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The Contribution of the EXCELSIOR Project for Cultural Heritage

K.Themistocleous*[ab], D. Hadjimitsis[ab], G. Schreier[ac], T. Krauss[ac] & H. Kontoes[ad]

[a]ERATOSTHENES Centre of Excellence, 2-8 Saripolou, 3036 Limassol, Cyprus
[b]Department of Civil Engineering and Geomatics, Faculty of Engineering and Technology, Cyprus University of Technology, Limassol, Archbishop 30 Arch. Kyprianos Str., 3036, Lemesos, Cyprus.
[c]German Aerospace Center (DLR), Muenchener Str. 20, D-82234 Oberpfaffenhofen, Germany
[d]National Observatory of Athens, Lofos Nymphon 11810, Athens, Greece

ABSTRACT

The ERATOSTHENES Centre of Excellence for Earth Surveillance and Space-Based Monitoring of the Environment (ECoE) will provide cutting-edge Earth Observation (EO) research in Cyprus, the Eastern Mediterranean, Middle East and North Africa (EMMENA) region, Europe and Internationally for the benefit of the environment and society. One of the main focus areas of the newly established ERATOSTHENES Centre of Excellence (ECoE) is using remote sensing and space-based techniques for effective, efficient and timely cultural heritage monitoring. Such monitoring can offer tremendous benefits to Cyprus governmental institutions and policy implementation bodies, towards the protection of cultural heritage sites, including cost- and time-effective control of cultural heritage sites/monuments, raising awareness on the preservation and protection of cultural heritage from anthropogenic and environmental pressures, early warning systems and systematic monitoring of cultural heritage. Satellite Earth Observation technologies provide the ideal resource of information to undertake a wide range of effective, cost-efficient and non-invasive activities, which cannot be so easily acquired with other tools. As a result of the Copernicus Program, Sentinel 1 and 2 missions provide free satellite imagery that is accessible, provides global coverage, a high temporal resolution enabling image time series analysis and temporal characteristics, allowing for the consistent and timely monitoring of cultural heritage monuments and landscapes. The efficient exploitation of high resolution dense time-series of multi-spectral and radar imagery for large scale applications introduces new important considerations including cost-effective and systematic monitoring service of cultural landscape sites with archaeological remains, monitoring significant risks that cultural landscapes face, as well as aiding archaeological mapping and interpretation. Further-on exploiting high spatial and temporal resolution (i.e. from other satellites beyond Copernicus) improves modelling and data assimilation solutions and integration of space based remote sensing techniques with advanced ground and aerial based ones. Both data allows to develop more efficient and effective tools of investigation and monitoring, able to ensure mapping and monitoring of buried and exposed archaeological structures.
This paper was developed under the auspices of the activities of the 'ERATOSTHENES: Excellence Research Centre for Earth Surveillance and Space-Based Monitoring of the Environment'- 'EXCELSIOR' project that has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 857510 and from the Government of the Republic of Cyprus through the Directorate General for the European Programmes, Coordination and Development. From 1st of October 2019, the ERC group (Department of Civil Engineering and Geomatics) at the Cyprus University of Technology is on the way to be upgraded to ERATOSTHENES Centre of Excellence (ECoE) through 'EXCELSIOR' H 2020 Widespread Teaming project (www.excelsior2020.eu).

Keywords: cultural heritage, EXCELSIOR, Copernicus, Earth Observation, Remote Sensing

*k.themistocleous@cut.ac.cy;

1. INTRODUCTION

Cultural heritage represents a priceless resource for the sustainable development in Europe and worldwide. It is an integral element of a European set of values and respect for heritage is vital for developing a common European identity. Cultural Heritage has finally been recognized as an incentive for strengthening the resilience of society in facing the impact of catastrophic events and its protection has been highlighted as having a key role in support of socio-economic development and sustainable tourism. The preservation of cultural heritage and landscape is today a strategic priority not

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only to assure cultural treasure and evidences of the human past to future generations, but also to exploit them as a strategic and valuable economic asset, if inspired by sustainable development strategies. This is an extremely important key factor for the countries which are owners of an extraordinary cultural legacy, which is particular fragile due to its specific characteristics and specific risks at which cultural heritage is continuously exposed. At global policy level, the Sendai Framework for Disaster Risk Reduction 2015-20306 represented a significant turning point, by including among its key priorities the protection of Cultural Heritage and by inviting national authorities to cooperate in increasing an awareness of Cultural Heritage impacts in the context of exposure to hazards [1]. UN sustainable development goal 11 Sustainable cities and communities, 11.4 strengthen efforts to protect and safeguard the world's cultural and natural heritage [1].

The application of Earth Observation (EO) techniques has proven essential to the detection, documentation, monitoring and preservation of tangible cultural heritage sites. Advanced remote sensing methodologies can provide a multi-temporal analysis and monitoring of cultural heritage sites, in order to provide essential information to stakeholders regarding the condition of the cultural heritage sites, so that appropriate measures can be taken for the preservation and conservation of the sites. Instruments based on the integration of EO products and in-situ data have been exhaustively proven to be a valuable tool in support of the protection and management of Cultural Heritage at risk [2]. One of the main advantages of remote sensing techniques is their capability to provide a huge amount of information in a non-invasive way in a cost-effective way than the traditional techniques. Data acquired by active and passive satellite, aerial and ground sensors have provided the opportunity to visually access areas that may be remote or hazardous, as in the case of wars, terrorist attacks or natural disasters. Especially in these cases, satellite sensing carries the advantage to monitor areas without being there and facing the challenges of political crisis and personal security. Taking advantage of large-spatial coverage, high-spectral and sensitivity satellite remote sensing can be usefully adopted for looting [2].

Such issues were examined within the auspices of the ATHENA project, whose overall objective was to create a centre of Excellence specialised in the field of Remote Sensing for Cultural Heritage applications at the Cyprus University of Technology. The ATHENA project focused on the development and systematic use of advanced remote sensing science and technologies for the multi-temporal analysis and interpretation of archaeological and built cultural heritage, and the distant monitoring of their natural and anthropogenic environment. The ATHENA project is currently integrated within the EXCELSIOR project, whose goal is the development of the Eratosthenes Centre of Excellence (ECoE). The project focuses on conducting basic and applied research and innovation in the areas of the integrated use of remote sensing and space-based techniques for monitoring the environment. The integration of novel EO, space and ground-based integrated technologies, can contribute to a more sustainable and systematic monitoring of the environment, the timely detection of societal risks/threats and the growth of vital economic sectors. The establishment of the Centre of Excellence in 2020 provides the infrastructure and experts necessary to conduct state-of-the-art research and innovation in the areas of the integrated use of remote sensing and space-based techniques for cultural heritage applications within Cyprus. Strategic Partners of the ECoE, such as DLR and NOA, will also provide capacity building for cultural heritage in order to facilitate state-of-the-art research and applications in cultural heritage.

2. EARTH OBSERVATION TECHNIQUES FOR CULTURAL HERITAGE

The European UNESCO sites comprise 40% of the UNESCO world heritage list globally (whc.unesco.org). A considerable amount of these sites lay in the Mediterranean region. The Eastern Mediterranean has a history spanning over 10,000 years, thus resulting in the presence of a rich archaeological and cultural heritage wealth [3]. Cyprus is the largest island in the Eastern Mediterranean and lies at the crossroads of three continents, Africa, Asia and Europe. As a result, it has proven to be a hub for the intersection of great civilizations, including Assyrian, Byzantine, Egyptian, Greek, Hebrew, Minoan, Ottoman, Persian, Phoenician and Roman civilizations [3]. These civilizations have provided a rich cultural legacy, which is still being identified to this day. The majority of the UNESCO World Heritage List of endangered sites are in the Eastern Mediterranean, Middle East and North Africa (EMMENA) region. Remote sensing can provide resources to assist the detection of ancient cultural heritage sites, so that the necessary actions can be taken to identify, survey and excavate cultural heritage sites. With the various wars and conflicts in the Middle east area, remote sensing techniques seem to be the most efficient, time effective way for monitoring cultural heritage's destruction even documenting cultural heritage prior its total extinction, as well as to monitor archaeological looting activities which represent one of the main risks affecting archaeological heritage throughout the world. Figure 1 shows the distribution of UNESCO cultural heritage sites in Europe, Middle East and North Africa.

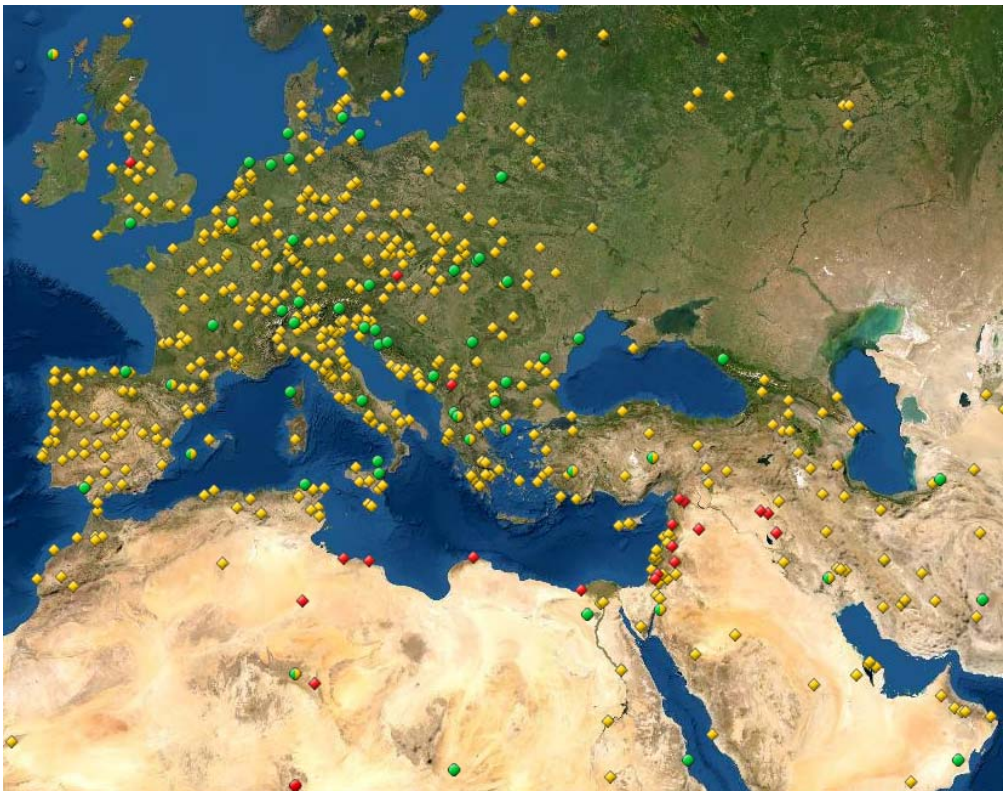

Figure 1: UNESCO cultural heritage sites in Europe, Middle East and North Africa (whc.unesco.org)

The preservation of cultural heritage is a strategic priority to preserve cultural treasures and evidence of the human past for future generations. This is an extremely important key factor for countries which are owners of an extraordinary cultural legacy, which is particularly fragile due to its specific characteristics and risks at which cultural heritage sites are continuously exposed. By taking advantage of large-spatial coverage and a detailed spectral information, satellite remote sensing can be usefully adopted for contrasting looting, especially in countries where the surveillance on site is not particularly effective and time consuming, or non practicable due to military or political restrictions [4].

The impact of EO technologies for archaeology [4] is expected to have a greater effect in cultural heritage access and exploitation through the activities of the ECoE. Over the past decades, passive space technologies for cultural heritage applications have increased due to the enhanced spectral and spatial resolution of satellite sensors and the availability of user-friendly software and routines for data processing and analysis. The use of the Copernicus Program Earth observation data, products and services for monitoring and assessing the potential impact of natural and anthropogenic disasters, humanitarian crises, and conflicts provides new opportunities for EO techniques for cultural heritage applications. Several Copernicus services are currently provided from the Sentinel satellites and other supporting missions. Sentinel-1 and Sentinel-2 can provide systematic radar and optical data worldwide with a high temporal resolution [5]. Progress beyond the state-of-the-art Sentinel 1 and 2 missions provide free data that is accessible, provides global coverage and a high temporal resolution enabling image time series analysis and temporal characteristics, allowing for the consistent and timely monitoring of the Cultural Heritage monuments and landscapes. The European Commission therefore initiated a study and established a task force to map the requirements of the archaeological and cultural sites preservation community versus existing and possibly new services, Copernicus can provide [6]

The Centre of Excellence is dedicated to conducting research and creating applications that will focus on the use of EO for cultural heritage in areas such as (a) supporting, understanding, analyzing, documenting and monitoring cultural

heritage sites; (b) monitoring of existing sites regarding their vulnerability and exposure to natural and anthropogenic hazards; (c) documenting the structural analysis of existing cultural heritage sites; (d) detecting buried cultural heritage and archaeological sites; (e) facilitating the exploitation of big data for cultural heritage applications; (f) improving EO data interpretation using a multidisciplinary network of experts and (g) integrating data from diverse sources [7].

3. CENTRE OF EXCELLENCE ACTIVITIES FOR CULTURAL HERITAGE

The data resulting from EO techniques can be exploited for the benefit of the general public, education, stakeholders, researchers and other countries in the region. To maximise the benefits of the application of digital technologies to cultural heritage, important challenges and obstacles need to be addressed through research in order to develop a holistic approach which meets the needs of all existing and potential groups and thereby increases the social and economic value of cultural heritage. This will reinforce and expand partnerships and networks, exploiting the unique and strategic position of Cyprus and other countries in the Mediterranean. The activities of the EXCELSIOR project will be based on the research domains of cultural heritage, spatial analysis & computation and built heritage protection. Following, these research domains will be linked with the research and innovation hub, which incorporates activities that include services, digital products, tourism and regional development, to research promotion and entrepreneurship. This will be under the auspices of the stakeholders, namely, academic and research institutions, industry and the private sector and policymakers, who are responsible for research and innovation.

3.1 Increase awareness

The primary activity for exploiting EO data through the EXCELSIOR project is to raise awareness in the local community regarding the innovative aspects of space technologies for cultural heritage. This can be accomplished by promoting cultural heritage applications to primary and secondary schools through a series of presentations and workshops. This would include visits to schools and invitations to events such as the “Researcher’s Night”, which encourages students to engage in remote sensing. In addition, the general public can also be informed regarding activities involving EO for cultural heritage through dissemination activities, such as informal lectures.

3.2 Societal Impact

Effective, efficient and timely cultural heritage monitoring can offer tremendous benefits to the region, to the national governmental institutions and policy implementation bodies, towards the protection of cultural heritage sites. To name a few: a) cost- and time-effective control of cultural heritage sites/monuments; b) raising awareness on the preservation and protection of CH from anthropogenic and environmental pressures; c) early warning systems and systematic monitoring of CH sites, at national and regional levels, of invaluable socio-economic impact; d) risk assessment and mitigation strategies. Finally, the inter-disciplinary nature of the EO-based cultural heritage monitoring will bring in state-of-the-art research capacity, addressing multiple diverse and fast-evolving scientific areas. The ECoE will also have a societal impact, where the ECoE will provide services and applications for stakeholders to utilize EO data to make informed decisions. The ECoE will also monitor and document cultural heritage sites, thereby providing precise information to stakeholders, which can then be used for conservation efforts. The social impact for cultural heritage should focus on the importance of preserving cultural heritage sites, especially in areas where tourism plays a significant role in the economy. As well, 3D reconstructions of cultural heritage sites can be developed using in situ and high-resolution images.

3.3 Research

Research in remote sensing will take place under the domain of ‘resilient society’ within the ECoE framework. State-of-the-art research will take place by exploiting the skills and knowledge of expert researchers which will lead to research excellence. The various research topics that will be researched include cost-effective monitoring service of cultural landscape sites with archaeological remains, systematic mapping and monitoring of cultural landscapes with buried and exposed archaeological remains, monitoring risk factors at cultural heritage sites and the integration of space based remote sensing techniques with advanced ground based ones in order to develop more efficient and effective tools of investigation and monitoring, able to ensure mapping and monitoring of buried and exposed archaeological structures. As such, the main topics in the field of cultural heritage include the systematic monitoring of cultural heritage, disaster risk assessment, looting monitoring, fusion of ICT with space technologies, etc.

For a more efficient systematic monitoring and risk assessment for the protection of cultural heritage sites, specific cutting-edge equipment is required. As a result, the ECoE will require the following infrastructure to be able to conduct research in cultural heritage [8]. The equipment includes new field spectroradiometers; visible, infrared and thermal

cameras; UAVs; Laser scanners; georadar; magnetometers; Electrical Resistivity Tomography (ERT) and software for the integrated raster and vector processing of photogrammetric data. The ECoE will use data obtained from the Copernicus Data Hubs for Sentinel data, ECoE antenna for NRT regional acquisition of satellite data, proprietary Very High Resolution (VHR) satellite imagery, cloud infrastructure (i.e. DIAS), among others.

3.5 Education

The academia sector is critical in regard to using EO techniques for cultural heritage applications. A degree of MSc in Advanced Earth Observation Studies will provide the student with the necessary skills to conduct state-of-the-art research and innovation within the field. Within the graduate level, lectures and courses will take place for Master and PhD students on cultural heritage related topics. As well, Master and PhD students will be supervised over their dissertation on EO and cultural heritage. Summer school programs with hands-on training on cultural heritage related topics will take and will consist of professionals from around Europe and the Mediterranean region. As well, knowledge transfer can also take place among professionals, through secondments between different centers. In order to create a group of heritage professionals with relevant EO skills in Cultural Heritage monitoring, conservation and protection, the EU Commission should contribute by promoting academic courses that include both EO and Copernicus monitoring capacity knowledge.[1]

3.6 Regional initiative

Regional initiative can include networking with countries within the EMMENA region in terms of working together in using EO techniques for cultural heritage. In such initiatives, countries within the EMMENA region who also have a strong cultural heritage history (such as Jordan or Egypt) can provide information on their cultural heritage applications, so that each can benefit from the other's activities. Relationships with a range of regional and International partnering organizations will be developed and their role will be a formally branded relationship. Partnering organizations will work closely with the ECoE to develop and deliver services of a strategic value for mutual benefit. By developing collaborations with partnering organization, the ECoE will acquire knowledge, create innovative products and practical applications and provide EO services and data from its station's coverage. By working together, the ECoE stakeholders and partnering organizations can drive innovation and research development beyond what any one group could do alone.

3.7 Innovation

The ECoE will foster the regional cooperation of research entities with industry and SMEs, focusing on knowledge-intensive sectors. Expertise and high-level knowledge in novel geospatial techniques and methodologies will promote skill upgrade in the EO field, unique opportunities for the funneling of research results in entrepreneurship, opportunities for spin-offs, new jobs for local and International researchers and new markets in Cyprus. Through the capitalisation of existing networks, ECoE will reach significant innovation ecosystems related to cultural heritage in order to foster the conditions needed to unleash the potential of EO solutions in relation to cultural heritage protection and preservation implementation. Exploiting the connection between the scientific innovations, national and regional policy bodies, there is a great potential for commercialization of such products. The innovation services are expected to consult with end-users and stakeholders to understand the needs and design services tailored for them, widen the network of stakeholders and end-users on the field of cultural heritage, calibrate EO products through the collection of ground-truth data for the purposes of quality assurance and validation, develop operational services and products that can be used by stakeholders, public authorities and end-users for the monitoring and protection of cultural heritage sites and create the provision of consultation services on the integration of EO based cultural heritage monitoring products within the existing operations/systems of the stakeholders.

4. CONCLUSIONS

The EXCELSIOR project seeks to build critical scientific mass in Cyprus and the EMMENA region by connecting Centres of Excellence in the region, thereby overcoming local barriers and modernizing research culture. In addition, the project seeks to foster multidisciplinary research and training activities, modernise research culture, and become a leading provider of geospatial and related services in support of cultural heritage research and education in the region. Last, the project seeks to promote Excellence by actively seeking out scientists and researchers on a global scale, while promoting sustainable new job creation.

The EXCELSIOR project provides remote sensing techniques to the EMMENA region in order to document and analyze cultural heritage data for both tangible and intangible heritage as well as monitor cultural heritage sites for damage from

looting, geo-hazards, etc. To further monitor and document cultural heritage sites, the Data Acquisition Station Hosting (DASH) that will be installed at the ECoE will provide near-real time data for cultural heritage monitoring, especially for disaster response.

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