HORIZON EUROPE – EXCELLENCE HUBS – GA 101087146
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Blue Culture Technologies: deployable solutions for Underwater Cultural Heritage

BCThubs – Blue Culture Technology Excellence Hubs in EU Widening Member States: three regional hubs in Greece, Malta and Bulgaria, seven technologies validated in the field at TRL 6–7

I. BCThubs in a nutshell – from fragmented heritage to Blue Culture Technology hubs

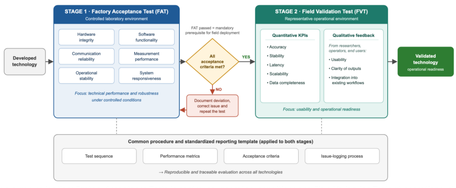
15 partners 4 countries	€4.99 M Horizon Europe funding	3 regional hubs: GR • MT • BG	48 Months Jan 2023 – Dec 2026	7 technologies validated	TRL 6–7 reached in the field	4 UCH sites *across* 3 seas	20+ monitored dives

The challenge. Europe's underwater cultural heritage (UCH) is a finite, non-renewable resource – shipwrecks, submerged settlements, ancient ports – threatened by degradation, looting and coastal development, and largely inaccessible. Blue Culture Technologies are a niche, emerging field; cooperation between research, industry, public authorities and society has been temporary, and Widening member states lacked permanent structures to sustain innovation at the interface between UCH and the Blue Economy.

The response. BCThubs established three place-based Excellence Hubs – Greek (coordinator Region of Thessaly), Maltese and Bulgarian – as quadruple-helix innovation ecosystems with a joint Research & Innovation Strategy aligned with the EU Green Deal, EMFAF, Blue Growth, MSP and the UNESCO 2001 Convention. The strategy is built on four pre-competitive pillars, each served by the technologies validated in this work.

1. **UCH research support** – 3D seafloor modelling, geophysical survey, sediment coring
2. **On-site & remote accessibility** – virtual diving for non-divers, augmented diving for divers
3. **Asset safeguarding** – AI/ML 3D–4D reconstruction and change detection
4. **Underwater health & safety** – real-time physiological monitoring of divers

II. Validation methodology – from factory acceptance to real submerged sites



Two-stage validation: Factory Acceptance Tests in controlled laboratory conditions and Field Validation Tests at operational sites.

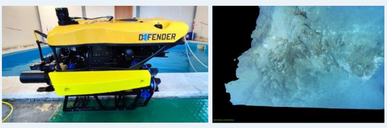
- Validation sites: Fourni Archipelago (Aegean, GR) – two archaeological shipwrecks; Sozopol harbour, Gradina Bay and the Urdoviza wreck (Black Sea, BG); the Danube; plus controlled and public settings in Calabria (IT) and Sofia (BG).
- Passing the FAT is a mandatory prerequisite for field deployment; deviations are documented and tests repeated until all acceptance criteria are met.
- Outcome: every technology satisfied its acceptance criteria, operated reliably under real conditions and reached the maturity required for operational use (TRL 6–7).
- Where end users were directly involved (archaeologists, divers, students), user-acceptance activity was reported within the FVT – e.g. a System Usability Scale of 70.2 ± 16.7 (n = 13) for Augmented Diving.

III. Seven validated Blue Culture Technologies

1 UCH RESEARCH

Robotic platform for opto-acoustic seafloor DTMs — *3D Research*

- ROV integrating a multibeam echosounder with an upgraded optical module: variable-baseline 4K stereo pair + 61 MP full-frame mirrorless camera, rated to 300 m, dimmable lighting; unified navigation/acquisition interface.
- Validated in Calabria, Fourni (GR) and Sozopol (BG): a textured model of 1,000,081 faces from only 30 unfiltered images in high-turbidity water. TRL 7 – ready as a seafloor-modelling service.

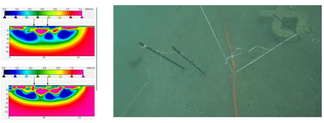


ROV with the new opto-acoustic configuration; photogrammetric reconstruction of the Fourni UCH site.

2 UCH RESEARCH

High-resolution electro-resistivity survey — *Underwater Heritage Institute*

- 64-channel multichannel system (Dipole–Dipole, Schlumberger, ZZ) adapted to marine and riverine sites; 0.5 m electrode spacing resolves stratigraphic detail, larger spacing probes deeper volumes.
- Confirmed buried targets invisible on the seabed: a sunken wooden vessel in Gradina Bay (later verified by archaeologists) and the 19th-century Urdoviza wreck. Now a standard method of the Institute.

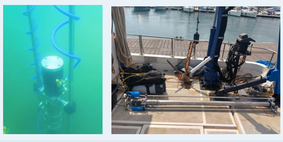


Vertical resistivity sections along measured profiles and diver positioning of the electrode cable.

3 UCH RESEARCH

Shallow-water sediment coring system — *Underwater Heritage Institute*

- Diver-assisted vibro-impact corer operated from a small vessel: 2 m coring tube with transparent liner, cutting head and pneumatic vibro-impact head.
- Three test series in Sozopol harbour (5–10 m depth): full 2 m penetration in >90 % of attempts; liner filled up to >70 %. In the Institute's equipment since autumn 2025.



The corer in operation underwater and on deck of the Hristina.

4 ACCESSI - BILITY

Virtual Diving – cloud-based VR for remote access — *3D Research*

- Meta Quest 3 dry-dive of digital replicas of UCH sites: modernised rendering (volumetric light, caustics, depth-dependent colour), physics-informed swimming locomotion, distance-responsive POIs, sequential cloud download.
- Full FAT cycle and two public deployments (Researchers' Night, Univ. of Calabria; Sofia plenary) with questionnaires and debriefing – mature for museums, schools, heritage outreach and tourism promotion.

New POI HUD over Mediterranean flora; public test sessions in Italy and Bulgaria.

5 ACCESSI - BILITY

Augmented Diving – on-site survey and guided visits — *3D Research*

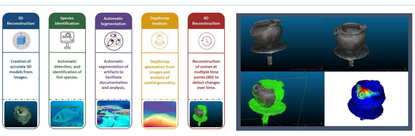
- Pressure-proof smartphone with acoustic communication and USBL localisation: in-water position, contextual multimedia, short messaging, georeferenced imagery; new Dive-Master-driven mode synchronising POIs across the group.
- Validated at two Fourni sites and in a two-day Sozopol campaign. SUS 70.2 ± 16.7 (n = 13); coherence between devices rated 4.31 ± 0.63, ease of use 3.92 ± 1.19.

Underwater smartphone in low visibility; divers and surface unit in Sozopol; tracked trajectories of three divers.

6 SAFEGUAR - DING

AI/ML toolchain for UCH asset safeguarding — *CERTH*

- Four integrated services: multi-colormap 3D reconstruction, automated artefact segmentation (foundation models), marine-fauna surveillance with depth-map analysis, and 4D change detection across monitoring campaigns.
- Validated on data from four UCH sites; for Sozopol two independent pipelines produced four comparable digital products. Detects sediment movement, colonisation, degradation and human interventions.

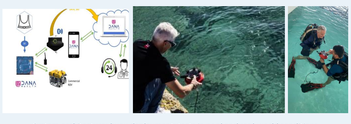


The integrated safeguarding ecosystem; 4D monitoring of an amphora with change map.

7 HEALTH & SAFETY

Diver physiological monitoring – DANA Health platform — *DAN Europe*

- Smart Body Area Network: certified ECG chest band (HR, RR intervals) → sub-500 MHz RF bridge → DiveSense edge hub with depth and temperature → acoustic modem → surface buoy → GDPR-compliant cloud portal and app for supervisors and medical responders.
- FAT + FVT over 20 monitored dives in diverse environments: high acquisition accuracy, robust communication, detection of intra-dive heterogeneity (HRV drops, sympathetic surges) invisible to dive computers – towards physiology-aware ascent guidance and lower DCS incidence.



System architecture; buoy deployment; tests in pool and real-world conditions.

IV. From pilots to platform – hubs, marketplace and the Blue Economy cluster

Three operational hubs

- Greek Hub – legal anchor University of Thessaly; RoT, CERTH, HIMA, Skopelos Diving Center, Atlantis
- Maltese Hub – Institute of Tourism Studies; DAN Europe, AquaBioTech, Superintendence of Cultural Heritage; first bachelor in diving safety
- Bulgarian Hub – Underwater Heritage Institute; IICT-BAS, Balkan Heritage Foundation, Acqua Prom
- Joint R&I Strategy and Investment & Financing Plan per hub, aligned with RIS3; 104 endorsements, community of 100+ organisations

Exploitation pathway

- Consolidation towards higher TRL and packaging as products and services
- BCThubs Marketplace – a free platform where hubs, researchers and SMEs list underwater tools, datasets and services (marketplace.bcthubs.eu)
- Adoption within the three hubs: training (scientific diving, diver safety, bootcamps), secondments, demonstration events
- New application domains beyond UCH: engineering and ecological surveys, maritime safety, marine spatial planning

What we offer the EH Community

- Open hubs and test sites on Mediterranean and Black Sea UCH for cross-hub pilots
- Validated technologies ready for new seas and sectors
- A replicable hub model, governance and strategy
- A Blue Economy EH Cluster: Memorandum of Understanding with SeaTecHub, MarTe, INNO2MARE and every interested EH project, break-out session, Monday 26 Oct, 14:40, common room

V. Conclusions

- Two years after the prototypes presented at the 1st BCThubs Conference (Volos, 2024), all seven Blue Culture Technologies have passed a structured FAT + FVT campaign at real UCH sites in the Aegean, the Black Sea and the Danube, reaching TRL 6–7.
- The portfolio covers the four pillars of the joint R&I strategy – advancing UCH research, enabling on-site and remote accessibility, reinforcing safeguarding, improving diver health and safety – with measurable added value for divers, researchers, museums and heritage authorities.
- Three legally anchored hubs, a joint strategy, an investment plan and the Marketplace turn the project into a permanent regional structure; the next step is an EU-wide Blue Culture Technology cluster and a Blue Economy cluster of Excellence Hubs.

bcthubs.eu marketplace.bcthubs.eu

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