is extensive, as is their usefulness in the economy, in National and European identity and pride and in the understanding of European history, which reinforces core European values and guides the future of the European project.

Sources:

- Stefan Doytchinov, Augusto Screpanti, Giovanni Leggeri, “Effects of Air Pollution on Materials, Including Historic and Cultural Heritage Monuments”, ENEA Italy, <http://www.enea.it/it/produzione-scientifica/EAI/anno-2012/knowledge-diagnostics-and-preservation-of-cultural-heritage/effects-of-air-pollution-on-materials-including-historic-and-cultural-heritage-monuments>
- Michael Reddy, “PRESERVING AND PROTECTING MONUMENTS AND HISTORICAL SITES”, US Geological Survey, http://wwwbrr.cr.usgs.gov/projects/GWC_Crystal/teachers-pupils/index.html
- Various authors, “Environmental Impacts on Historical and Cultural Monuments - Measures to Protect Cultural Heritage”, part of the Monitoring Armenia series of UNECE <http://www.unece.org/fileadmin/DAM/env/europe/monitoring/Armenia/en/Part%20III%20-%20Ch.%201.pdf>
 - Various authors, “Impacts of Acid Rain on Buildings”, Air-Quality.org.uk, <http://www.air-quality.org.uk/12.php>
 - N. Venkat Rao, M. Rajasekhar, Dr. G. Chinna Rao, “Detrimental effect of Air pollution, Corrosion on Building Materials and Historical Structures”, published 2014 by American Journal of Engineering Research (AJER), USA, <http://www.ajer.org/papers/v3%283%29/ZT33359364.pdf>
 - Shoureshe Kanani, Hassan Zandi, “A Study of the Damages to Historical Monuments due to Climatic Factors and Air Pollution and Offering Solutions”, World Academy of Science, Engineering and Technology, <http://waset.org/publications/6941/a-study-of-the-damages-to-historical-monuments-due-to-climatic-factors-and-air-pollution-and-offering-solutions>