EO for Cultural and Natural Heritage Workshop 2024

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Monitoring of Cultural Heritage Assets in 3D+ Virtual Space, An Approach

AIDL4CH

Tamer Özalp *(Ph. D., ESA Fellow)*

Researchturk Space Co., Türkiye

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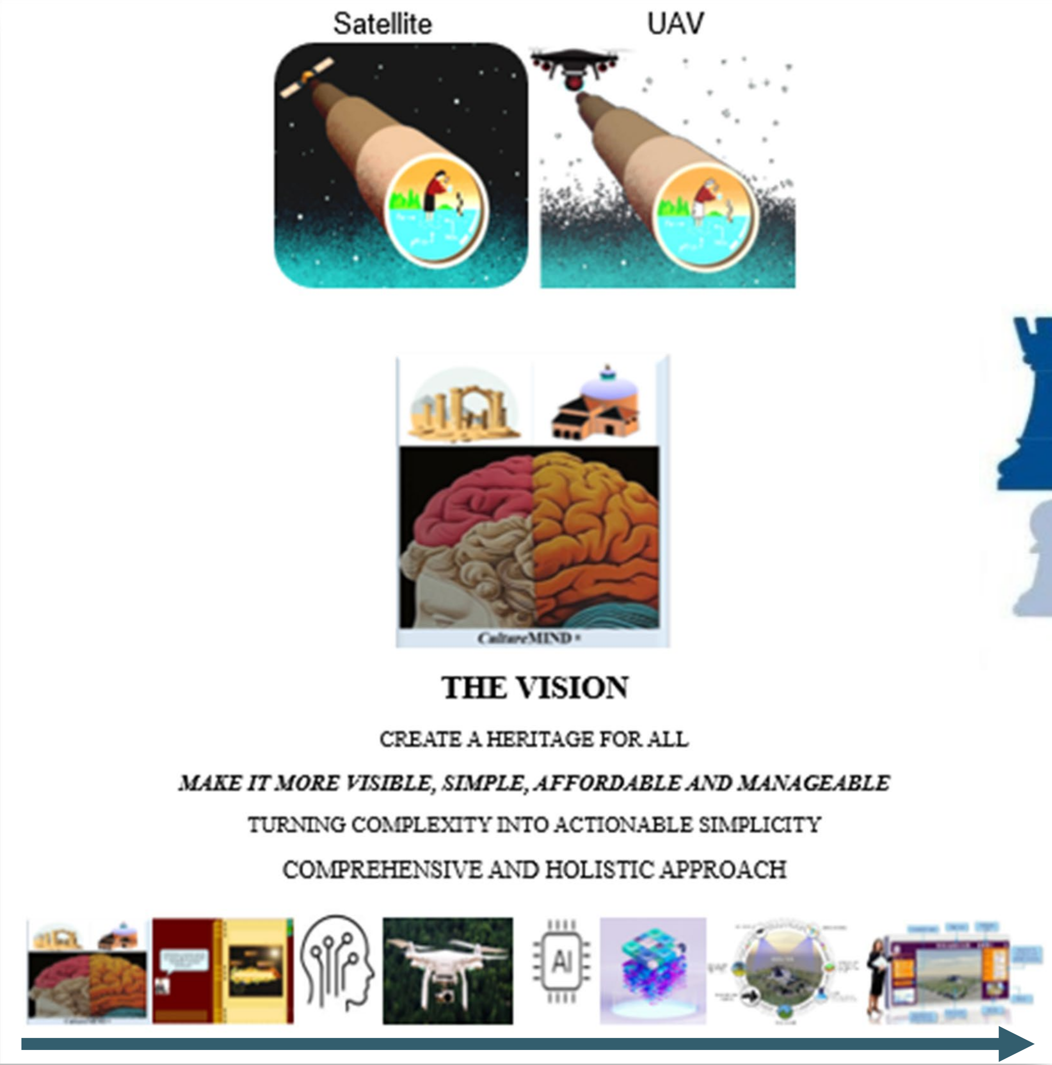
The Vision and Strategy



Our vision is to make cultural heritage accessible, visible, affordable, and easy to manage.

By simplifying complex systems into actionable insights, we aim to establish a sustainable, technologically advanced framework for preserving heritage assets worldwide.

To achieve this, our strategy revolves around three key pillars:

1. **Innovation**: Leveraging AI and deep learning, 3D+ virtual spaces for dynamic real-time, accurate monitoring and visualization of cultural assets that provide **continuous monitoring and early detection** of potential risks.
2. **Collaboration**: Building global partnerships among communities, governments, and experts to ensure tailored, effective solutions.
3. **Sustainability**: Implementing scalable, cost-effective monitoring systems that empower local teams and ensure long-term preservation.

Together, these strategic goals allow us to secure our cultural heritage for future generations.

Approach *(Simplified)*

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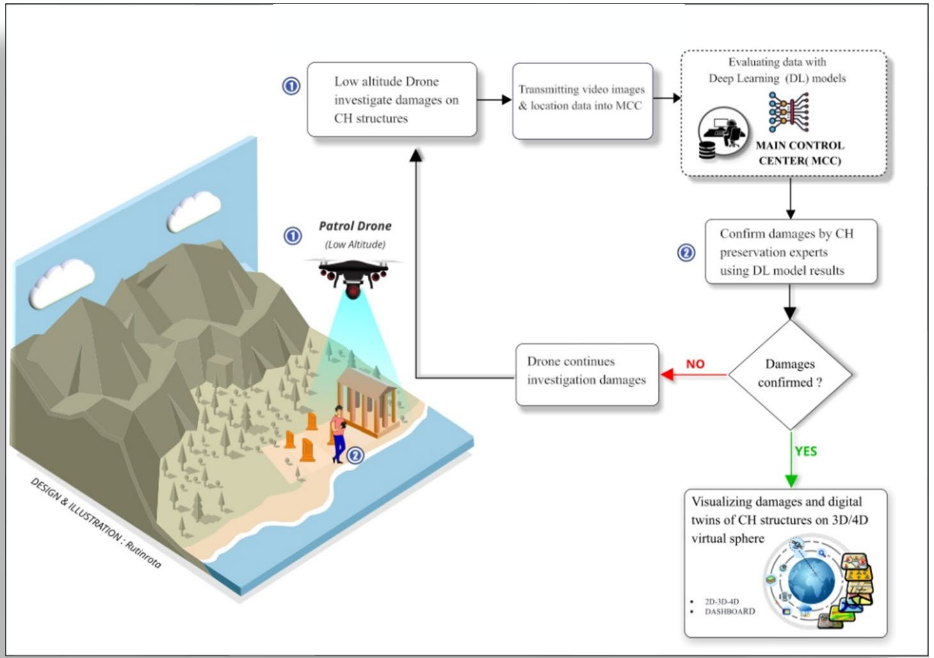
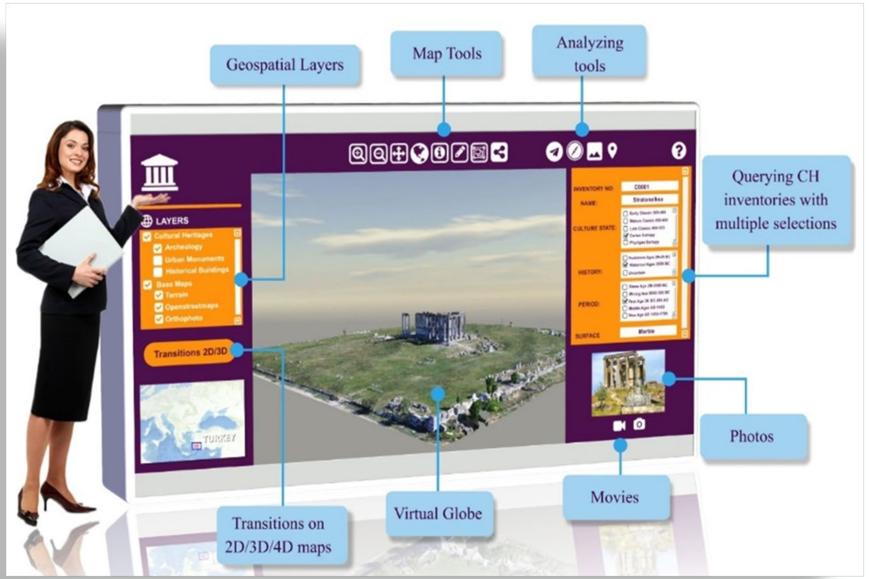
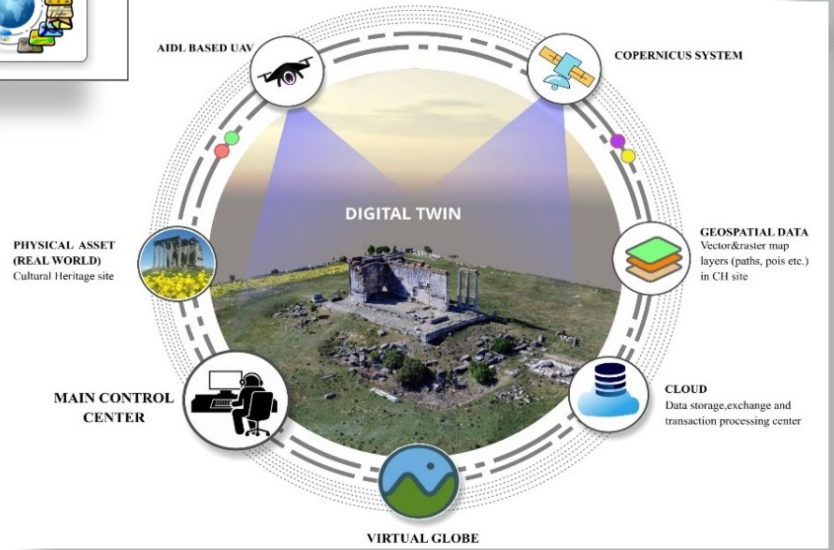


HOW IT WORKS



To detect and identify **damages/changes** in cultural heritage assets



To monitor **digital twins** of these assets on a 3D/4D virtual globe, and **monitoring platform** utilizing an AI-driven, cost-effective UAV drone camera in conjunction with deep learning models.

The Significance

The Significance of Cultural Heritage: A Connection to Our Past, enrich our present, and inspire our future

Cultural heritage is increasingly recognized as **vital** in a rapidly **changing and complex world**, leading to the emergence of new practices and concepts surrounding its preservation and valuation.

Heritage sites are essential to **global economic** and cultural activities, with heritage information becoming a **valuable commodity.**

The importance of passing down cultural heritage from generation to generation is emphasized, as it reflects the **history, identity, continuity and values** of communities and nations.

The **multifaceted significance** of these assets **highlights the need for monitoring,** evaluating, and preserving them as part of sustainable development efforts.

*The history of cultural heritage assets, particularly **monuments and protected sites**, underscores their global importance*

Threats

Cultural heritage assets encounter a multitude of threats, such as rapid urbanization, aridity, pollution, humidity, high solar radiation, extreme heat waves, prevailing winds, storms, wildfires, hazards, earthquakes, climate change, armed conflicts, war, and vandalism.

These threats have the potential to inflict substantial harm on CH assets. The heritage asset depreciates in value as a consequence. Once a heritage site has been lost, damaged, or destroyed, the restoration process is frequently slow and, in certain instances, unfeasible.

Challenges

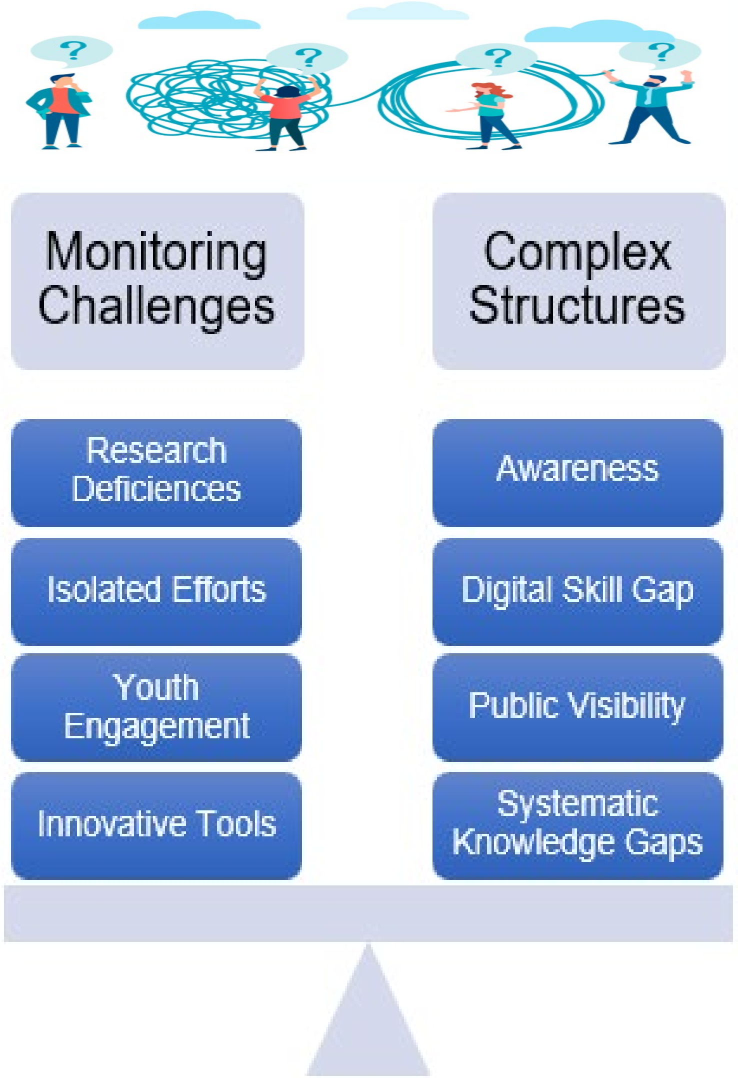
Digitization is essential for the conservation, renovation, study, and promotion of European cultural resources.

Only **15 percent of the world's cultural heritage** is **in a digitalized format**.

A great majority of ancient artifacts and heritage sites are prone **to corrosion and degradation** due to age and other reasons.

Traditional methods are often inadequate due to the complexity and large spatial scales of these structures, making detailed analysis and decision-making difficult.

And **inventory methods** applied with conventional mechanisms (such as filling, recording, archiving and reporting with documents) are **not efficient** for the protection of cultural heritage.



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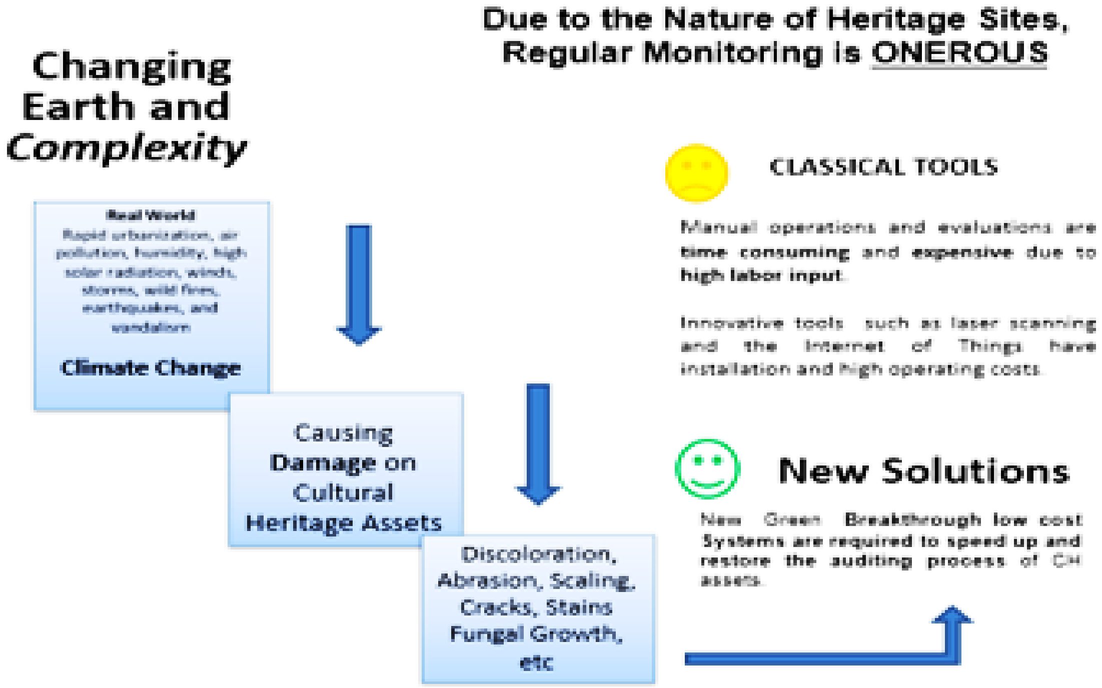
Solution

There is a need for **advanced monitoring and Low-cost preservation**,



AIDL 4 **CH**

WHAT

Artificial intelligence (AI)-based automation.
AI, which uses **deep learning-based convolution neural networks** to detect damages in images of CH assets obtained in real-time from drones

WHY

To overcome the limitations of manual and machine-based inspection.

HOW

A new prototyping **AI-powered unique HR camera** will be mounted on **a low-cost and low-altitude drone** and will automatically detect the damage on CH assets with DL models, geotag them and enable us to monitor them in a **Digital Twin 3D/4D virtual world**.

COMPLEXITY TO *ACTIONABLE SIMPLICITY*

LOCATION Muğla, Türkiye
Cultural Heritage Concept

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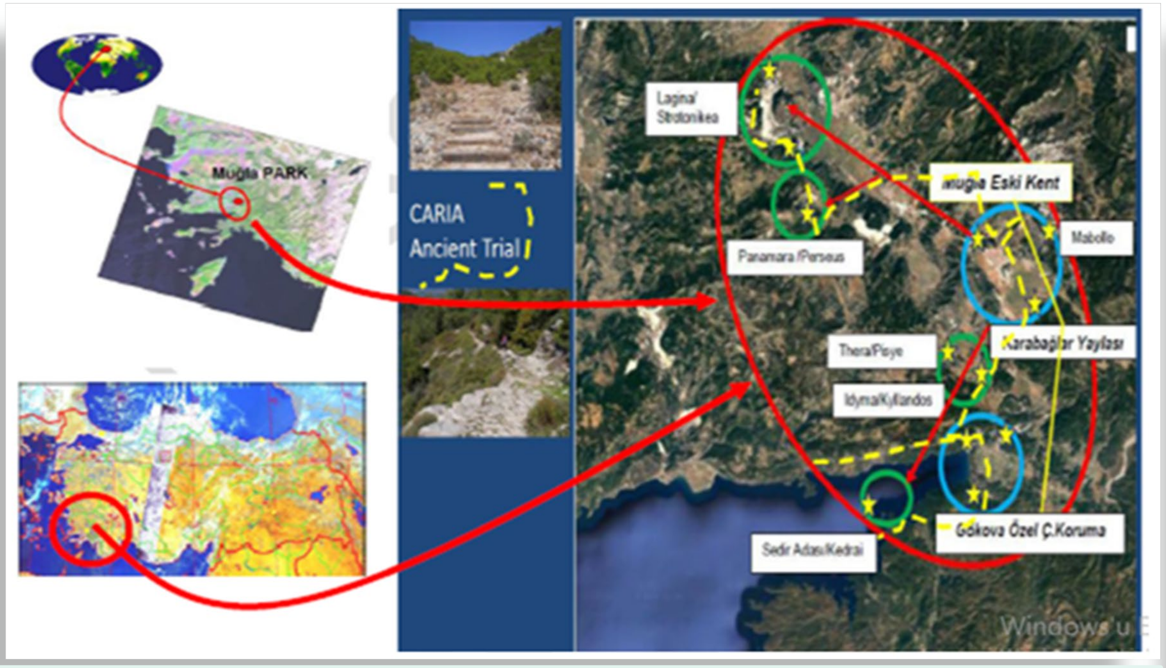
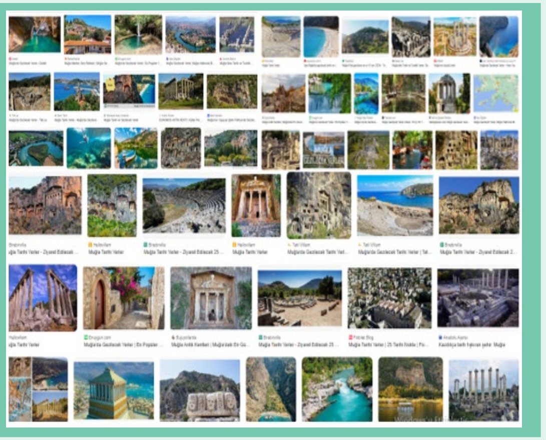
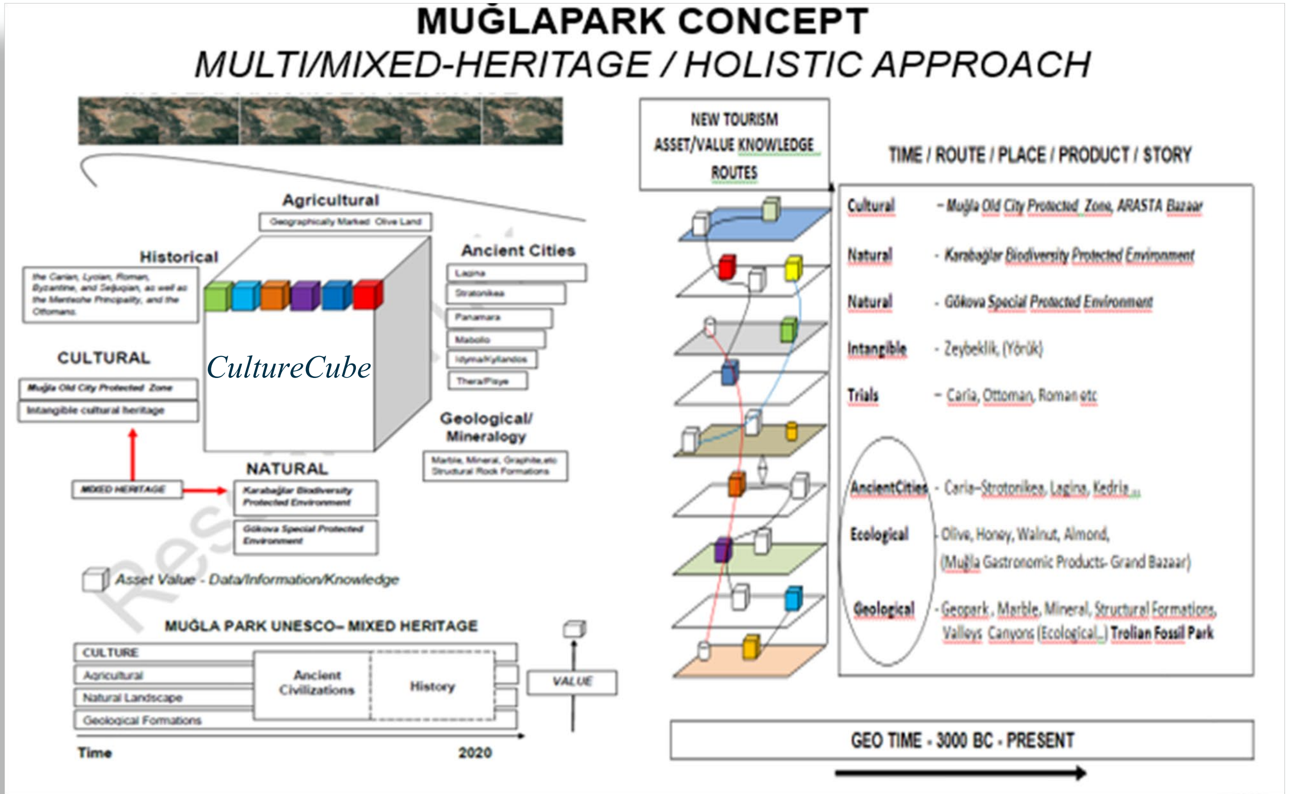
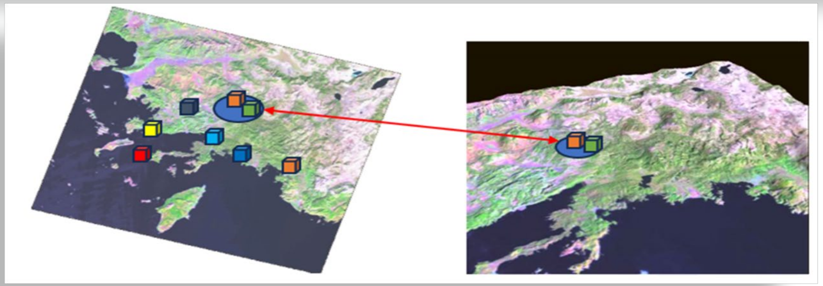


Muğla, *as both an area and a region, possesses a remarkably rich and diverse universal heritage, characterized by unique and rare cultural, natural, archaeological, geological, and historical attributes.*







Test Site-*Muğla-Menteşe*

MUĞLA REGION HAS HIGH RISK HERITAGE VALUES THAT NEED TO BE PROTECTED. (FIRE-EARTHQUAKE-FLOODS-DROUGHT)

Description of the pilot test area: It has been selected firstly for modeling purposes which is the historic city center, Saburhane, located in the province of Muğla, Turkey. This area encompasses a **total of 417 registered cultural assets,** including urban monuments, fountains, and religious buildings. All necessary permissions have been already obtained from the relevant authorities for these activities.

Cultural, Architectural structures and monuments

Archeological Protected Sites *(Caria, Roma, Byzantine, Ottoman)*

Natural Protected Sites

Value Chain and Cycle

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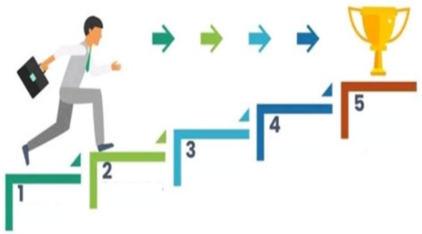
The approach is currently ***positioned at an intermediate stage of research and development maturity, serving as a bridge between the conceptualization and implementation phases, as well as between laboratory testing and commercialization.***

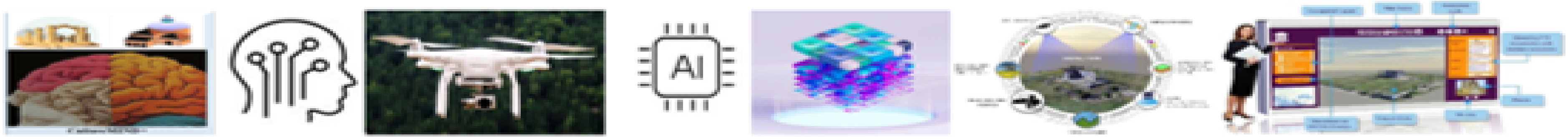
To establish a cost-effective, innovative, and competitive system that takes into account user requirements and legal constraints.

To create a comprehensive framework that integrates research, technology, and community involvement for effective cultural heritage conservation.

Needs and Requirement Analiz	Data Collection Processing Reconstruction	Technology Design, Development and Modelling	Prototyping, Testing and Demonstration	Implementation, Engagement Internationalism Marketing



TRL 3-4 *Proof of Concept*



CREATE A HERITAGE **FOR ALL**

MAKE IT MORE VISIBLE, SIMPLE, AFFORDABLE AND MANAGEABLE

Acquisition, Integration and 3D Reconstruction

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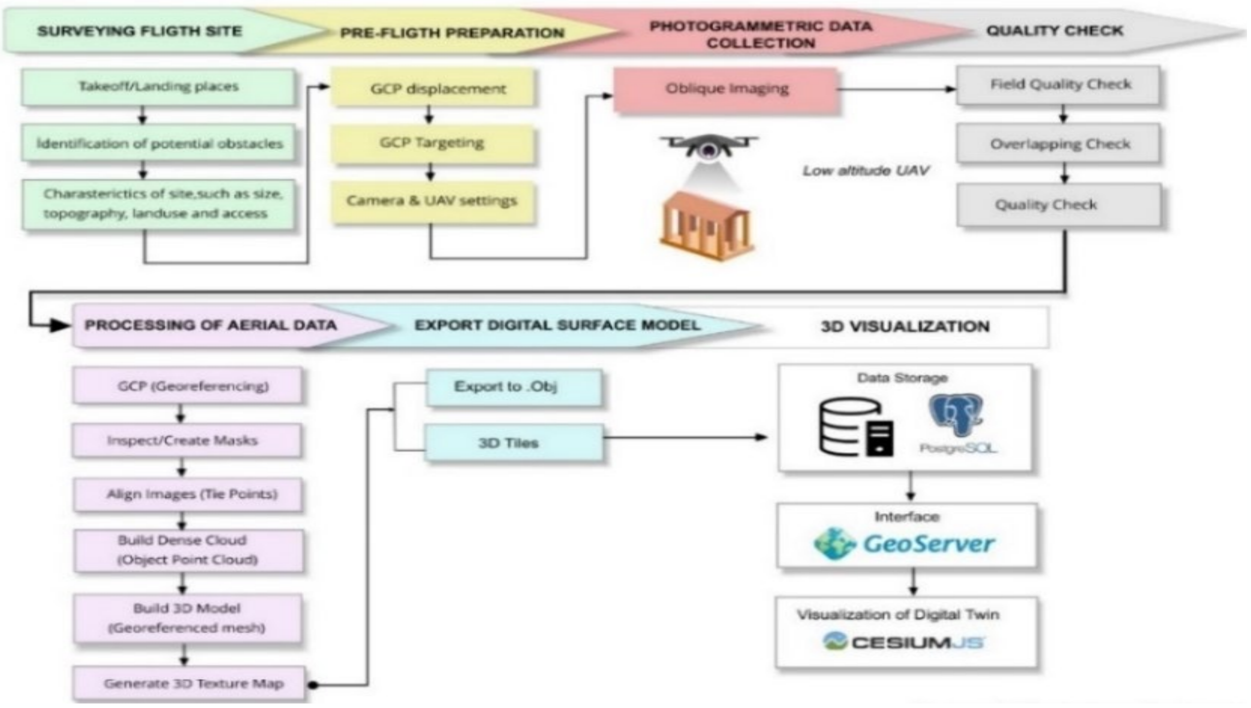
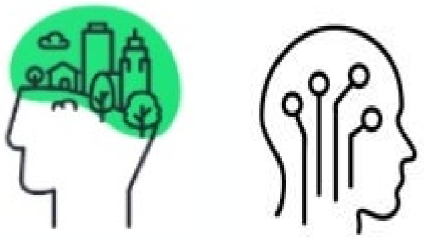
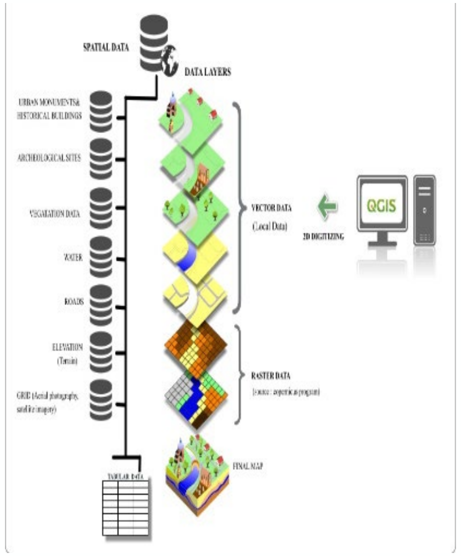
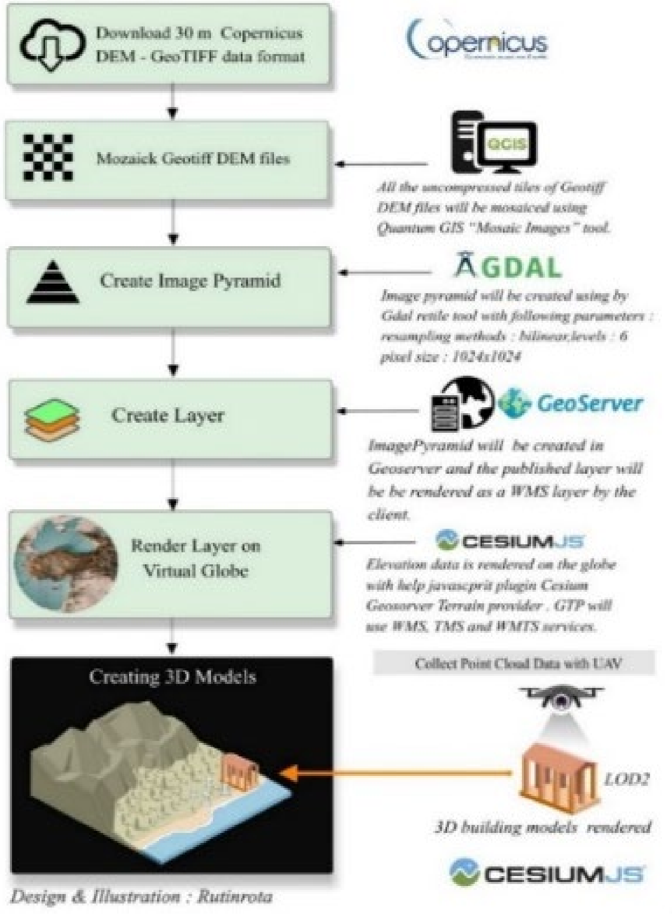


Digital Twin, 3D **reconstruction pipeline** and illustration of Terrain Data Presentation on Virtual Globe

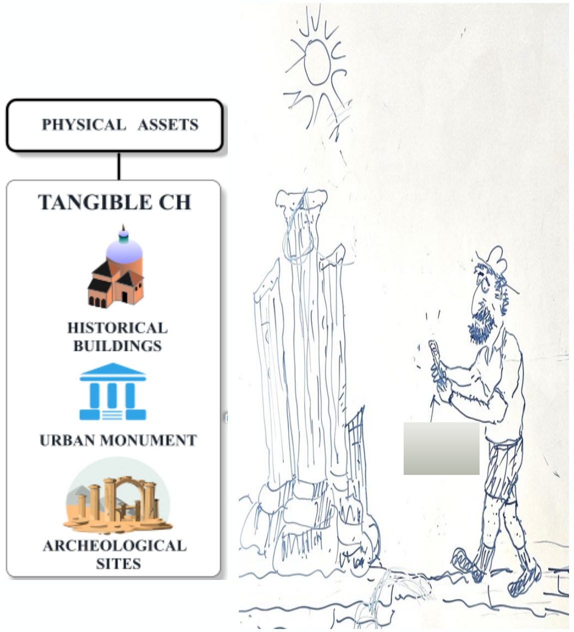






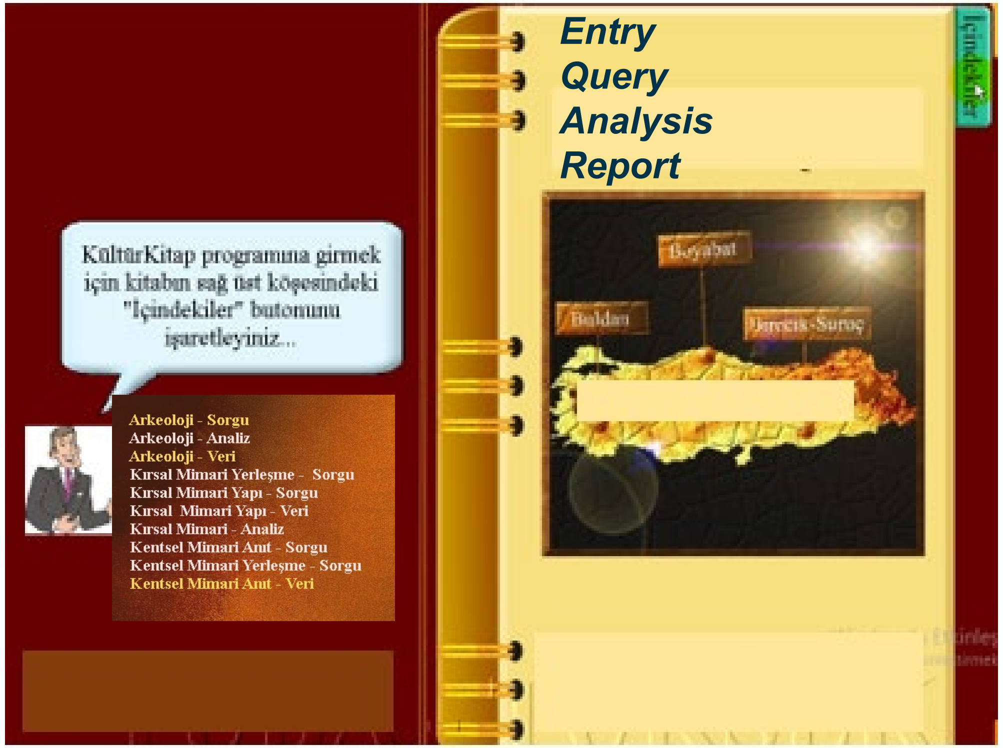
- AI-enabled UAV data acquisition- High-resolution camera systems
- Geospatial GIS data collection
- 2D and 3D GIS documentation
- Urban landmarks, fountains, ancient buildings etc.
- QGIS and Geoserver integration
- Digital documentation
- UAV systems: aerial images & 3D point clouds
- QGIS 3.20 for 2D data creation Geodatabase (PostGIS + PostgreSQL)

Data Collection Process and APP



To facilitate the collection of inventory data on urban monuments and archaeology
To enhance the efficiency and accuracy of field data collection
Utilize an EGNSS receptor to accurately measure the geolocation of historical buildings and team members.
To download map data for offline use, in areas with limited internet access.
Data can be synchronized and sent to a central database.

Inventory System - CultureBOOK
GIS-based Digital Platform



'CULTUREBOOK is a GIS-based software developed to enhance the culture sector by effectively managing and displaying cultural assets through an organized inventory system and serves as a spatial database utilizing information technologies such as Space Remote Sensing and GIS.

Inventory

Urban information system (buildings, parcels, roads, rivers, green areas etc.)

Geological layers (alluvium, formations micashist, gneiss, fault, slope, aspect)

Turkey specific layers (villages, districts, provinces, majör roads, hills, lakes, 1/25000 sheets, 1/100000 sheets, 3-d relief)

Satellite images (Muğla - Menteşe districts)

- To collect and integrate visual and geospatial data across various cultural groups, including archaeology, urban and rural architecture, ethnobotany, ethnography, oral history, and geological heritage.
- To interact with both static and dynamic data, offering features such as zooming, layer management, attribute querying, and the creation of customized maps and reports.
- Its user-friendly, book-like interface facilitates easy navigation between cultural groups and provides simultaneous views of data, with a layout that includes tabs for data entry, queries, analysis, and geographic information.
- To streamline the management of cultural assets while providing comprehensive tools for data analysis and reporting.

Urban Monument -Digital Inventory Data

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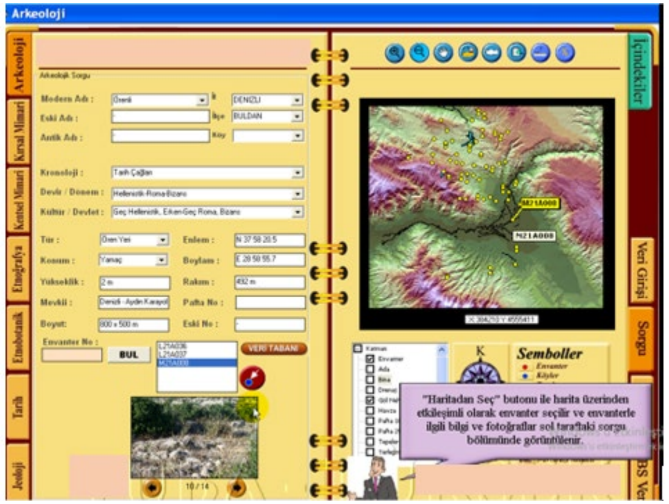
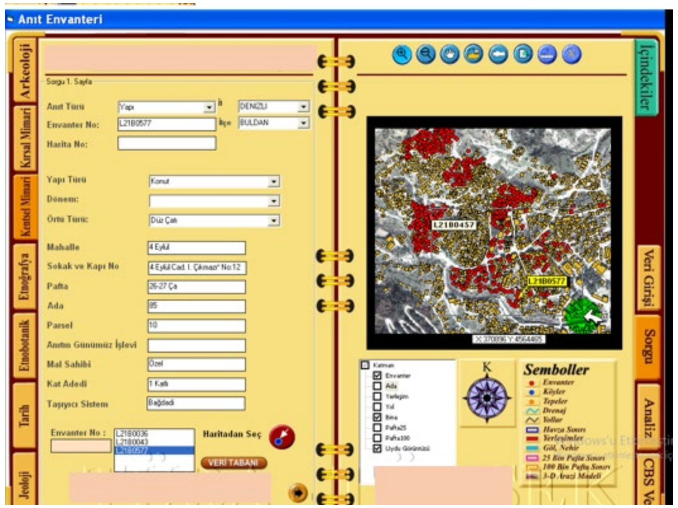
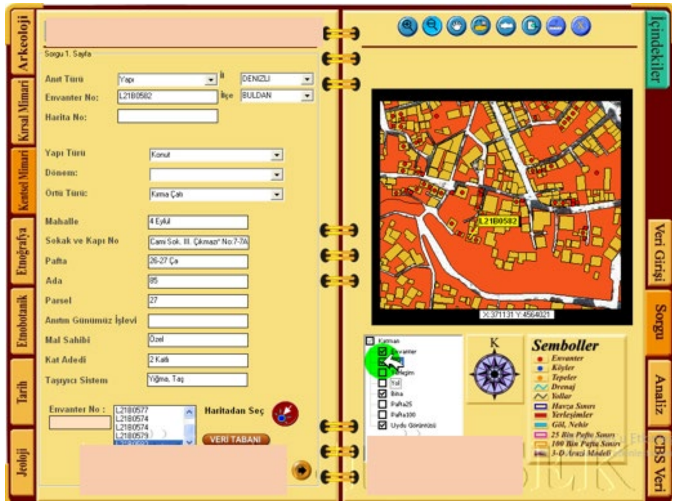


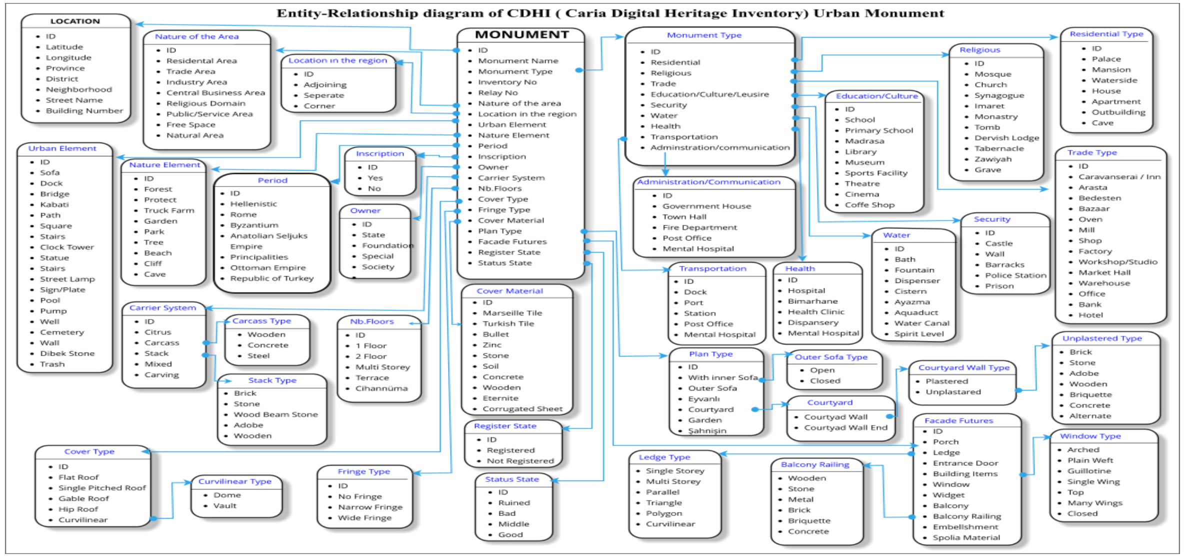




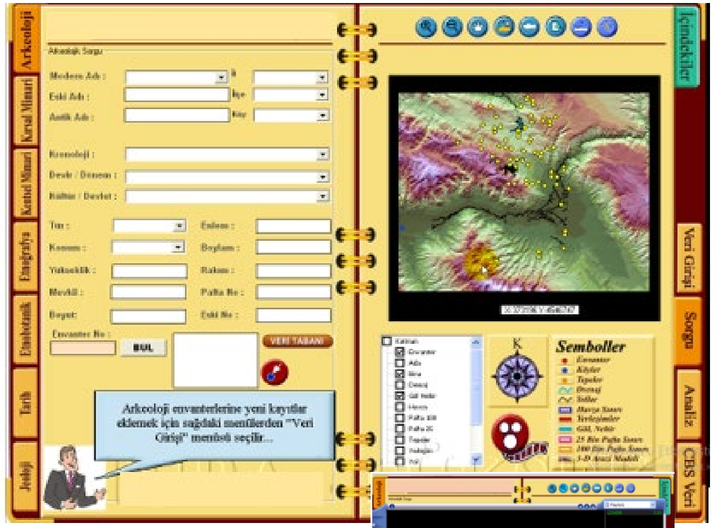
data titles, sub-titles and information to be collected

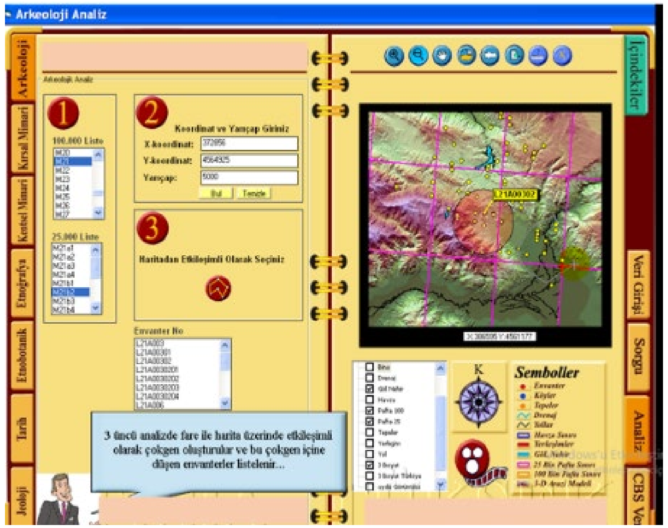
Collection of Urban Monument Inventory data: The Caria Collector application is being designed for architects to collect inventory data from multiple pilot locations throughout Europe. *A particular emphasis will be placed on urban monuments in Muğla, Turkey, which boasts 400 registered and 300 unregistered monuments.*

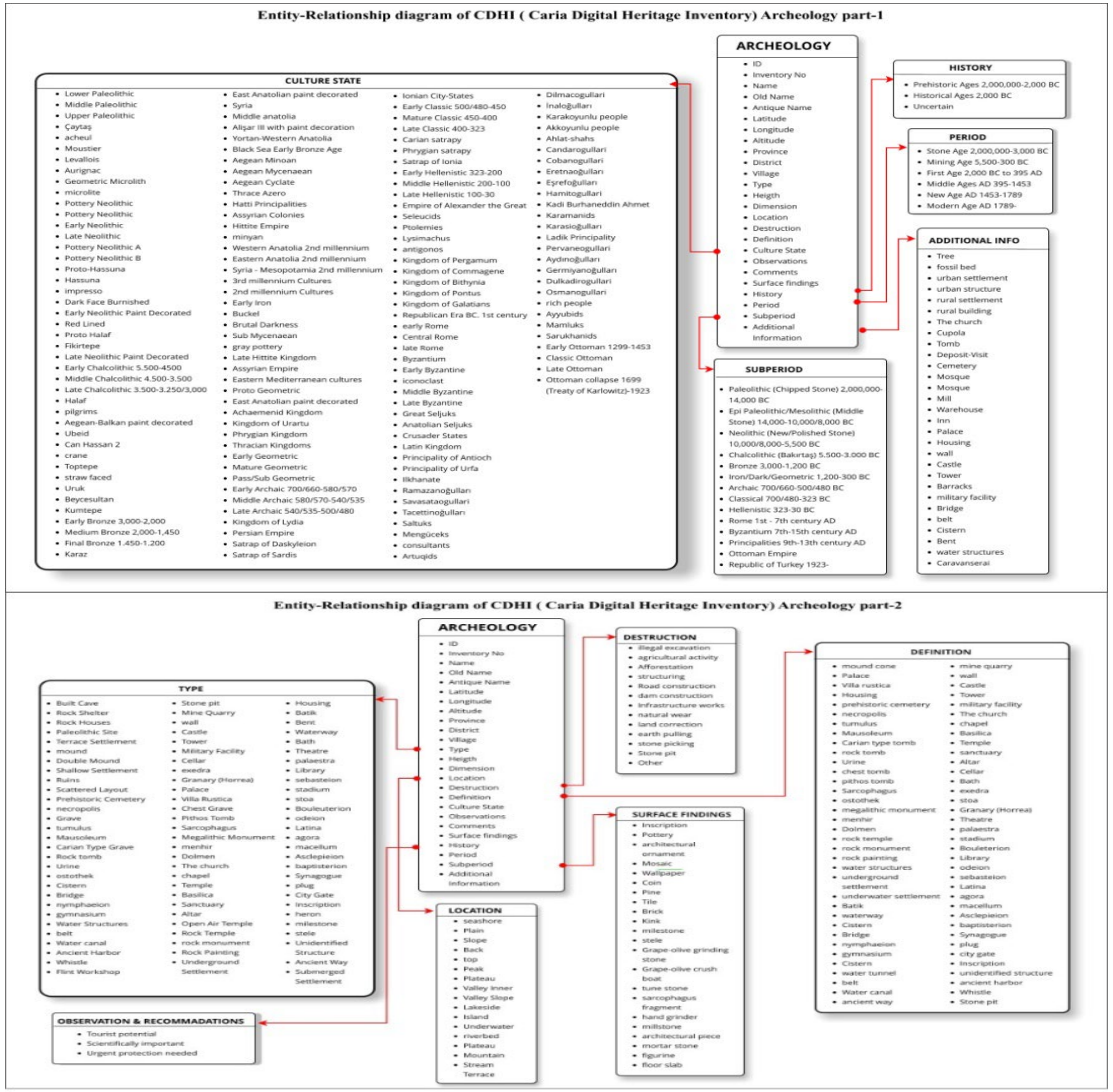
The application includes a multiple-choice Urban Monument Form that adheres to the standards set by the Turkish Cultural Inventory Project and ICOMOS. It also employs pre-designed urban architecture inventory slips for effective data collection.



Archeology- Digital Inventory Data



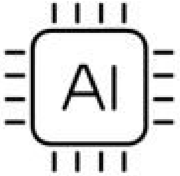


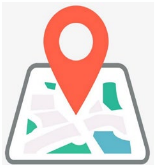


Collection of Archeology Inventory data: The Caria Collector application is allowing experienced archaeologists to compile inventory data on archaeological artifacts from specified test areas.

This application includes a **multiple-choice Archaeology Form** that complies with the **standards set** by the Turkish Cultural Inventory Project and **ICOMOS**, utilizing pre-prepared archaeology inventory slips. The accompanying figure illustrates the different data categories, subcategories, and specific details that will be collected regarding archaeological findings.

Technology Designing and Development



A state-of-the-art camera module
Automatic damage auditing
Object tracking
Rapid identification of deterioration

Reliable, efficient, and cost-effective
Early detection of damage
Modeling potential threats

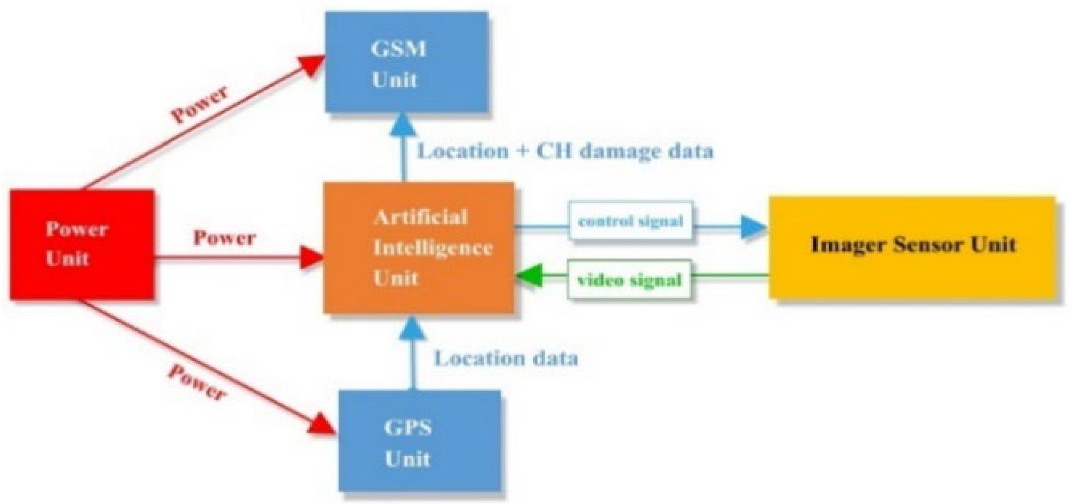
Priced between 300-500 euro


A new prototyping **AI-powered unique HR camera** will be mounted on a low-cost and low-altitude drone AND use it as a **handycam** and will automatically detect the damage / change real time on CH assets with DL models, geotag them and enable us to monitor them in a 3D/4D virtual.

A high-resolution camera enabled with artificial intelligence.
The objective is to develop a low-cost AI-enabled UAV system and project specified high-resolution camera module that is affordable and portable, to be integrated into cost-effective drones within a controlled laboratory setting.

System Definition and Components

System Definition: **Artificial intelligence-enabled camera modules** are being developed to be compact and easily integrated into drones and autonomous ground vehicles, allowing them to access remote and off-grid locations. These modules are designed for **low energy consumption and feature rechargeable batteries**, along with a ruggedized chassis for operation in challenging environments. They can function **independently without the need for continuous GSM**, satellite, or internet connectivity due to their memory block system. Additionally, a specialized camera system will be created for detecting damage in cultural heritage (CH) structures, capable of identifying issues such as scaling, exposed brick, color damage, and cracks, while also **transmitting the location information of these structures to a central control center.**



System Topology

1- ***Image Sensor Unit:*** The high-definition image sensor unit offers a wide field of view and produces high-quality images for the Artificial Intelligence unit. 2- ***Artificial Intelligence Unit:*** is tasked with identifying and categorizing structural damage in the area through AI image processing. It processes data from the image sensor unit to generate images, assesses these images, and identifies any structural damage. Upon detection of predefined damage, the AI unit communicates with the GPS/EGNSS unit to obtain **the location information of the damage** and transmits the data using the GSM unit. **3- *GPS/EGNSS Unit:*** is responsible for providing location information to the AI unit as required. **4- *GSM Unit:*** is responsible for transmitting location and damage information to the central station using GSM operators. **5- *Power Unit:*** supplies the necessary power to all subsystems and comprises a battery, filters, and regulators.

AI-powered Deep Learning Modeling

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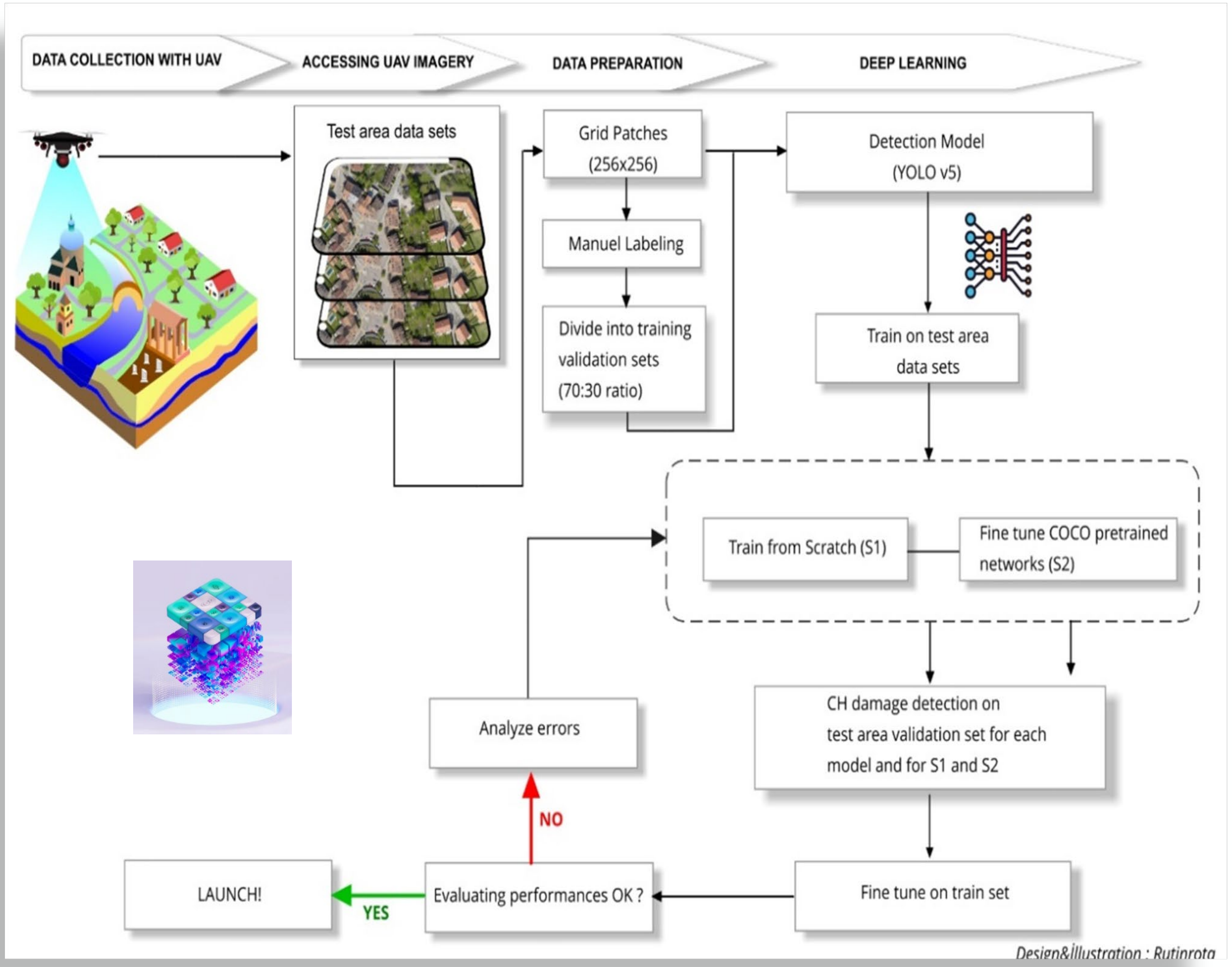
To analyze collected UAV and space imagery for automated feature extraction, detection and data interpretation.



The YOLOv5 CNN based algorithm is chosen for detecting damages and changes in Cultural Heritage (CH) entities due to its **high detection speed and accuracy,** especially in environments with limited computing resources and data availability.

Performance: The pre-trained YOLOv5 model is effective in detecting degradation in CH entities with high sensitivity and rapid training speed.
Efficiency: YOLOv5 is compact, has low computational complexity, and offers high inference rates, making it ideal for the project.
User-Friendly: It requires only torch and lightweight Python libraries for installation, making it more accessible than other object detection frameworks.
Versatility: The framework supports inference on individual images, video feeds, and webcam ports, with an intuitive file structure for easy navigation.
Conversion Capability: YOLOv5 models can be converted from PyTorch weights to ONNX weights and CoreML for iOS applications.

AI-powered Deep Learning Modeling

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The approach will involve the utilization of a cost-effective **YOLOv5 CNN-based algorithm** for object detection, specifically tailored for the identification of damages on CH assets and to develop a new model that leverages deep learning (DL) techniques to achieve a high accuracy of 0.5 IoU (Intersection Over Union) and a minimum of 90% mAP (Mean Average Precision) in detecting damages.

AI Model Training, Annotation and Augmentation

- Data Collection: Datasets will be obtained via drone imagery from selected pilot sites in the city center of Muğla province, Türkiye.
- Data Utilization: The training will leverage both historical and real-time data, emphasizing the importance of quality and diversity in the training dataset.
- Dataset Composition: The CH image dataset will include urban landmarks such as residences, commercial buildings, monuments, and fountains, with a minimum of 4000 images showcasing various imperfections (e.g., flaking, blistering, cracks).
- Image Acquisition: Images will be captured using UAV drones and high-resolution ground-based cameras equipped with GPS/EGNSS and GSM units.
- Annotation Process: Using Robofow and Yolo label software, borders will be delineated, and annotations will be added to the images.
- Data Augmentation: The annotated images will be augmented to create approximately 12,000 additional images through techniques like cropping, shifting, grayscale conversion, and rotation.
- Final Dataset: The final dataset will include label classes such as cracked, discolored, exposed brick, and flaking, with original images resized to 256 × 256 pixels to facilitate faster training.

Expert Involvement

Cultural property conservation experts manually **identify flaws** in the images, drawing rectangular boxes around each defect typology or multiple boxes for different defects within a single image. This expert input is crucial for training the flaw detection system effectively.

The Real-time Monitoring Platform

A web-based portal application designed for monitoring and **tracking 3D geospatial data** related to cultural heritage assets.

The application will feature a virtual 3D environment that visualizes these assets and their **time-dependent damage in a 4D format**.

This initiative aims to revolutionize the way cultural heritage assets are monitored and analyzed, providing a **comprehensive, interactive, and real-time platform** for users to engage with and protect these valuable resources

The portal aims to serve **as a foundation** for monitoring, protecting and transferring cultural heritage assets affected by climate change, natural disasters, and other threats. It will empower authorized users to access, share, interpret, and analyze cultural heritage data effectively.

The Real-time Monitoring Platform

Key Features

- 3D Virtual Space: The application will utilize Cesium.js libraries to create an immersive 3D environment that integrates reconstructed models and UAV imagery with real-time monitoring data.
- User Engagement: The platform aims to be intuitive and accessible for researchers, conservators, and the public, allowing them to explore, visualize, analyze, and monitor cultural heritage assets from multiple perspectives.
- Data Visualization Tools: Users will have access to various tools for overlaying change detection maps, historical timelines, and other relevant information onto 3D models, enhancing their understanding of the assets.

Real-Time Monitoring

- Dashboard Component: A real-time monitoring dashboard will continuously process incoming data from UAVs and the Copernicus system, providing updates on the condition of cultural heritage assets.

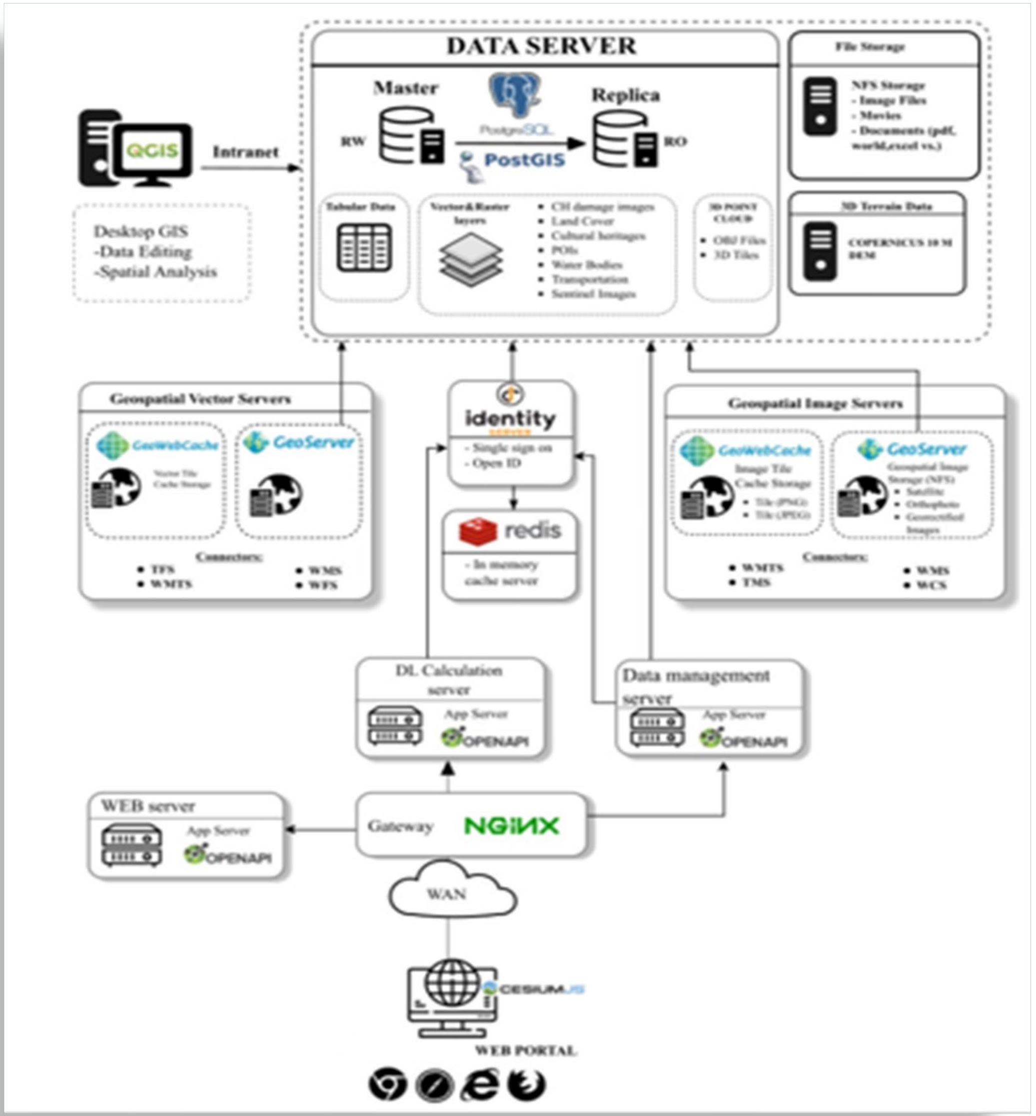
Dynamic Exploration

- Immersive Visualization: The platform will create interactive 3D/4D representations of cultural heritage assets, allowing for a dynamic understanding of changes over time.
- Deep Learning Integration: The real-time monitoring system will incorporate deep learning models to generate alerts for any identified damages, changes or anomalies, facilitating timely interventions and preventive measures

Assumptions and Challenges

The system assumes stable data transmission and sufficient computational infrastructure. Challenges such as data latency and sensor malfunctions will be addressed through redundancy and maintenance strategies

Software Architecture



Key Features

- Virtual 3D Space: The application will integrate reconstructed models and UAV imagery with real-time monitoring data, providing immersive visualization and interactive analysis tools.

- Real-Time Monitoring: Incorporation of UAV data and AI models will allow for continuous updates on the condition of cultural heritage assets, generating alerts for damage/changes or anomalies.

- Open-Source Web GIS Portal: The portal will monitor changes in tangible cultural heritage assets over time, facilitating protection and maintenance processes through an automatic 3D web-based visual inspection system.

- User-Friendly Interface: Users can load 2D and 3D geographic data, visualize **digital twins** of cultural heritage assets, and access cultural heritage inventory data easily.

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Software Architecture

Technical Implementation

- Cesium.js Libraries: The application will utilize Cesium.js, an open-source library, to create virtual spheres that include digital elevation terrain models (DTM) and multidimensional geospatial data.
- SaaS Development: The application will be developed as Software as a Service (SaaS), allowing users to log in, upload images, and detect different types of cultural heritage damage using deep learning models.
- Responsive Design: The portal will be accessible from mobile devices and will allow users to switch between 2D and 3D views.

Data Management

- Geospatial Data Server: A central server and database will document changes in physical authenticity, loss, damage, and destruction of cultural heritage works.
- ISO Standards Compliance: The design will adhere to ISO standards for usability and efficiency.
- Software Technologies: Development will involve Python, JavaScript, HTML5, and CSS, with the default Cesium.JS library providing navigation and basic functions.

User Interaction

- Informative Features: Upon logging in, users will see an information window and can watch a short film about the application.
- Inquiry Capabilities: Users can make inquiries based on cultural heritage inventories and display geographical data on the 3D virtual sphere.
- Screenshot Functionality: Users can save screenshots by dragging and dropping them within the application interface.

Business Plan and Model

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MARKET & SECTORS

Cultural Heritage

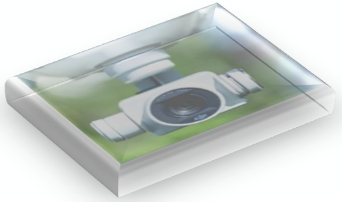
Tourism
Real Estate
Finance
Engineering
Architecture
Valuation

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

Making Better Informed Decisions with Reliable Data and Systems

PRODUCT

AI powered HR Camera-DL Models



DEAL

B2B & B2C & SaaS

1. We will provide this service as SaaS and charge based on credit and will determine service fee according to the image size that users will upload to the system.
2. The equivalent of 1 megabyte of data to be uploaded to the system will be 1 credit and 10 cents.
3. In return for this fee, users will be able to view, query and print out the digital twins of CH assets on a 3D/4D virtual globe.
4. In addition, a new high resolution camera with project-specific AI will be offered to the market for 300 – 500 euros.
5. Buyers can install this camera on low-cost drones and use it as a handycam if they wish.

IMPACT

Making Simple Use of Cultural Heritage Information for ALL

Good data from any source can help us report on the global goals to the UN

- Digital Economy (AI Data Analytics)
- Better management of Cultural Heritage Assets
- Contributiion to Climate Change (Increase awareness)
- Job creation (for NON CH users)

- The increase in preservation of CH assets and its awareness
- Increased use of technological tools
- Protect resources
- Reduce costs
- Lower time
- Good timely decisions

SERVICE

Open Source Web-based GIS Portal

3D/4D Virtual Globe, and Monitoring Platform

COMPETITIVE ADVANTAGE

Digital twins of CH assets on a 3D/4D virtual sphere
Sustainability
New, Innovative Unique Camera Prototype
Specific AI/DL Algorithm Damage Detection Model
Environmentally Sensitive
High Resolution Digital Image Data
Service & Business Quality
Low cost UAV systems for ALL
Regular Monitoring

The Team; Capacity and Stakeholders

EARSeL EUROPEAN ASSOCIATION OF REMOTE SENSING LABORATORIES

esa

Researchturk Space, led by Dr. Tamer Özalp, is a highly experienced and skilled company based in Turkey with a global presence. The company specializes in Space Solutions, Earth Observation, Radar imaging systems, geospatial analysis, Machine Learning, Project Management, International Networking, Space policy, Standards, Data Science, and System Engineering. Researchturk Space is a member of EARSC and EU Global Action on Space Programme, EuroGEO participant, GEO participant, Dr. Tamer Özalp is an ESA fellow and was a contact point ESA. He also serves as a Lecturer at Middle East Technical University. Dr. Özalp was the coordinator of the first Turkish Space Programme (2005-2014) and the launch of the Göktürk 2 Earth Observation Satellite in 2012. With 25 years of experience in the Space Domain, Dr. Özalp brings a wealth of expertise to Researchturk Space.

Rutinrota Software and Optimization Company specialized and well experienced in Advanced GIS, AI based geospatial analysis and technologies and GIS projects in every sector since 25 years

Asisguard is one of Industry leaders in Türkiye and worldwide drone manufacturing, AI software development, and high-resolution camera unit production. This partner will provide cutting-edge technology solutions and equipment for data collection and analysis.

Heritage Conservation NGOs: "***MUĞLAPARK Platform***" is a non-governmental voluntary initiative which is composed of educated people, from all colors of community focused on cultural and natural heritage preservation in Muğla, Türkiye. They bring in-depth knowledge of heritage site conservation, community engagement, and ethical considerations in cultural and natural preservation

Stakeholders Muğla Governance, Municipalities, Chambers, NGO, University, Culture and Tourism Dept., Conservation and Environment Dept.

1995-1998

ESA Trainee, IP office during the stay in ESRIN, ESA, Italy

2007-2012

GÖKTÜRK-2 EO SATELLITE, Ankara Türkiye

Thank You for Your Attention

I welcome any questions or discussions on how we can collaboratively advance the preservation of cultural heritage through technological innovation.

ozalp.tamer@gmail.com

2018- Present