



D12.5 – Final report on knowledge discovery and JRA activities

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Executive Summary

This deliverable describes the achievements of the last year of the Joint Research Activities (JRAs for short) of the ARIADNEplus project, with a special emphasis on the Knowledge discovery and browsing service, implemented by the ARIADNE Portal with the support of the ARIADNE Aggregation Infrastructure.

The report provides an integrated overview of all the scientific and technological developments that have taken place in JRA Work Packages during the abovementioned period. These Work Packages are:

- WP12 JRA1 - Data Integration and Interoperability (Lead beneficiary CNR)
- WP13 JRA2 - ARIADNEplus Infrastructure Operation and Management (Lead beneficiary CNR)
- WP14 JRA3 - The ARIADNEplus knowledge management system (Lead beneficiary FORTH)
- WP15 JRA4 - Innovative Services for Users (Lead beneficiary SND)
- WP16 JRA5 - Innovative Methods and Pilots (Lead beneficiary INRAP)

This deliverable corresponds to the activities of tasks 12.5 (Knowledge discovery and browsing) and 12.6 (Monitoring JRA activities).

The document consists of one main Section (Section 3) which provides an overview of the progress in the JRA WPs covering four main fronts:

- Infrastructure and Virtual Research Environments setup and operation
- Aggregation infrastructure
- The ARIADNE Content Cloud
- Services and pilots

A separate Section (Section 4) is devoted to the Knowledge discovery and browsing service.

Sections 5 to 9 are devoted to the JRA WPs, from WP12 to WP16, in the order. Each WP Section has the same structure:

1. Goal of the WP
2. Planned schedule of activities (table)
3. Results obtained from Month 37 to Month 48 (bulleted list)
4. Problems encountered and open issues, if any

No milestone was set in the fourth year of the project for the JRAs.

1 Introduction and Objectives

This deliverable describes the progress on the Joint Research Activities (JRAs for short) of the ARIADNEplus project achieved during the final year, by providing an integrated overview of all the scientific and technological developments that have taken place in JRA Work Packages in that period. These Work Packages (WPs for short) are:

- WP12 JRA1 - Data Integration and Interoperability (Lead beneficiary CNR)
- WP13 JRA2 - ARIADNEplus Infrastructure Operation and Management (Lead beneficiary CNR)
- WP14 JRA3 - The ARIADNEplus knowledge management system (Lead beneficiary FORTH)
- WP15 JRA4 - Innovative Services for Users (Lead beneficiary SND)
- WP16 JRA5 - Innovative Methods and Pilots (Lead beneficiary INRAP)

This deliverable covers Months 37-48 of the project. The activities carried out in the previous periods of the project lifetime have been reported in previous deliverables, namely D12.1 (“Initial report on JRA activities - JRA1”, covering months 1 to 18 and delivered at month 18) and D12.3 (“Interim report on JRA activities - JRA1”, covering months 19 to 36 and delivered at month 36). During the period covered by this deliverable, the following deliverables have been produced by the JRA WPs (in addition to the current one):

Deliverable No.	Deliverable Title	Delivery Date
D12.4	Final report on data integration - JRA1	M46
D13.3	Software Release Final Activity Report - JRA2	M46
D13.4	VREs Operation Final Activity Report	M48
D14.2	Final report on the ARIADNEplus knowledge management system - JRA3	M47
D15.2	Final report on the ARIADNEplus services - JRA4	M47
D16.2	Final report on the ARIADNEplus pilots - JRA5	M47

All these deliverables have been completed within the scheduled timeframe. Likewise, all objectives have been reached. The present document provides a quick reference guide, concisely and homogeneously structured. The detailed descriptions of the activities of the involved Work Packages can be found in the deliverables reported in the previous Table.

2 Overview of progress

This Section provides an overview of the progress achieved in the period covered by the deliverable. It is divided into two sub-sections: the first recapitulates the workplan for the JRA WPs, as presented in the project proposal, while the second identifies the main areas of work and elaborates on the progress achieved in each area.

2.1 Workplan

The following Figure (from page 32 of the ARIADNEplus proposal) schematises the Work Plan of the project and indicates the role of the different JRA WPs in relation to the other WPs of the project.

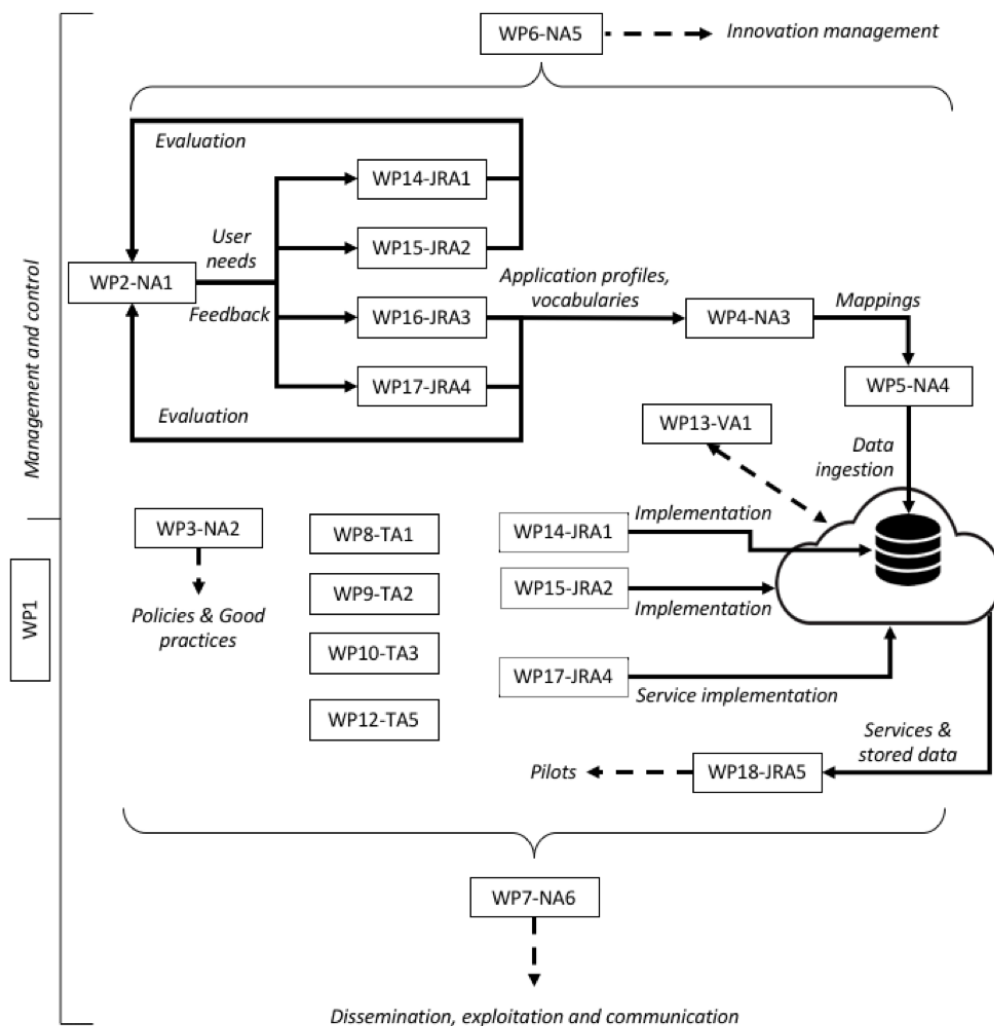
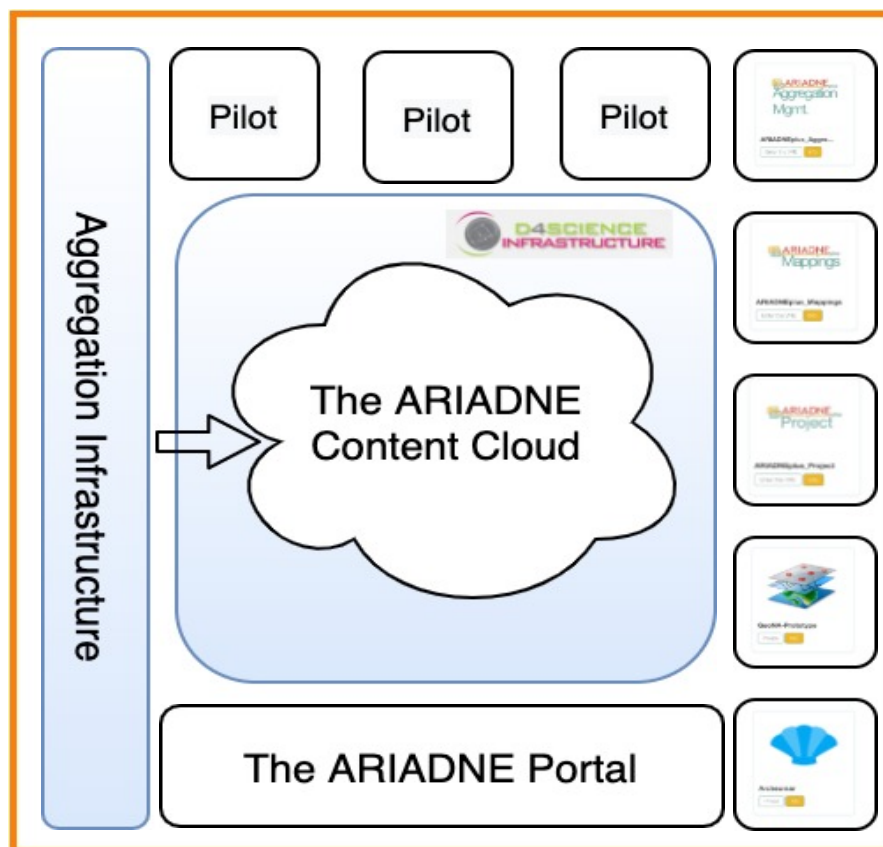


Figure 1 PERT of the ARIADNEplus project.

- In WP12 the ARIADNEplus Aggregation Infrastructure was set up and the main knowledge base of the project established, creating the ARIADNE Content Cloud.

- In WP13 the ARIADNEplus Data Infrastructure is instantiated from D4Science, configured and further developed to serve the needs of the archaeological community. Moreover, the Virtual Research Environments (VREs) offering the services to support the R&D activities of the project were created on top of the Data Infrastructure, duly implemented, and put into operation.
- WP14 focuses on the creation of the ARIADNEplus Knowledge Organization System (KOS), defining application profiles (used in WP4 (NA3) for mappings and in general for managing the KOS), vocabularies and gazetteers.
- WP15 implemented services, including visual, annotation, text mining and geo-temporal services. It also implemented the back-office services that manage queries.
- WP16 implemented a number of innovative pilots based on the ARIADNEplus technology and dataset integration.

All JRA WPs began in Month 1 with preparatory activities (planning, internal WP organization, design, etc.) and had a WP kick-off meeting as part of the project Kick-Off. They ended at Month 48, contributing to the final reporting, including the project Progress Report.



The ARIADNE Research Infrastructure

Figure 2 The different elements that make up ARIADNEplus.

2.2 Progress achieved

Progress in the JRA WPs was carried out on five main fronts (see the figure above):

- Infrastructure and Virtual Research Environments setup and operation
- Aggregation infrastructure
- The ARIADNE Content Cloud
- The ARIADNE Portal
- Services and pilots

A separate sub-section is devoted to each, except for the Portal, which is described in depth in Section 4.

2.2.1 Infrastructure and VREs setup and operation

This part of the work has been carried out exclusively within WP13.

During the third year of the project, the infrastructure for ARIADNEplus was maintained and enriched to cater to the needs of the project.

In addition, several VREs were in operation:

1. ARIADNEplus Project
2. ARIADNEplus Mapping
3. ARIADNEplus Aggregation Management
4. Geoportal Prototype
5. Archeomar
6. ARIADNEplus Lab
7. GNA
8. Esquiline

A more detailed account of Infrastructure, including statistics on the accesses of the VREs, is given in Section 6.

2.2.2 Aggregation infrastructure

Data aggregation is essentially an inter-WP activity, carried out by WP12 in cooperation with WP14, and two WPs in the NA set of activities: WP4 *Integrating the datasets of the Archaeological Research Communities* and WP5 *Extending the ARIADNEplus Data Infrastructure* (ADI). The objective of this activity is to set up, implement and operate the ARIADNE Aggregation Infrastructure to create the ARIADNE Content Cloud (AC).

At the beginning of the project, it was decided to re-perform the aggregation of the data already aggregated by the ARIADNE project for two main reasons:

1. The enhanced scope and functionality of ARIADNEplus required the development of an improved ontology than the ARIADNE Catalog Data Model, better aligned with the CIDOC CRM and more tightly related to the objectives of the project. Consequently, the original data had to be transformed using the new ontology, which required a new aggregation process.
2. The infrastructure for ARIADNEplus aggregation is different from that used in ARIADNE, as it is based on different technologies and now fully integrated with the D4Science platform. Consequently, the inevitable update of the previously aggregated data required a re-definition of the aggregation process for these data, making it easy to re-aggregate the existing data as well.

During the third year of the project, server-side data aggregation was carried out on three main fronts:

- aggregation of collection-level metadata from the ARIADNEplus partners into the ARIADNEplus Catalogue, a major component of the ARIADNEplus Content Cloud (described more fully in next Section); this is a continuation of the activity started at the beginning of the project;
- aggregation design of the item-level data from the ARIADNEplus partners into the domain knowledge-bases, which all together constitute the other major component of the ARIADNEplus Content Cloud. This is a new activity started during the current reporting period, which has mainly involved the development of application profiles (see below for details) and of the mappings required to harmonise the item-level data provided by the partners according to these profiles;
- aggregation design of the item-level data from the THANADOS project into the burial knowledge base of the ARIADNEplus Content Cloud; this is also a new activity started in this reporting period, aimed at acquiring the data produced by the THANADOS project for the enrichment of the ARIADNEplus Content Cloud. The activity so far has tested the burial Application Profile for these data, and the design of the mappings for harmonising them with those provided by the ARIADNEplus partners.

Client-side data aggregation has resulted in the development, implementation, testing and release of the Activity Dash, a tool for monitoring the data provision and aggregation process, fully integrated in the D4Science environment. A tutorial on Activity Dash was given to 26 partners in February 2021.

Regular bi-weekly conference calls were held amongst representatives of the four relevant WPs to monitor the progress of data aggregation since the beginning of the pandemic.

2.2.3 The ARIADNE Content Cloud

The ARIADNE Content Cloud (AC) is the information repository collecting all the knowledge managed by the ARIADNE infrastructure.

From a technical point of view, the AC is an RDF dataset consisting of several RDF graphs. From an application point of view, the AC is a composite knowledge base that can be understood as consisting of several related parts, namely:

- the ARIADNE Catalog, giving collection-level knowledge about the resources of the AC, including data resources, services and the entities needed for contextualisation;
- several knowledge bases, each containing item-level knowledge about a specific Archaeological domain.

The ARIADNE Ontology (AO for short) is the ontology axiomatising the terms for making the statements in the AC. The AO is a formal ontology of the resources managed by the research infrastructure, with a special focus on the archaeological domain and the ARIADNE infrastructure, developed by the ARIADNEplus project.

Mirroring the structure of the AC, the AO was structured into sub-ontologies, namely:

- a Catalogue ontology, named AO-Cat, which axiomatizes the terms for the statements in the ARIADNE Catalogue;
- several Application Profiles, axiomatising the terms for the domain-specific parts of the AC.

During the third year of the project, the work on AO-Cat mainly focused on extending the ontology to cater to the new requirements coming from the data providers or from the Portal user group. Three main extensions were:

- adding images to archaeological records;
- allowing description of level of precision for spatial information;
- allowing description of provenance, authoring and versioning information.

The first two extensions are described in detail in deliverable D5.3 because they are of interest to the content providers. In contrast, the integration of the PAV ontology has not been exposed to the content providers, as it was automatically derived by the aggregative infrastructure and kept for technical purposes, hence not offered as an access criterion. In fact, there is no application requirement for accessing the AC based on provenance, authoring and versioning information and consequently there is no functionality within the Portal for expressing queries on these aspects of the data.

During the same period, work on Application Profiles was more intense, leading to the development and release of four Application Profiles, including:

- the Inscriptions, marks and graffiti Application Profile (task 4.4.13)
- the Heritage Science Application Profile (tasks 4.4.4 and 4.4.5)
- the aDNA (ancient DNA) data Application Profile (task 4.4.2)
- the Burials and mortuary Application Profile (task 4.4.14)

The Application Profiles relative to Palaeoanthropology (task 4.4.1), Environmental Archaeology (task 4.4.3), Field Survey (task 4.4.6), Metal Detector Surveys (task 4.4.7), Geospatial Data (task 4.4.10), Maritime and Underwater (task 4.4.11) actually coincide with the AO-Cat ontology, as the ontology covers the representational requirements of the corresponding data.

More details are given in Section 7.

2.2.4 The ARIADNE Services and Pilots

This is the area of the Project where the pandemic caused more delays, as the development of services requires greater interaction between service providers, user communities and technology providers supporting the integration of services on the D4Science platform. For this reason, a workshop for relevant people was planned to be held at CNR in Pisa in the beginning of March 2020, to be followed by additional events. Due to the pandemic outbreak the workshop was cancelled, and no other events were organised. Separate online tutorials between partners were held instead to explain the possibilities offered of the platform. These tutorials only addressed one aspect of the interaction however, and they could not replace the in-person interaction necessary for the sharing of data, tools and scenarios to plan the service integration.

Nevertheless, during the third period of the project the only Milestone about services, MS17 *Design of innovative ARIADNEplus user services* due at Month 28 was met, and several services were integrated into the platform, namely the TEXTCROWD service, the space-time service, the multilingual query service and the geoserver service. The integration of other services followed in the final year. This included the VisualMedia service and the tool for the visual organisation of archaeological data. More details can be found in Section 6.

The development of pilots also suffered during the pandemic, as it was difficult to understand requirements without in-person interaction. Nevertheless, during the third year of the project a seminar within INRAP, the Leader of WP16, and the partners involved in the pilots, was held via Zoom. During the seminar, a common framework for the pilots, based on Virtual Research Environments and services already integrated into the platform, or to be integrated in the next few months, was shared, discussed and validated. As a result, the pilots could all be launched and milestone MS19 *First four innovative pilots launched* was achieved (see Section 8).

3 Knowledge Discovery Services

3.1 Goal

The goal of Task 12.5 was to design knowledge discovery and browsing services according to the user needs identified in Task 2.2 and respond to user evaluation and feedback during the life of the ARIADNEplus project. The task was led by UoY-ADS, based on their archaeological experience and extensive engagement with the archaeological user community since 1996. Relevant use cases were provided by SRFG, and the implementation of the discovery and browsing services was undertaken by CNR (ISTI) and SND. It was agreed that the primary means of discovery and browsing should be via the GUI of the ARIADNE portal, implemented in Task 12.3. The portal is able to support query and browsing at item and collection level and allows the user to address many research questions in its own right. For more specific item level queries which could not be undertaken within the portal a dedicated ARIADNElab VRE was constructed to allow more advanced users to undertake SPARQL queries directly, using the ARIADNE Knowledge Base in the triplestore.

3.2 Approach

ARIADNEplus has incorporated data from a much wider range of archaeological research domains than ARIADNE, including environmental archaeology, maritime and underwater archaeology, biological and inorganic materials studies, radiocarbon, dendrochronology and other dating methodologies. Furthermore, the project integrated more datasets at item level, including artefacts and coins, inscriptions, rock art, and burials, to provide advanced semantic data search to find data items based on semantically defined relations.

Our approach to prioritisation of data aggregation, and discovery and browse features was developed in response to two initiatives. Firstly, in early 2019 PIN and UoY-ADS updated a review of the datasets that the archaeological partners planned to make available for aggregation, initially conducted in 2018 during the project proposal stage. This was essential for Task 12.5 as approaches to knowledge browsing and discovery could only be designed in response to the datasets that were made available via ARIADNEplus. Secondly SRFG undertook a user survey to investigate several closely related questions on data search and access: current online availability of the different types of archaeological data, and how helpful it would be to discover and access the data via the ARIADNEplus portal, at both the collection level and item level (Deliverable 2.1). Respondents indicated that the availability of large number of site/ monument records which had been a focus of the first ARIADNE project was much appreciated by users. But the survey results also tentatively suggested the following prioritisation of additional data types for integration in the ARIADNEplus portal:

- Excavation data (*e.g.*, excavation archives)
- Artefact/finds databases or image collections
- Radiocarbon, dendrochronology and other dating data
- Environmental archaeology datasets
- Unpublished fieldwork reports

- Field survey/prospection data

In addition, there was also demand for subject-based data types of the following sub-domains:

- Maritime and underwater archaeology data
- Scientific data/analysis of inorganic remains
- Scientific data/analysis of biological remains
- Inscriptions, coins or other special databases

Survey participants also rated which data types they would find helpful for their research if able to search items within datasets integrated from multiple sources, and artefact/finds databases or image collections were ranked highest.

The prioritisation for data aggregation and the specification for portal services was therefore informed by the intersection of data supplier availability and data consumer user needs, and will be discussed in Section 4.3.

User feedback and evaluation fed into the development and refinement of portal features during the lifetime of the project, sometimes leading to modifications of the AO-Cat, including for example, the ability to add images of individual artefacts, or the option to mask the precise location of an archaeological discovery to protect the site. All archaeological partners were asked to provide feedback on the portal interface and, using additional (non-project) UK funding, UoY-ADS also commissioned UX/UI consultants, the Error Agency, to undertake a User Experience assessment of users of the ARIADNE portal and a number of equivalent online interfaces for heritage data, including the in-house interface of the Archaeology Data Service itself.¹ Error designed user profiles and sampled university researchers and students, professional fieldworkers, government-based archaeologists and curators, holding focus groups in which they monitored individual users attempting to completed preset tasks using the different web sites. In all cases the ARIADNE portal scored highest for knowledge discovery and browsing. Nonetheless, their report made several recommendations for improvement to the GUI. These were reviewed by the portal working group (See Deliverable 12.4) and the majority were implemented in revisions of the portal software.

For queries that could not be addressed by the portal, UoY-ADS provided a specification for the ARIADNELab VRE, using more complex queries and user scenarios which they had encountered and these were implemented by CNR-ISTI.

Finally, both the Portal and the ARIADNELab VRE were tested during an ARIADNE Hackathon held as part of the Linked Pasts VIII Symposium, at the University of York from 29 Nov – 1 Dec 2022.² A mixed group of c.20 in person and online participants, ranging from university students to archaeology and heritage professionals were asked to complete a range of research tasks, using both the Portal and

¹ <https://error.agency>

² <https://www.seadda.eu/?p=1808>

ARIADNElab VRE. The majority used both interfaces effectively to address the questions, demonstrating their value in combination for Knowledge Discovery and Browsing.

3.3 Implementation

This section describes how the main features of the Portal were designed so as to support Knowledge Discovery and Browsing Services. It does not repeat information about the Portal implementation already provided in Deliverable 12.4, but gives a user perspective on the features available.

The free text search box on the portal welcome page, and at the top left of the results page, provides a powerful discovery tool. This initially searched all fields but the search was made more effective by allowing users to search specific data fields: Time period, Place, Title and Getty AAT subject. The other options on the results page provided a search and browse function both for these fields, along with some additional key properties from the AO-Cat.

The majority of archeological knowledge discovery queries (and indeed research questions) are covered by a combination of the Where, When, and What facets. In response to user feedback, it was agreed that Where and When queries were best supported by full page Advanced Where and When search and browse functions, whilst the inset map and timeline displays on the results page were best used to visualise results, rather than perform searches. As our user needs survey had identified a demand for basic GIS functions, the map-based search was enhanced to support pan and zoom, and the definition of polygonal or bounding box search areas. The option was also included to select a number of base maps according to user preference. The placement of user options was adjusted during the project lifetime in response to feedback from the Error focus groups, collecting mapping functions on the right-hand side, and search filters on a pop out menu on the left.

The 'When' search is another powerful feature which allows users to select a 'From' and 'Until' data range, based on the definitions of archaeological periods published by the project in the PeriodO online system. In response to user feedback the search was adjusted to include periods which overlap with the selected range, rather than just those contained within it, to provide the user with a comprehensive list of results. The use of cultural periods to provide a search by temporal zone proved more problematic. The project wanted to be able to allow users to select resources from multiple cultural periods e.g. 'Bronze age and Iron Age', and also from the same cultural period but from different temporal zones e.g. 'Iron age' and 'Age du Fer'. A beta version of this function has been implemented on the staging portal.

On the results page, a number of additional filters allow users to perform Boolean AND queries across multiple properties. One of the most important is the Resource type. In order to provide different user views according to the needs identified by the user survey we defined a property of the AO-Cat as 'ARIADNE_subject', and enabled users to filter resources according to this property, displayed as "Resource type". Each resource type is a high-level subject type in its own right, and is mapped to the Getty AAT, but the filter allows more rapid discovery. It can also be used in hard-wired settings for other implementations of the portal infrastructure to provide alternative views of the ARIADNE Knowledge base. Figure 1 shows the full list of ARIADNE subjects, and the number of resources of

each type in the public portal, as of 3 December 2022. Inevitably there is uneven coverage, as the quantities are determined by those resources made available by providers. Nonetheless, the project has largely met the user needs expressed by the survey. For example, as of 3 Dec 2022 it provides direct item level access to 539,594 artefacts, and 471,403 coins. There are also 276,850 fieldwork reports available, and 113,360 fieldwork archives, and 395,124 records about a fieldwork event, but lacking reports, or archives. Fieldwork surveys was the only one of these areas where we were unable to identify suitable datasets at this stage. Scientific data was more problematic, reflecting that this is still a challenging area where practitioners struggle to meet the FAIR principles. Nonetheless, the Portal already provides access to 9015 records about archaeological scientific dates and 7785 scientific analyses. In other requested sub-domains we were more successful, cataloguing 33,336 maritime and underwater resources, and 83,357 inscriptions.

▼ Resource type	
Enter text to filter on Resource types.	<div>Name</div> <div>Hits ▼</div>
Site/monument	1208412
Artefact	539594
Coin	471403
Fieldwork	395124
Fieldwork report	276850
Fieldwork archive	113360
Inscription	83357
Maritime	33666
Rock art	26805
Date	9015
Scientific analysis	7785
Building survey	1274
Burial	42

Figure 3 ARIADNE portal resource type filter on ARIADNE subject, 3 December 2022.

For ‘What’ subject-based searching using controlled vocabularies our adoption of the Getty AAT as a common spine to which all partners were required to map their native subject terms has proved to be an extremely powerful tool for Knowledge Discovery, as well as for the support of multilingual searches. The portal search interface has been able to take full advantage of the hierarchical nature of the Getty thesaurus, so that if a broad term is entered the query also returns all narrower terms.

For example, if a search were to be made on ‘weapons’ only the portal returns 753 resources; however, if the search is expanded so that it returns ‘weapons’ and all narrower terms, such as ‘sword’, ‘spear’, ‘shield’ etc, the results list is now expanded to 24,834 resources (figures 4 and 5).

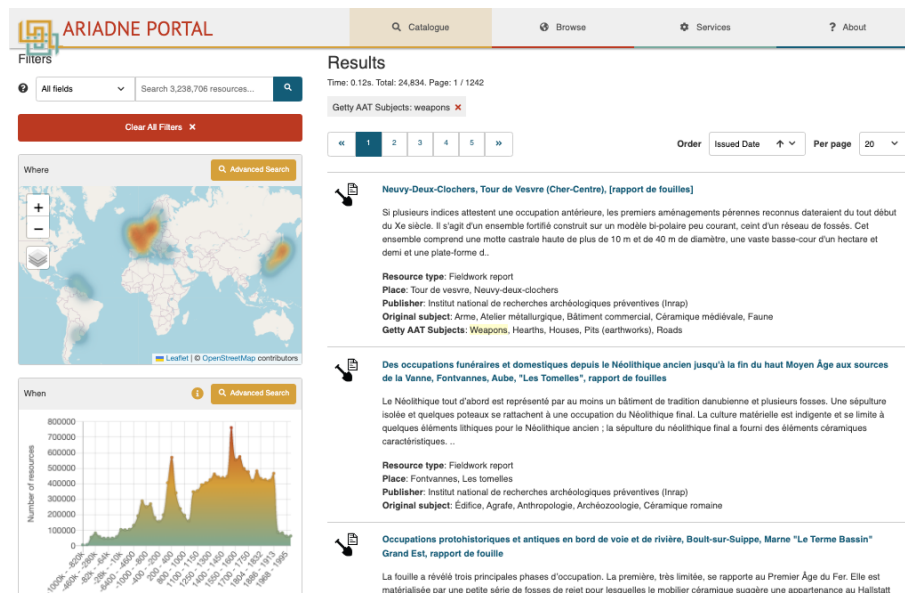


Figure 4 Searching on ‘weapons’ only - 753 resources.

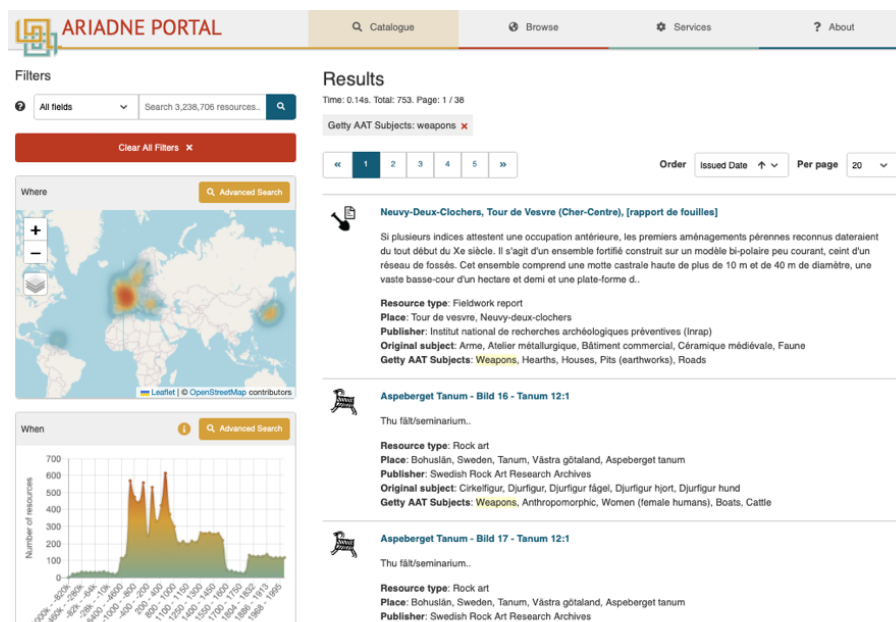


Figure 5 Searching on weapons and all narrower terms- 24,834 resources.

The value of this feature in achieving interoperability is apparent from a second example. In the mapping of native terms to the Getty AAT, in the case of ‘warships’ Historic England only used the higher-level term, whereas Historic Environment Scotland preferred narrow terms. Thus, if the user searches on ‘warships’ they discover 580 resources, but all limited to England, whereas if they are able to include narrower terms they now discover 1023 resources, distributed all around the UK coast (Figures 6 and 7).

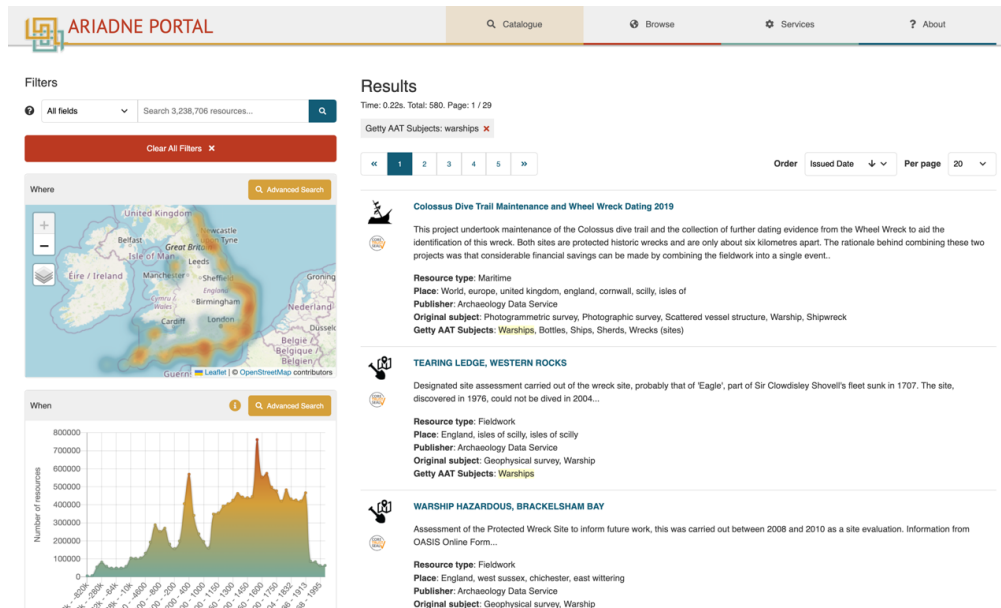


Figure 6 Search on ‘warships’ only – 580 resources.

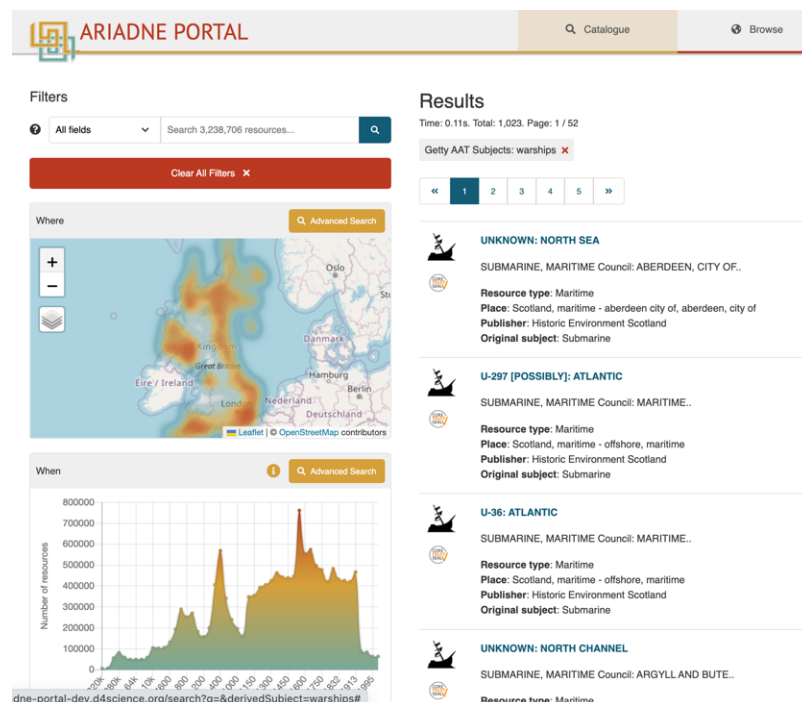


Figure 7 Search on ‘warships’ and narrower terms – 1023 resources.

▼ Publisher

Enter text to filter on Publishers. Name Hits ▼

1 Archaeology Data Service	1114931
1 British Museum	945228
1 Historic Environment Scotland	334636
1 Archaeological Information System of the Czech Republic (AIS CR)	229999
1 Nara National Research Institute for Cultural Properties	139368
1 Data Archiving and Networked Services (DANS)	99291
1 HNM	59684
1 CEIPAC - Universitat de Barcelona	57054
1 Institut national de recherches archéologiques préventives (Inrap)	37616
1 Swedish Rock Art Research Archives	25223
1 National Heritage Institute - Romania	18279
1 International Association for Classical Archaeology	14279
1 ZRC SAZU	8775
1 Aarhus University	8687
1 CENIEH	8405
1 Heidelberg Academy of Sciences and Humanities	7517

Figure 8 Publisher is defined by AO-Cat as the organisation making the data available online.

incredibly powerful tool for Knowledge Discovery, and these have been implemented in the Portal, with additional features in the ARIADNElab VRE. User feedback and evaluation demonstrated that the portal is intuitive to use, and is able to support a wide range of archaeological research questions.

Finally, it was agreed to include filters on two of the primary ARIADNE ‘agents’ in the Portal interface: Publisher and Contributor. Publisher is defined by AO-Cat as the organisation making the data available online. It is generally the same as the ARIADNE partner or associate partner. Contributor is a longer list, of those contributing to the resource. Both provide powerful filters to allow users to select resources from specific organisations, but then to add further filters to aid browsing and comparison of resources.

As several publishers provide access to resources from more than one country, we have also identified that it would be useful to add an additional filter by country. Unfortunately, ‘country’ is not a property in the AO-Cat, but might be added to a future iteration. Nonetheless, it should be possible to derive country by deploying an international polygon coverage of national boundaries using the Geoserver VRE. Since this would require reindexing all records this been set to one side for the present, but might be implemented in a future version of the portal.

In conclusion, Task 12.5 was able to specify the functionality and features which constitute an

4 Overview of WP12: Data Integration and Interoperability

4.1 Goal

The goals of WP12 are to develop, deliver and maintain the components of the ARIADNEplus infrastructure that support the integration and interoperability of the data provided by the members of the consortium and associate partners.

- 3M Editor: definition of the mappings from local metadata format to AO-Cat format.
- Vocabulary Matching Tool: definition of mappings from local subject terms to Getty AAT.
- The ARIADNEplus aggregator is based on the D-Net software toolkit. It collects provider XML records and integrates them using the X3ML toolkit for the execution of 3M mappings. It is configured to implement the aggregation workflows defined in collaboration with WP5.
- The ARIADNEplus Knowledge Base (KB) is implemented with GraphDB, a database for knowledge graph offering Semantic Web and Linked Data capabilities
- The ARIADNEplus Portal: the main entry point for humans willing to search, browse and access the aggregated resources. It uses an OpenSearch index server where resources of the KB are indexed

Errore. L'origine riferimento non è stata trovata. shows the main components and interactions implemented for data integration and interoperability. Data is collected from partners and transformed into RDF records compliant with the AO-Cat model. Records are stored on GraphDB, where they are enriched and mapped to the Getty AAT and PeriodO. The KB exposes a SPARQL endpoint, and its content is indexed using OpenSearch, which serves the ARIADNEplus portal. The phases of collection, transformation, storage, enrichment, and indexing are orchestrated by the aggregative infrastructure with the supervision of an aggregation manager.

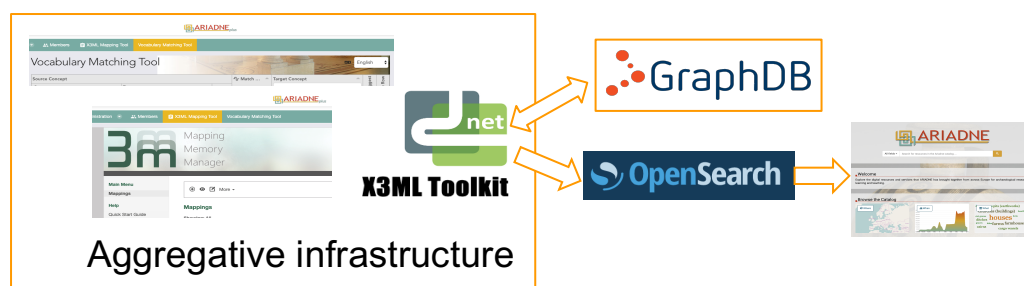


Figure 9 Services and tools for data integration and interoperability in the ARIADNEplus infrastructure.

Finally, the deeper integration of item level data (item-level integration) is investigated in task 12.4 for the domains of mortuary archaeology, numismatics and epigraphy.

4.2 Planned schedule

The table covers M37-M48.

Goal	Planned delivery date	Status
Portal release v3.0	M42	Delivered by M42
Migration from elasticsearch to OpenSearch	M42	Migrated by M42
Documentation for aggregation managers	M48	Draft shared with PIN in M47
Update documentation of the ARIADNEplus KB	M48	New Jupyter notebook with charts available since the Hackathon at Linked Pasts (M48)
Portal final release	M48	Delivered by M48
Finalise demonstrator for item level integration	M48	Finalised by M48

4.3 Results obtained in M37-M48

The ARIADNEplus aggregator

- Development, testing, and deployment of the software for the collection of metadata records from THANADOS
- Documentation for aggregation managers

The ARIADNEplus Knowledge Base

- Defined policy for the content negotiation of Linked Data resources
- New feature to add centroids with spatial information to the indexed records
- Updated documentation on how to use the KB

Portal

- Two new versions of the portal were released
- Migration of the index server from elasticsearch to OpenSearch

Item-level integration

This subtask focused on three domains mature enough and suitable for deeper integration, the domains of mortuary archaeology, numismatics and epigraphy. For the domains of numismatics and

epigraphy an experimental platform was implemented based on ResearchSpace in order to test specific queries. For all datasets we ran integrated queries on the SPARQL endpoint of GraphDB.

Details of the integrated datasets and the relevant research questions are presented in deliverables D12.4 *Final report on data integration* and D14.2 *Final report on the ARIADNEplus knowledge management system*.

The services delivered by the project will be operational after the end of the project as specified in the grant agreement. Thanks to the newly established legal entity for ARIADNE, the services may be subject of further exploitation.

4.4 Encountered problems and open issues

Nothing to report.

5 Overview on WP13: ARIADNEplus Infrastructure Operation and Management

Goal

The goal of WP13 was to deliver and operate the ARIADNEplus Infrastructure.

This infrastructure is built by exploiting the computing and stored resources operated and provisioned by D4Science together with services for their management and administration. Upon those resources, data, tools, and services were deployed and made available to the project research communities for access and use, via an authentication and authorisation mechanism (also provisioned by this task) compliant with the EOSC identity federation.

The activities performed include:

1. the set-up of monitoring, alerting, and accounting services for all federated resources to guarantee the required Quality of Service (QoS);
2. the operation of a number of Virtual Research Environments (VREs) providing support for the exploitation of the provisioned storage and computing facilities to the other project JRA Work Packages via the production of training material and how-tos aiming to simplify all phases of the preparation of new tool and service candidates for integration.

Virtual Research Environments (VREs) are “systems” to provide users with web-based work environments offering the entire spectrum of facilities (including services, data, and computational facilities) needed to accomplish a given task by dynamically relying on the underlying infrastructure. VREs are key products delivered by the ARIADNEplus project to meet the needs of its target community and scenarios, they are dedicated to discussing and developing various approaches and solutions to be applied to concrete cases and scenarios, and serve specific communities and practitioners confronting a given research question.

The above-mentioned storage and computing facilities are meant to be accessible via a VRE - exploiting the procedures and tools already validated and used in D4Science - by the tools and data required by the services developed in the context of WP15 (ensuring that the proper allocation of resources is guaranteed for their operation) and by WP16 activities.

As a complement, WP13 manages the software release process covering all stages from integration, through documentation and validation, up to provisioning in JRA work packages. Therefore, it defines release and provisioning procedures, establishes the release plan, coordinates the release process, and operates the tools required to support the release and provisioning activities by also taking care of the distribution of the software.

5.2 Planned schedule

Goal	Planned delivery date	Status (textual description)
ARIADNEplus e-infrastructure Gateway	M1	Completed
MS12 First Virtual Research Environments deployed	M20	Completed
ARIADNEplus Laboratory	M30	Completed
Design, configuration and delivery of the GNA VRE	M38	Completed
Enhancement of the ARIADNEplus Lab VRE	M42	Completed
Adoption of the new Gateway service	M46	Completed

5.2 Results Obtained

The following table reports the complete list of VREs created and/or operated during the project, which include: five VREs from January 2019 to December 2020 (shaded background), 3 VREs from January 2021 to November 2022) in regular background.

VRE name	Start date	Membership	#Users ³
ARIADNEPlus Project	Jan. '19	Private	150
ARIADNEPlus Mapping	Feb. '19	Restricted	142
ARIADNEPlus Aggregation Mgmt.	Mar. '20	Restricted	11
Geoportal Prototype	Apr. '20	Restricted	24
Archeomar	Apr. '20	Private	16
ARIADNEPlus Lab	Jul. '21	Open	64
GNA	Jan. '22	Private	25
Esquiline	Oct. '22	Private	4

The complete list of the results obtained is given in the following:

- Operation of the ARIADNEplus e-infrastructure Gateway available at <https://ariadne.d4science.org>.
- Operation of the AggregationMgmt, Mappings, GeoNA-Prototype, Archeomar, and Project VREs.
- Integration of new computing resources to support the configuration and deployment of a Kubernetes cluster and a computational cluster.
- Adoption of the new Identity and Access Management (IAM) supporting the standard OpenID Connect (OIDC). This activity required the porting of existing users, roles, VREs settings, services privileges, etc. to the new technological framework.

³ Number of members of the VREs in November 2022.

- Release of the new geographical Map Viewer allowing increased and customisable zoom levels, tailored Web Feature exploitation and role-driven access to geographical features.
- Release of the new Map Explorer allowing access to textual descriptions, images, and any other related information associated with a geo-package.
- Exploitation of the new version of the Spatial Data Infrastructure (SDI) provided by D4Science. The SDI is composed of a set of technologies for the storage, indexing, cataloguing, discovery, and access to geographical datasets according to OGC (Open Geographic Consortium) standards. This activity required the porting of existing datasets, styles, VREs settings, access privileges, etc. to the new technological framework.
- Configuration and deployment of JupyterHub technology in the Kubernetes cluster. This technology enabled the activation and exploitation of a JupyterLab service and the exploitation of computational environments and resources without burdening users with installation and maintenance tasks. This JupyterHub environment is preconfigured with libraries and packages to ease the execution of common data analytics tasks, and provides access to the Workspace enabling sharing of resources with other members much easier.
- Configuration and deployment of RStudio services in the newly added computational cluster. RStudio provides an integrated development environment for R. It includes a console and a syntax-highlighting editor and enables code execution. Tools for plotting are also included. This RStudio environment is *(i)* preconfigured with libraries and packages to ease the execution of common data analytics tasks; and *(ii)* provides seamless access to the Workspace enabling sharing of resources with other members much easier.
- Configuration and activation of the Analytics engine framework (DataMiner) to permit the execution of an array of analytics methods by transparently relying on distributed computing infrastructure. Executions can run either on multi-core machines or on distributed working nodes. New software can be integrated by using the dedicated Software Importer (SAI).
- Integration of GraphDB. GraphDB provides users with access to the ARIADNEplus Knowledge Base, an archaeological Linked Open Dataset modelled according to the ARIADNE ontology and provided by an international network of organisations. With GraphDB any user can explore the knowledgebase with the available web GUI or programmatically with SPARQL queries.
- Design, configuration, and provisioning of a new VRE named ARIADNEplus_Lab which hosts all users needing to perform any type of computations on data and metadata. This new environment is open and accessible to all ARIADNEplus users that can easily create a new notebook, for example, using RStudio, or integrating their software and running it as-a-service by using the Web Processing Service (WPS) standard API. ARIADNEplus_Lab VRE also provides access to the GraphDB.
- Design, configuration and delivery of the D4GNA VRE⁴ (Dataset per il Geoporatale Nazionale per l'Archeologia), an open access environment that provides access to Italian archeological excavations. It collects spatial stratigraphic excavation data from the entire national territory. Data from stratigraphic excavations can be visualized either via a map-based application or a more traditional catalog view.

⁴ <https://gna.d4science.org/>

- Enhancement of the ARIADNEplus Lab VRE⁵, the ARIADNEplus Lab VRE has been enhanced to provide archaeologists and scholars with a virtual research lab and a set of tools to aggregate the data of the ARIADNE infrastructure, make this data interoperable with personal external data, and to analyse and manipulate the data to answer specific research questions of archaeology or related disciplines.
- Adoption of the new Gateway service, a new version of the Gateway service brought enhancements such as the adoption of “Web Component” standards.
- Design, configuration and delivery of the Esquiline VRE that integrates the data and tools operated by SITAR WebGIS, offering services for the exploitation of temporal GIS technology to provide new methods of investigation and data presentation, paving the way to innovative site analyses aimed at integrating excavation data from different archives, allowing the re-creation of the archaeological context where layers of findings overlap over the time.

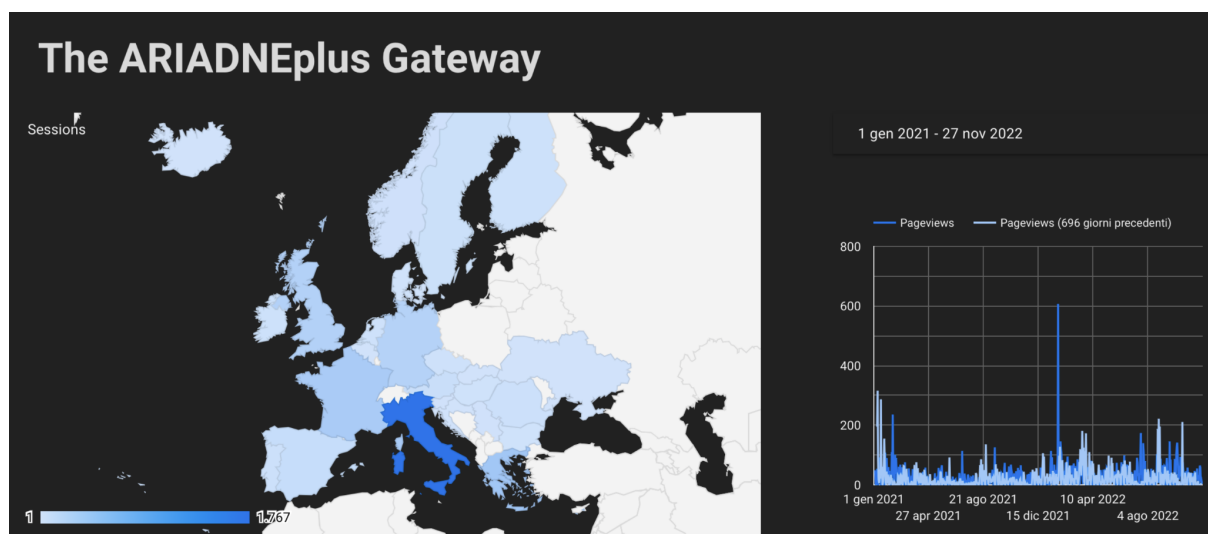


Figure 10 The European geo-distribution of user sessions on the ARIADNEplus Infrastructure Gateway in the second period of the project.

⁵ https://ariadne.d4science.org/web/ariadneplus_lab

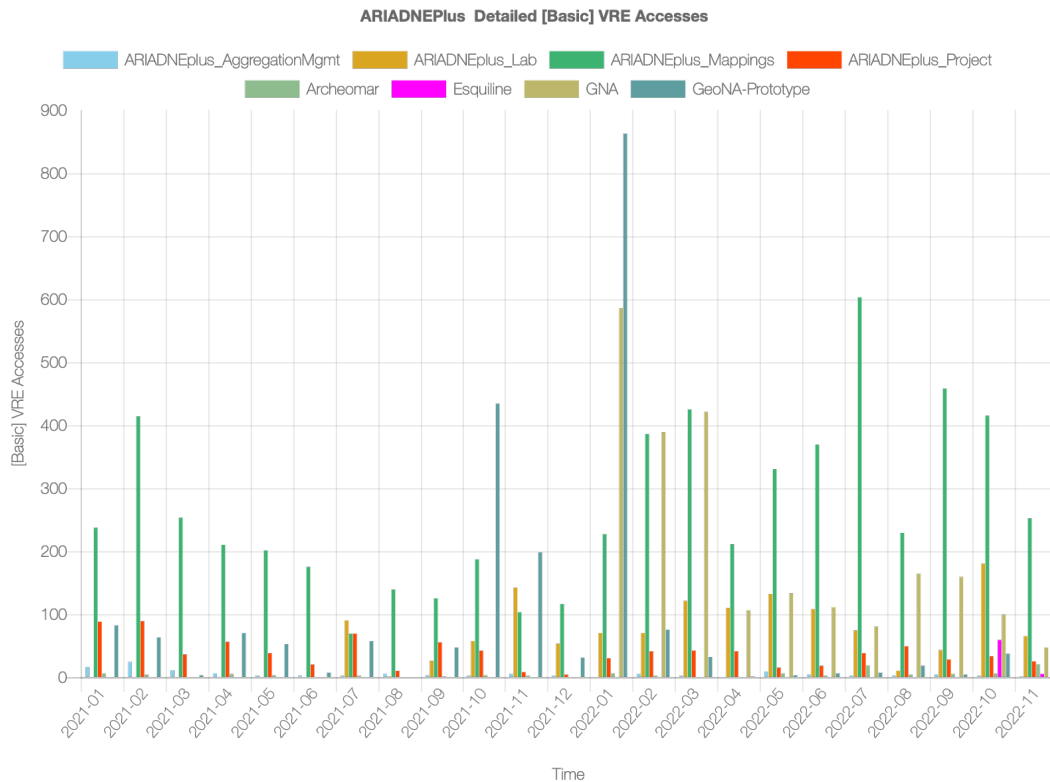


Figure 11 Number of VRE User Accesses per month (January. '21 - November. '22).

Figure 10 reports on the number of VRE user accesses per month in the second period of the project, hence by showing how often the ARIADNEplus Project members have accessed and exploited these VREs. This chart shows peaks up to 600 accesses per month on more than one VRE and one peak of 900 accesses. As in the first period, the most accessed VRE in the second period has been the ARIADNEplus Mappings, its average number of accesses per month for the second period has grown up to 266 access per month, reflecting the frequent mapping activity that VRE members have been doing in the period.

5.4 Encountered Problems And Open Issues

Nothing to report.

6 Overview of WP14: the ARIADNEplus knowledge management system

6.1 Goal

The goal of WP14 is to define the ARIADNEplus semantic framework which:

- monitors the data provision and aggregation process, through a convenient and easily accessed system. This system offers a flexible and friendly collaborative environment, to be used by many users simultaneously for managing workflow activities and tracking their progress. The system acts as a reference point for any ARIADNEplus stakeholder to check the status of any process and provide the appropriate feedback;
- defines appropriate disciplinary Application Profiles required for the diverse types of data handled by ARIADNEplus. Application Profiles are specialisations expressed as CIDOC CRM extensions for the different thematic groupings broadly corresponding to those identified in Task 4.4, and aggregated according to similarity;
- provides domain specific vocabularies, a space-time gazetteer and a periodisation system to address the interrelation between space and time.

The work done in WP14 was assessed in Task 14.4 in close collaboration with T4.4 and provided feedback and changes where necessary.

6.2 Implementation schedule

Goal	Planned delivery date	Status
Testing and Validation of the Activity Dash v1.0	M48	Completed
Usage of the Application Profiles (Inscriptions, Heritage Science, Mortuary data, aDNA) to provide data to the ARIADNE Cloud	M48	Completed
Analysis and development of other application profiles	M48	Completed
Substantial space-time vocabulary via PeriodO (based on T4.4 data integration)	M48	Completed
Supporting data partners as they enter their specific time periods into PeriodO	M48	Completed
Supporting data partners mapping their native subjects to AAT	M48	Completed
Assessing Application Profiles, CRM extensions	M48	Completed

6.3 Results obtained in M37-M48

6.3.1 Activity Dash

Activity Dash is an online web application used for tracking workflow processes within the ARIADNEplus project. The tool was designed, implemented and tested by a small group of people for validation purposes during the first two years of the project.

In the second part of the project, Activity Dash was extensively used to track the aggregation process. A template workflow was defined and used to set up dedicated workflows for every provider. The individual tasks in each workflow were assigned to relevant people. This allowed users to track the progress of their task through the interface and to communicate with other involved users. Currently, a total of 26 workflows have been completed and another 37 are in the tracking process.

Activity Dash helped the aggregation team significantly in keeping track of the different workflows and communicating problems, inconsistencies or other issues that would appear during aggregation. At the same time the tool was validated, improved and expanded. Continuous support was given to the partners when they encountered problems in using the tool.

The details of Activity Dash are presented in the deliverable D14.2 Final report on the ARIADNEplus knowledge management system.

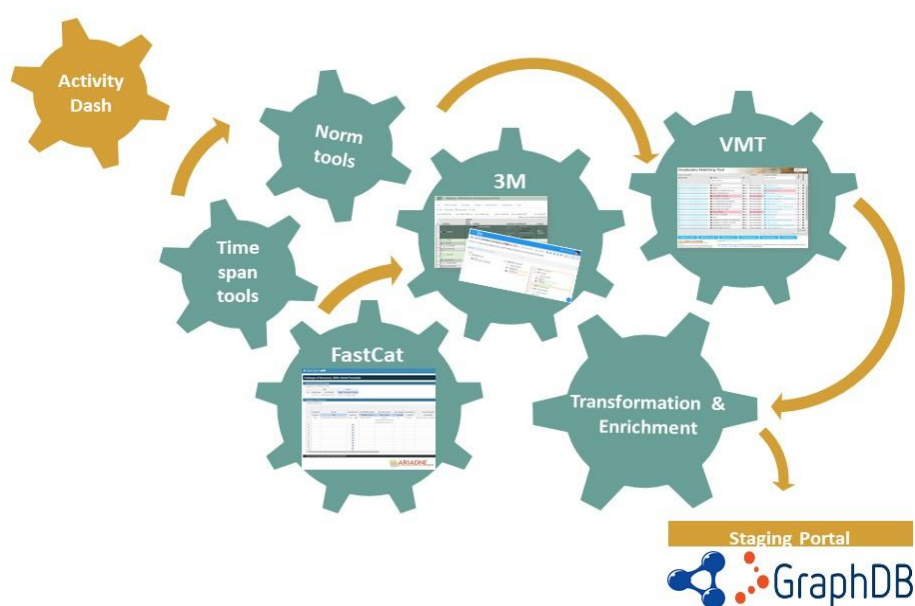


Figure 12 Conceptual Architecture of the Aggregation Toolkit.

6.3.2 Application Profiles

During the period from M37 to M48 the work on different application profiles was finalised. The following table presents a summary of all the application profiles developed along with their latest version:

Subtask	Application Profile	Current Version	Description
ARIADNEplus catalogue	AO-Cat	1.1.10	AP for the representation of the resources in the ARIADNE Catalogue. It is described in D4.1 Initial report on dataset integration https://zenodo.org/record/4916262#.Y3TuenZByic and D4.3
Ancient DNA data (4.4.2)	aDNA AP	v1.0	The aDNA application profile is designed to describe the aDNA wetlab methodologies integrated with the contextual information regarding the samples. It is described in D4.2 https://zenodo.org/record/4916299#.Yanxe9BByid
Heritage science data (4.4.4, 4.4.5)	CRMhs AP	1.0	The CRMhs application profile is specifically designed for the encoding of information produced in the domain of Inorganic Materials Study, Dating, and in general for all types of data deriving from Heritage Science research. (https://data.d4science.net/ngRG)
Inscriptions, marks and graffiti (4.4.13)	CRMtex	v1.1	CRMtex, the CIDOC CRM extension for the description of textual entities, has proved to be the ideal tool for the description of inscriptions, marks and graffiti. It is described in D4.2 https://zenodo.org/record/4916299#.Yanxe9BByid
Burials and mortuary data (4.4.14)	Mortuary AP	v1.2	The Mortuary Data AP is designed to model different types of burial data. https://zenodo.org/record/7252485#.Y3TwIXZByic

Subtask	Application Profile	Current Version	Description
Palaeoanthropology (4.4.1) Environmental Archaeology (4.4.3) Field Survey (4.4.6) Metal Detector Surveys (4.4.7) Geospatial Data (4.4.10) Maritime and Underwater (4.4.11)	Not needed		The use of AO-Cat and the other Application Profiles developed by ARIADNEplus (e.g. CRMhs and aDNA) has proved to be sufficient for the encoding of information for these research domains. In some cases, entities from the CIDOC CRM ecosystem have been combination with extensive use of vocabularies and dedicated services (e.g.: Geographic systems) to implement a deeper integration.

Details about the Application Profiles are presented in D4.4 *Final report on ontology implementation* and D14.2 *Final report on the ARIADNEplus knowledge management system*.

6.3.3 Vocabularies and gazetteers

Work on multilingual vocabularies overlaps with WP5 vocabulary integration via mappings from partner vocabularies to the Getty Art and Architecture Thesaurus (AAT), and via the PeriodO framework for temporal periods (see also WP5 Deliverables and the User Manual for the ARIADNEplus Data Aggregation Pipeline). Following strategies developed in the first phase of the ARIADNE project, the AAT plays a central role as a vocabulary hub for the ARIADNEplus data aggregation process and as a multilingual vocabulary. For temporal data, PeriodO serves as a repository for the named periods relevant to (and contributed by) each partner, with corresponding spatial region and numeric year spans. Multilingual concepts from Wikidata with mappings to the AAT have also been extracted via SPARQL queries as an additional multilingual resource. Data partners were supported when entering their period data to PeriodO and when creating the mappings of their native subjects to AAT.

During the last year of the project, the work supporting partners in implementing PeriodO collections for ARIADNEplus and in mapping local subject concepts to the Getty AAT continued as part of the routine integration activity. The resulting set of partner period definitions yielded the definitive PeriodO ARIADNE data collection.

6.3.4 Assessing the CRM extensions

The assessment of the CRM extensions included testing integrated data from the fields of numismatics, epigraphies and mortuary archaeology. A semantic search demonstrator was built to query and test the numismatic and epigraphic data integrated to the item-level. The mapping of the THANADOS database to the infrastructure was used to test the mortuary data AP. The experiments proved that AO-Cat, together with the appropriate specific Application Profiles and the extensions of

CIDOC CRM provide a solid basis for heterogeneous resource integration, but dedicated VREs are necessary to support query formulation and result presentation.

The details of the assessment of the CRM extensions are presented in the deliverable D14.2 Final report on the ARIADNEplus knowledge management system.

6.4 Encountered problems and open issues

There are no specific issues to be reported.

7 Overview of WP15: Innovative Services for Users

7.1 Goal

The overall goal of Work Package 15 was to provide services to archaeologists using ARIADNEplus data. This includes integrating existing services, developing new features within existing services, as well as development of new services. All services are integrated into the ARIADNEplus infrastructure by making them available on the D4Science platform.

The services cover a wide range of features useful for researchers, ranging from front-office services such as visualisation, various types of annotations and documentation, to more back-office oriented services, such as the multilingual query service used by the ARIADNEplus Portal for querying the underlying aggregated partner resources.

Task 15.1 was to analyse the existing services available in the prior version of the ARIADNE Portal, as well as services already available to partners and others, available as open source. This included finding and integrating other possible candidates as services in the ARIADNE infrastructure, and produce a service design for the other services to use.

Tasks 15.2 through 15.5 cover the front-office services and Tasks 15.6 and 15.7 are the back-office services, which are developed under the ARIADNEplus umbrella.

Task 15.2.1 built upon the VisualMedia EOSCPilot Science Demonstrator. The VisualMedia service, which enables the display of archaeological information in the form of images and 3D models, will be adapted to the ARIADNEplus infrastructure and made available as an ARIADNEplus service.

Task 15.2.2 took the pre-existing 3DHOP service at CNR, which links archaeological documentation to the 3D model of an artefact or monument and visualise it accordingly, and adapted it to the ARIADNEplus infrastructure.

Task 15.2.3 reworked the Ephemera service provided by CYI. The service visualises the layers of archaeological excavations in 3D, together with related documentation. The service will also be adapted to the ARIADNEplus infrastructure.

Task 15.3.1 concerned the development of an annotation tool for archaeological reports and other related texts, building upon existing open-source tools.

Task 15.3.2 extended the image annotation tool DAP, developed by CNR and AMZ.

Task 15.4 concerned the implementation of the text mining and NLP service, based on the previous ARIADNE NLP tool, which was later developed into TEXTCROWD, a cloud-based Science Demonstrator within the EOSCPilot EU project. Work will consist in porting the previous ARIADNE NLP tool in the cloud environment, following what has been done for TEXTCROWD, and extending the NLP functionality to other languages beyond Italian (as done in TEXTCROWD), English and Dutch (as done in the ARIADNE tool). The task made extensive use of the vocabularies, gazetteers and time period vocabularies.

Task 15.5 implemented the usual space-time services present in GIS systems and make it available through the ARIADNEplus infrastructure.

Task 15.6 concerned the development of a multilingual query service used by the ARIADNEplus Portal for querying the underlying aggregated partner resources.

Task 15.7 implemented a geoserver for geographical information provided by partners.

7.2 Implementation Schedule

Goal	Planned delivery date	Status
MS17 Design of innovative ARIADNEplus user services defined	M28	Finished
Deployment of the VisualMedia service on the ARIADNEplus infrastructure	M28 – M48	Finished
Deployment of the tool for visual organisation of archaeological data on the ARIADNEplus infrastructure	M28 – M48	Finished
Deployment of the Ephemera service on the ARIADNEplus infrastructure	M28 – M48	Being finalised
Deployment of the archaeological text annotation tool on the ARIADNEplus infrastructure	M28 – M48	Finished
Adaptation of the DAP tool to be interoperable with the ARIADNEplus infrastructure	M28 – M48	Finished
Deployment of the ARIADNE NLP tools on the ARIADNEplus infrastructure	M28 – M48	Finished
Deployment of the space-time service on the ARIADNEplus infrastructure	M28 – M48	Finished
Deployment of the multilingual query service on the ARIADNEplus infrastructure	M28 – M48	Finished

Deployment of the geoserver service on the ARIADNEplus infrastructure	M28 – M48	Finished
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7.3 Results obtained in M37-M48

- Service descriptions and search added to the ARIADNEplus portal. (Task 15.1)
- Visual Media Service deployed in the ARIADNEplus infrastructure. (Task 15.2.1)
- Texture processing added to the Visual Media Service. (Task 15.2.1)
- Nexus for Unity added to the Visual Media Service. (Task 15.2.1)
- A Lidar visualisation interface developed and added to the Visual Media Service. (Task 15.2.1)
- All extensions for visualisation of archeological imagery implemented in the Visual Media Service. (Task 15.2.2)
- Image gallery, Image slider and Model explosion features added to the EpHEMERA service. (Task 15.2.3)
- An EpHEMERA-Plus instance of the EpHEMERA service created to be hosted by the ARIADNEplus infrastructure.
- A prototype for the vocabulary-based annotation tool developed using a framework based on the spaCy platform and made available within the ARIADNEplus infrastructure as Jupyter Notebooks. (Task 15.3.1)
- DAP tool for annotations and visualisation developed in OpenLime (image/rti viewer) with CIDOC-CRM compliant annotations of archaeological images. (Task 15.3.2)
- Tokenizer data conversion added to the DAP tool. (Task 15.3.2)
- Complete multilingual date span utility and temporal NLP patterns and NLP recommendation tools for temporal metadata for archaeological reports in a range of languages made publicly available. (Task 15.4)
- GeoPortal GUI enhanced with new features: Project Viewer and Project Manager. (Task 15.5)
- Query service migrated to OpenSearch and continuously updated to support queries needed by the ARIADNEplus portal. (Task 15.6)
- GeoPortal Service engine refactored to use MongoDB for persistence. (Task 15.7)
- GeoPortal Service extended to support Clone and Unpublish operations. The former operation allows cloning of an entire project including all files and geographical layers belonging to it. The latter operation allows unpublishing of a project while keeping it at disposal of the owner only. (Task 15.7)
- Various improvements to the GeoPortal Service engine API have been added continuously. (Task 15.7)

7.4 Problems encountered and open issues

None.

8 Overview on WP16: Innovative Methods and Pilots

8.1 Goal

The general goals of the WP were to:

- Define the innovative methods enabled by ARIADNEplus services for archaeological research communities
- Test the services and innovative methods in pilots using real use cases
- Demonstrate the advantages of using ARIADNEplus to the archaeological user communities
- Showcase how ARIADNEplus data and services are building applications for professionals, heritage managers and the public at large

The general approach consists of:

- Adopting an End-User perspective
- Alignment with the first objective of the project, namely, that the infrastructure is used, useful and innovative
- Creating elements that reinforce the archaeological perspective of the infrastructure
- Developing pilots demonstrating the innovation potential of the project results, methodology and tools
- Following a Case study approach

The pilots include seven case studies involving fourteen partners.

8.2 Implementation schedule

Goal	Planned delivery date	Status
MS19 First four innovative pilots launched	M35 (November 2021)	Completed

8.3 Results obtained in M37-M48

Each pilot is described in a specific section of D16.2 *Final report on the ARIADNEplus pilots*, which details the archaeological issue addressed, including the necessary background, the perspective target users, the data to be used, the pilot results and the deviation from the work plan, if any. Furthermore, the main activities carried out in the period between M37-48 included:

- Organisation of an online workshop on October 12th, 2022. All task leaders attended the workshop and reported on the final results of their pilot. All discussion mainly focused on the ways of disseminating the results of these experiments inside and outside ARIADNE network.

- Intensive discussions were held between WP pilots, which brought the perspective of archaeological users to the project. This mechanism allowed the services and all the actors within the project to be fed with the needs and expectations of this community.
- Testing of the infrastructure and its services by the archaeological community with concrete use cases, to provide tested operational tools for archaeologists.

8.4 Problems encountered and open issues

No specific issues or open problems.

9 Conclusions

This deliverable presented the status of the JRA activities at M36 of the project. The presentation has been homogeneous and synthetic, in line with the purpose of the deliverable, which is to provide the fundamental elements necessary to evaluate the JRA activities of the project at the first review.

After introducing the objectives of the JRA work packages in ARIADNEplus, and the structure of the workplan (Section 2), Section 3 gave an overview of the progress, focusing on the four main areas of work:

- Infrastructure and Virtual Research Environments setup and operation
- Aggregation infrastructure
- The ARIADNE Content Cloud
- Services and pilots

Section 4 was devoted to the Knowledge Discovery and browsing service. The detailed work performed in each Work Package was given in Sections 5 to 9, each devoted to a single Work Package.

Overall, the JRA activities of ARIADNEplus proceeded according to the planned schedule. We therefore conclude that the project has achieved all of objectives set for the Joint Research Activities.