How can space assets support the Cultural Heritage ecosystem? Use cases and commercial applications

Overview of Cultural Heritage ecosystem and value chain

Cultural Heritage is gaining attention, notably from the public sector, which provides the largest part of funding, but also from the private sector, that is trying to seize the associated growing commercial opportunities. Indeed, in the last decades, in addition to the historic, social and anthropological dimension, Cultural Heritage has also become a major driver for economic growth and sustainable development by attracting tourists which in turn boosts the economies of the destinations visited. In Europe, it is estimated that cultural tourism accounts for 40% of all tourism[1]. This creates employment: when it comes specifically to Cultural Heritage, around 300,000 Europeans work directly in this sector[2].

But what exactly is Cultural Heritage?

Today there are 1,157 sites on UNESCO's World Heritage list[3], 900 of which are cultural sites and 39 of which are mixed sites (both cultural and natural). Among the 900 cultural sites, 39 are considered in danger.

By assigning places as Cultural Heritage Sites for already a half century, UNESCO has helped to pass them on to future generations by encouraging commitment to Cultural Heritage conservation. This includes providing emergency assistance for sites in danger, offering technical assistance and professional training, and supporting public awareness-building activities. But Culture Heritage is of course more than Cultural Heritage sites. The meaning of Cultural Heritage has expanded over time from single objects to historic cities, cultural landscapes, and serial properties.

◆ Cultural site

● Natural site

◐ Mixed site

HERITAGE IN DANGER

◆ Cultural site

● Natural site

◐ Mixed site

UNESCO's map of World Heritage sites

1. CULTURAL TOURISM...
2. EU POLICY FOR CULTURAL HERITAGE...
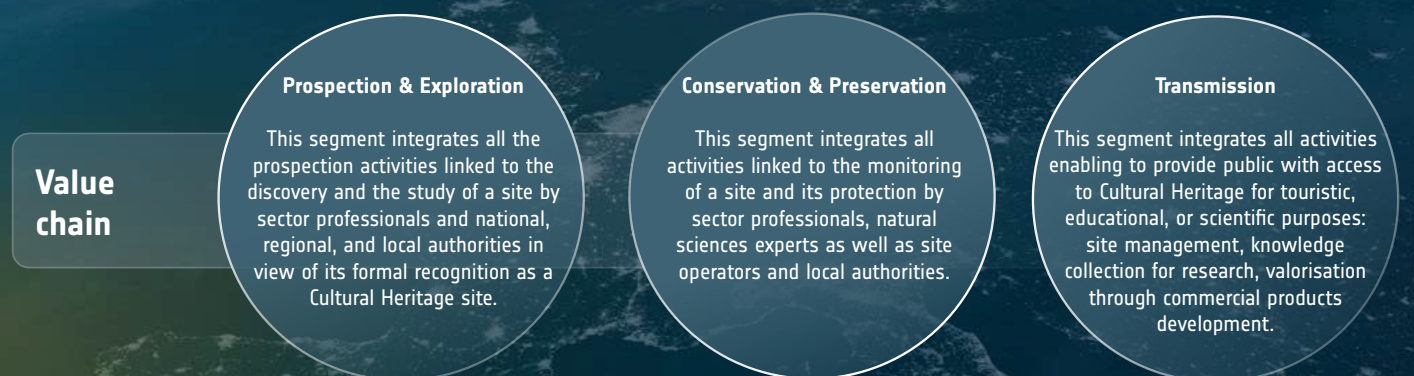3. WORLD HERITAGE LIST...

Because of its very important socio-economic impact, Cultural Heritage is now addressed by a large variety of actors at various levels: international organisations, the European Commission, national governments, regions, site managers, etc.
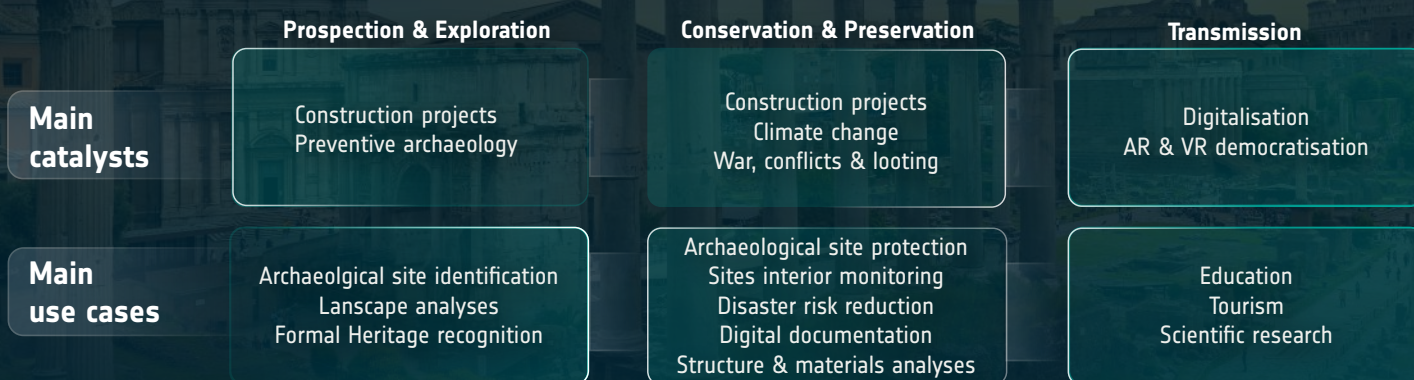
Main Cultural Heritage international stakeholders

The United Nations Educational, Scientific and Cultural Organization

CIPA Heritage Documentation

The International Centre on Space Technologies for Natural and Cultural Heritage

The International Centre for the Study of the Preservation and Restoration of Cultural Property

The Digital Heritage Research Lab

The International Union for Conservation of Nature

The International Council on Monuments

The United Nations Institute for Training and Research

The International Council of Museums

The International Criminal Court

They are providing support across the Cultural Heritage value chain:

Value chain

Prospection & Exploration

This segment integrates all the prospection activities linked to the discovery and the study of a site by sector professionals and national, regional, and local authorities in view of its formal recognition as a Cultural Heritage site.

Conservation & Preservation

This segment integrates all activities linked to the monitoring of a site and its protection by sector professionals, natural sciences experts as well as site operators and local authorities.

Transmission

This segment integrates all activities enabling to provide public with access to Cultural Heritage for touristic, educational, or scientific purposes: site management, knowledge collection for research, valorisation through commercial products development.

Main Cultural Heritage needs and space added value

	Prospection & Exploration	Conservation & Preservation	Transmission
Main catalysts	Construction projects Preventive archaeology	Construction projects Climate change War, conflicts & looting	Digitalisation AR & VR democratisation
Main use cases	Archaeolgical site identification Lanscape analyses Formal Heritage recognition	Archaeological site protection Sites interior monitoring Disaster risk reduction Digital documentation Structure & materials analyses	Education Tourism Scientific research

As highlighted during a dedicated one-day workshop organised by the European Space Agency's (ESA) Commercialisation Gateway[4], space-based solutions address emerging needs across the whole Cultural Heritage value-chain:
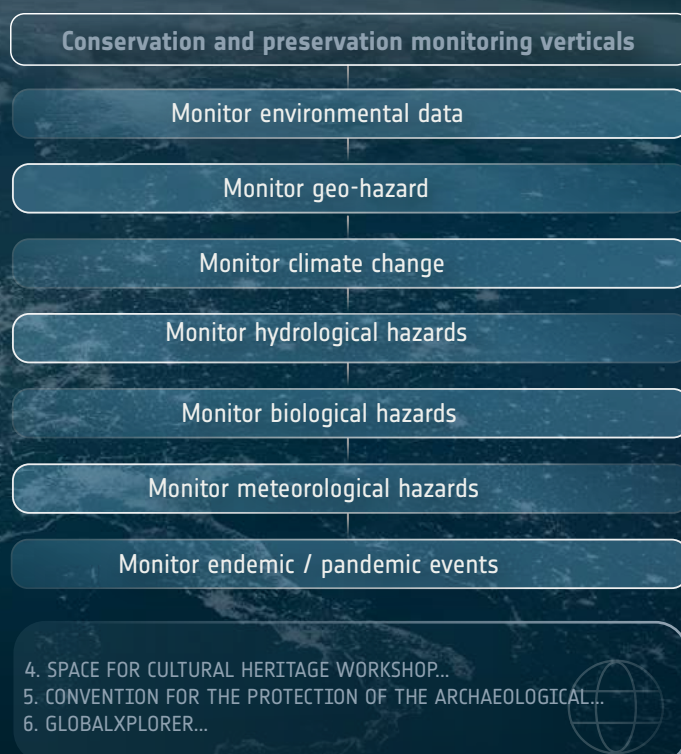
Prospection & Exploration:

Archaeological research, traditionally mainly funded by governmental and philanthropic sources, has grown exponentially in the last two decades with new research units, but also emerging private sector companies. The sector is facing increasing demands to become more results-driven and cost-effective, in times where activities such as site surveying have considerably increased in costs in Europe but also in emerging countries. Moreover, as reflected by the Valetta Convention[5] adopted in 1992, construction projects have emphasised the importance of development-led, rescue and preventive archaeology, driving new commercial opportunities for space-based solutions.

Today, in Europe, prospection and exploration activities are mainly carried through on-site inspections, in person or by drones, or commissioned aerial photography inspections. LiDAR has also long been viewed as the 'gold standard'. However, these in-situ approaches are both labour and time intensive, but also expensive and inappropriate for large, dangerous, and hard to access areas. This is changing thanks to Earth Observation methods that are increasingly finding their way into mainstream archaeology and enable to cover large, previously inaccessible areas effectively and precisely. Since the 1980s, the use of Synthetic-aperture radar (SAR) data has for example been explored to identify buried archaeological features in dry desert areas. Currently, a rising interest has been seen in the use of Earth Observation (EO) for prospection of marine, coastal and fresh water archaeological sites. To process and analyse space derived data, the use of experts' team is well established. In addition, new approaches such as crowdsourcing or automated site detection and change detection based on Artificial Intelligence (AI) are also gaining ground. Crowdsourcing is notably carried by the

GlobalXplorer[6] online platform that uses the power of the crowd to analyse satellite images currently available to archaeologists.

Conservation & Preservation:

Cultural Heritage sites are in danger. Climate change (especially changes in temperature, precipitation, and atmospheric moisture), that is already having negative impacts on 34% of natural World Heritage sites, has become the number one threat to them. Moreover, Cultural Heritage is also facing many more human-induced threats (war and conflicts, exploitation of resources, pollution, overtourism, etc.) as well as geo-hazards, land change or ground movements, etc. Urgent safeguarding measures therefore must be deployed to mitigate their impact. This includes the surveillance and modelling of the evolution of the natural environment surrounding Cultural Heritage sites based on a very diverse range of monitoring verticals:

Conservation and preservation monitoring verticals

- Monitor environmental data
- Monitor geo-hazard
- Monitor climate change
- Monitor hydrological hazards
- Monitor biological hazards
- Monitor meteorological hazards
- Monitor endemic / pandemic events

4. SPACE FOR CULTURAL HERITAGE WORKSHOP...
5. CONVENTION FOR THE PROTECTION OF THE ARCHAEOLOGICAL...
6. GLOBALXPLORER...

All these verticals can benefit from the use of EO data, models, dedicated monitoring of changes and connectivity. These can be used to understand changing site surroundings at scale and in a systematic manner, automate the identification of criticalities or deformations affecting structures, secure rapid emergency interventions, etc. Global Navigation Satellites System (GNSS) data moreover brings another essential layer of information, for example to precisely map ground deformation or access visitors' positioning for flow analysis.

Transmission:

Knowledge about Cultural Heritage is not equally accessible to everyone, in particular not to the youngest generations, and should therefore be improved. Cultural tourism as well as Cultural Heritage education and scientific research are all heavily disrupted by the development of new digital technologies: developments in 3D-capturing, 3D-processing, and multimedia tools such as augmented reality or virtual reality are some examples expected to increase in

adoption. Covid-19 has accelerated this digitalisation of Cultural Heritage in times of limited possibilities of visiting physical visits.

Digitalisation however raises the question on how to best capture, document, store, preserve and provide 3D data effectively to the Cultural Heritage community. If capture is currently mainly done through methods such as photogrammetric acquisition, mobile scanning, UAV-flying, ground/aerial survey and LiDAR, there is a growing interest to use raw satellite data (e.g. SAR) to support the development of 3D surface models of Heritage sites. Space also has a role to play in this through GNSS which can trigger information based on the visitor's position on the Heritage site. The emergence of future generation mobile network 5/6G will also bring these immersive technologies to the next level by offering enhanced computing power and thus improving user experience and furthering the potential for mass adoption. Satellite communications could potentially support the enablement of these services for sites where there is insufficient terrestrial coverage.

Digitalisation

Cultural Tourism

Education

Scientific Research
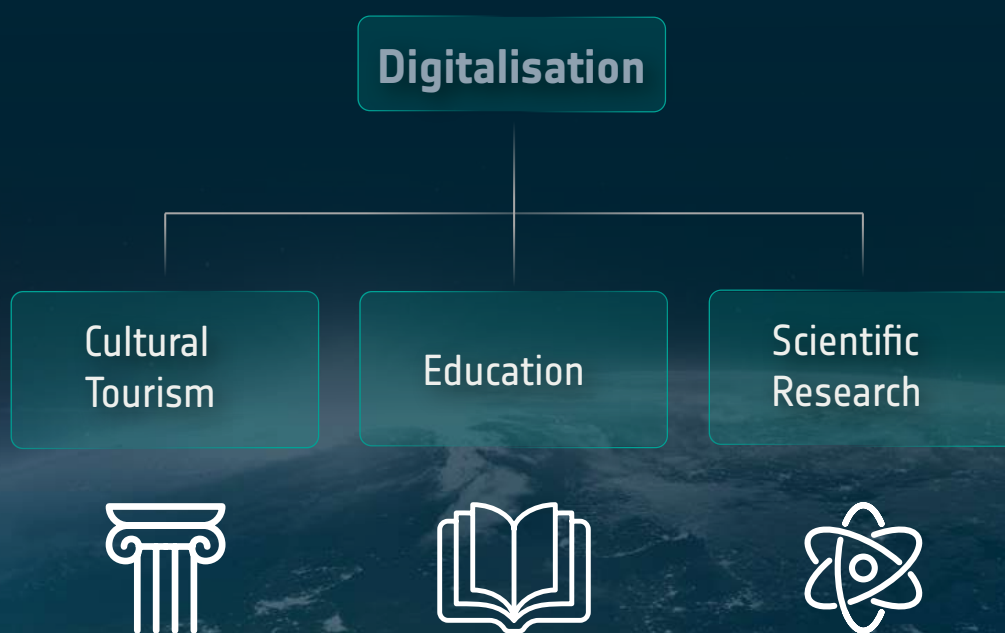
→ To unveil, safeguard and capitalise on Cultural Heritage, decision makers need data: this is where the space sector, combined with cutting edge technologies such as Artificial Intelligence and machine learning, can play an important role.

Space-added value by public initiatives

As attention to Cultural Heritage management is still very much driven by the public actors, so is the use of satellite remote sensing data in the sector. On the European level, UNESCO and ESA have long been working for the integration of both fields, notably through the joined launch of the "Open Initiative on the Use of Space Technologies to Support the World Heritage Convention"[7] in 2003. Since then, ESA has been developing various projects across the whole Cultural Heritage management value chain:

The Copernicus Programme is also a key lever for applying space to Cultural Heritage use-cases. A dedicated study called "Copernicus services in support to Cultural Heritage"[8] has been carried out in 2018, assessing the possibility of initiating institutional actions for the promotion of Copernicus data for Cultural Heritage preservation, monitoring and management. The study highlighted that the different Copernicus core services have already

internally the relevant products to cover partially and entirely 16.5% of the user requirements expressed by the Cultural Heritage user communities over the value chain. This percentage moreover increases when considering Sentinels capabilities and Copernicus Contributing missions. Nevertheless, as of today, Cultural Heritage is not directly mentioned in any delegation agreement of the Copernicus core services' entrusted entities, thus not encouraging the development of specific products or adaptation of existing ones to respond to Cultural Heritage-associated needs.

Finally, on the national or local levels, many initiatives are flourishing. As an example, the Research Centre of the Slovenian Academy of Sciences and Arts (RCSAS) is developing a tool for visualising LiDAR data in the context of the Cultural Heritage sector that is expected to make EO data and AI methods more accessible to the Cultural Heritage community.

Example of ESA projects

PROSPECTION & EXPLORATION

ArchEO

The **Arc**haeological application of **E**arth **O**bservation Techniques project aims to identify favourable conditions favourable for the analysis of archaeological sites and landscapes in Central Europe with the use of satellite-based optical data.

CONSERVATION & PRESERVATION

AMOR

The **A**dvanced **M**ultimedia and **O**bservation services for the **R**ome cultural heritage ecosystem project aims to safeguard (through a predictive restauration and conservation model) and fructify Roman cultural heritage with the use of EO and global navigation satellites.

TRANSMISSION

INVENTA

The **IN**novative ser**V**ices to **EN**hance the valorization, promotion and the preservation of cul**T**ural herit**A**ge project aims to valorise Cultural Heritage with the use of Virtual and Augmented Reality combined with the 5G network Satellite Navigation and Earth Observation space technology.

7. SPACE TECHNOLOGIES FOR HERITAGE: TWO CASE STUDIES...
8. COPERNICUS SERVICES IN SUPPORT TO CULTURAL HERITAGE

Space-added value by commercial initiatives

In the field of prospection & exploration, private sector companies have emerged. Among these, ArchAI[9] is the first company proposing a platform that leverages EO, AI and computer vision models to automate Heritage feature detection. It joined ESA BIC UK in 2021 to focus on the development of its second product to de-risk the construction industry by automatically detecting archaeological sites.
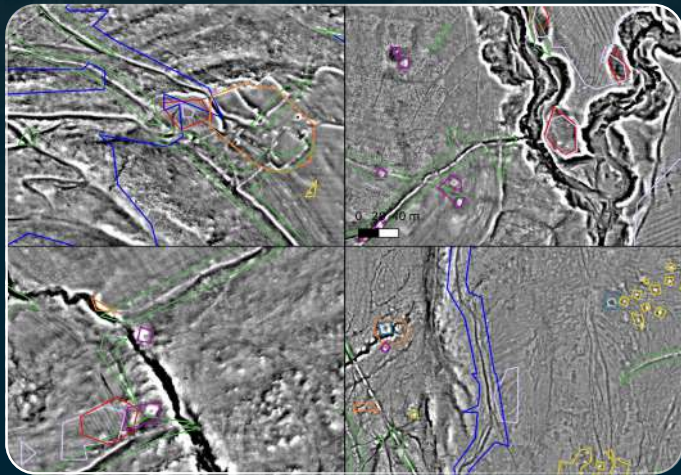
Images of the Isle of Arran in Scotland with predictions showing all the different site types that ArchAI has trained their Artificial Intelligence on

In the field of Conservation and Preservation, the need to monitor and record a large panel of data linked to climate change has been highlighted, as well as geo or hydro-hazards, tourism flow, etc. As per the diversified nature of data types to monitor and associated data collection methods, there is a great need to centralise this information in easy to access structured information platforms. Although not only specialised on Cultural Heritage use-cases, many EO companies do so by proposing platforms for critical infrastructure monitoring, environmental risk analysis, emergency planning, etc. The Romanian based company Terrasigna[10] for example provides ground deformation and infrastructure stability risk analysis services mainly based on Synthetic Aperture Radar Interferometry (InSAR) and Persistent Scatterer Interferometry (PSI). The Romanian Palace of Parliament, one of the largest buildings in the world and a major tourist attraction, was notably subject to such a risk evaluation[11].

Satellite radar scans show various points on and around the Palace that are slightly rising in blue or sinking in yellow/ orange (source: Terrasigna)

In the field of transmission, the global augmented and virtual reality market size was valued at $27.6 billion in 2021 and is projected to reach $856.2 billion by 2031. However, the adoption rate under Cultural Heritage sites is still low due the current price point. This has also partially to do with the fact that the sector is reliant on public funding which in some cases can limit the investments in these types of technologies. Some companies working on Cultural Heritage use-cases nevertheless foster digitalisation of the sector and are showing interest in the possibilities offered by space. This is the case of Mindesk, in which the CEO took part in the dedicated one-day workshop organised by the European Space Agency (ESA) Commercialisation Gateway[12]. The company that offers expertise to effectively present and review infrastructure projects in Virtual Reality, believes satellite data is fundamental for feeding 3D models for exploration and learning at different local, regional, and global scales.

→ ESA can support European companies willing to bridge the gap between space and Cultural Heritage through many initiatives such as the InCubed Programme[13], the ESA BIC network[14], TIA BASS[15], the Destination Earth programme[16], and much more.

9. ArchAI...
10. NATIONAL GROUND MOTION MONITORING: ROMANIA...
11. ROMANIAN PARLIAMENT PALACE - RISK ASSESSMENT
12. SPACE FOR CULTURAL HERITAGE WORKSHOP...
13. INCUBED IS AN ESA PROGRAMME MANAGED...
14. ESA BUSINESS INCUBATION CENTRES...
15. TIA BASS...
16. DESTINATION EARTH...