SEVENTH FRAMEWORK PROGRAMME

ARIADNA

MARITIME VOLUMETRIC NAVIGATION SYSTEM

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1. Executive Summary

In the current worldwide context, close to 90% of goods travel to destination by sea, a percentage that will steadily increase even further. This forecast implies a growth in maritime traffic at sea and at inland waterways and, therefore, an increased risk of maritime accidents. Nowadays, human factors account in part from 75 to 96% of casualties so that there is an obvious need to avoid a surge in the latter due to the rise in traffic.

The waterborne community is aware of the limitations in the capacity of infrastructures such as ports, traffic separations schemes, rivers, channels, and their access areas, which bring restrictions to the overall traffic situation. In this context, the maritime and inland communities are demanding new supporting tools in order to enhance the efficiency in navigation, from the point of view of both: infrastructure optimisation and safety, and, needless to say, the increase in traffic will only make matters worse.

Under this context, ARIADNA brings in the opportunity to accomplish the mentioned goals based on the revolutionary so-called Volumetric Navigation concept, which defines the position of the vessel by means of a geo-referenced virtual volume instead of a single point (latitude and longitude).

The virtual volume combines the volumetric and temporal information of the vessels involved in a specific scenario with the real environmental data, as wind effects and hydrodynamic parameters, in order to manage their relative movements. In this context, ARIADNA proposes a new collaborative navigation approach in which the information is shared and managed among all the actors and elements involved in the specific coverage area thanks to its two subsystems, the User Terminal (UT) allocated on board the vessels and the on shore part, the Local Control Station (LCS).

The ARIADNA solution is able to optimize the infrastructures avoiding added risks in the current navigation conditions. In this way, for some critical scenarios, ARIADNA brings in some benefits as:

- Volumetric Navigation System provides a value added given by the AIS (position, velocity and vessel's size) including a volume associated to the own vessel. Such volume, which not only integrates information about position and vessel's size, in addition provides information about position estimated in the future, taking into account external factors foreign to the own vessel as wind or currents. With the information provided by ARIADNA, it will be able to estimate future movements of the vessel, supporting decision to be taken in risk awareness situations.

- Allowing to efficient and safety traffic management in channels, rivers and ports and, in general, high dense congestion in the traffic.

- The integration in the current modern integrated bridges and navigation systems provides ARIADNA as a valuable tool to in order to avoid human error in navigation, support personal training and enhance best human practices.

- In addition, thanks to the integrity provided by the GNSS systems, it is also an important tool which can support docking manoeuvres and navigation through narrow channels.

- Remote monitoring of the movements and manoeuvring of the vessels from the LCS, the onshore system, will improve in the behaviour of the skippers who will be aware of comply the regulations.

2. Summary Description of Project Context and Objectives

2.1. Project Context

The overall objective of ARIADNA project is to optimise the use of maritime and inland infrastructures in order to manage the increment of the traffic density and, at the same time, improve safety at congested maritime and inland areas with the support of the use of GNSS technologies and last ICT navigation aids.

ARIADNA combines navigation and position information with time of the own and other surrounding ships for a better use of infrastructures. Information on these infrastructures, surfaces, draft allowances, currents, wind, waves, squat effects... are included in the ARIADNA context based on the implementation of the Volumetric Navigation concept. This concept defines the position of the vessel by means of a volume instead of a single point, defined by latitude and longitude typically.

The Volumetric Navigation concept, applied onto maritime and inland waters traffic, is based on the development of a collaborative navigation tool that implements virtual-safety-volume which is geo-referenced instead of a single point and ARIADNA so does. The system associates ARIADNA volumes to vessels and infrastructures sharing and managing volumetric information among all the actors and elements involved in the specific coverage area.

Figure 2-1 ARIADNA system representation in a real scenario

Although nowadays there are several means for transmission of ship information, as AIS, AtoN, VTS and other communication systems, ARIADNA proposes to share the volumetric information ship-to-ship and ship-to-shore by AIS format based on ITU-1371, IALA-126 and IMO Circ289.

ARIADNA volume is generated by taking into account the real shape of the ship, its size, cargo, speed, drift, course, wind effects and hydrodynamic parameters as well as the surrounding environment.

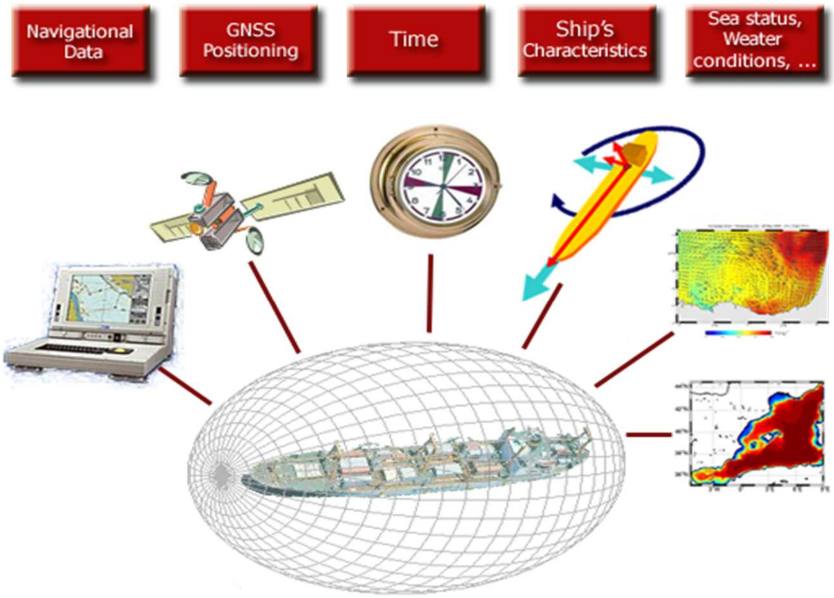


Figure 2-2 Geo-referenced ARIADNA safety volume

Even though ARIADNA volume is designed with parameters which define the geometry in 3D, its representation is displayed in 2D overlapping a layer on ECDIS viewer. Representation on ECDIS will allow optimisation of infrastructures (locks, ports, canals, etc…) and guiding all parties involved in a safe way, facilitating manoeuvring and avoiding collisions and groundings when ARIADNA volumes interact each other's.

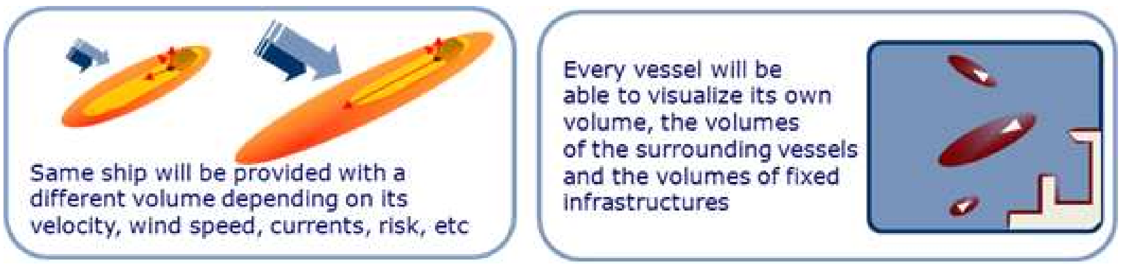


Figure 2-3 ARIADNA volume representation under different conditions

ARIADNA's system technological approach is divided into two sub-systems:

- UT (User Terminal), allocated in the own vessel which functionality is to build ARIADNA's volume with information about the own ship, surrounding ships (traffic) and data received by LCS.
- LCS (Local Control System), an onshore system similar to UT, which includes information with renewal information on Port Data Bases and generates volume of fix infrastructures broadcasting all this information in order to enhance the volume generated by UT.

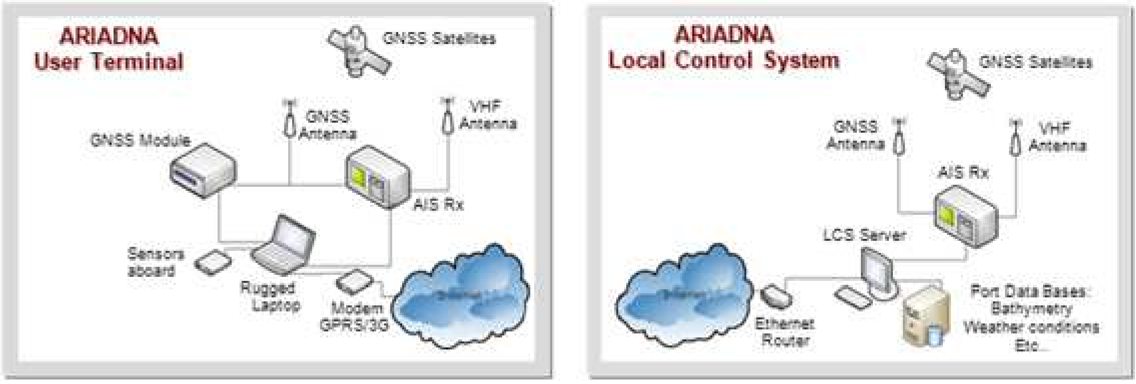


Figure 2-4 ARIADNA UT and LCS architecture

2.2. Project Objectives

2.2.1. WP1 State of the Art and User Requirements

The main objectives of **WP1** were:

- To have a clear idea of the state of the art as regard current situation of navigation systems, related projects and programs as well as policies as regards navigation activities.
- To define the necessary requirements for the ARIADNA system, both from the functional and technical point view.

2.2.2. WP2 System Engineering

The **WP2** governed the total technical effort to get the system requirements from the final users (customers) needs and to transform those requirements into a feasible system solution. System Engineering WP split his objective into the next ones:

- To define and manage general, functional and technical requirements based on the analysis of the user new functionalities versus the state of the art.
- The generation of system and low level specifications based on requirements allocation.
- To get a system design from the system specification and analysis of alternative physical solutions.
- To define a system assembly, integration and validation plan.

2.2.3. WP3 System Development and Integration

The objective of the **WP3** was to carry out the complete design and development cycle of an ARIADNA prototype with the previously designed architecture comprising each subsystem of ARIADNA system. Furthermore there was an objective inside WP3 of developing prototypes of one Local Control Station and two User Terminals. This main objective could be split into the next list:

- To define and execute the design, development, system assembly, integration and validation plan of the LCS.
- To define and execute the design, development, system assembly and validation plan of UT.
- To integrate and validate complete ARIADNA system (LCS+UT).

2.2.4. WP4 System Validation

WP4 had as objective to test and validate the ARIADNA system performance by means of a field test in a real-life environment under normal operations conditions. Specific objectives were:

- The validation of the system components in a real-life environment scenario.
- The evaluation of the geo-referencing software in a real-time environment.
- The evaluation of the system performance vs. the project objectives.
- The system evaluation by real end users.

2.2.5. WP5 Implementation

The general objective of **WP5 Implementation** was to assess and facilitate the implementation of ARIADNA results on products and services, assessing economic potential, anticipating possible gaps, and facilitating administrative and customer acceptance.

- Assessment of potential products and services and explore possible implementation models on general and specific areas and its socio-economic impact on employment and business.
- Verify compliance along project development with on-going framework regulations from IMO, IALA and navigation authorities.
- Assess interoperability, regulation compliance, added value and redundancy with existing navigation systems and standards issues, and develop widely accepted operation protocols.
- Develop a road map to extend the acceptance and use of ARIADNA, anticipating barriers and further development needed on product, services, and users training and feedback. Competition and IPR on exploitation issues

2.2.6. WP6 Dissemination and Exploitation

- Definition of the methodology for exploitation and dissemination to support creation of awareness and information to stakeholders concerned by the ARIADNA research and facilitate exchanges with these external groups.
- General dissemination and exploitation of the ARIADNA benefits and results among the user community and the scientific community (Establishment and maintenance of a project website)
- Organisation of workshops for exploitation and dissemination.

3. Main S&T Results/Foregrounds

During the duration of the whole project, activities related to WP1, WP2, WP3, WP4, WP5 and WP6 have been achieved, concretely; the following results are highlighted in each technical WP.

3.1. WP1: State Of The Art And User Requirements

This activity performed a study of the state of the art in order to have a deep knowledge of baseline scenarios: ship's routing (including Traffic Separation Schemes and channels/straits under VTS management), ports and inland waterways.

To be able to achieve this, the study detailed the different off-the-shelf equipment systems and services available, technical aspects and new technological tendencies, being an input for WP2 and WP3 where a Local Control System (LCS) and a User Terminal (UT) were designed and developed.

Within the first work package, it was also performed a review of R&D projects that were still running or had been recently ended about navigation activities in Europe in order to avoid overlapping and taking advantage of possible synergies. That study included the review of European regulations and policies regarding navigation, both at sea and inland waterways, which served as basis to start the work under WP5: Implementation.

Moreover, and based on the study, this WP1 identified functional and technical requirements, addressed in a parallel way and based in users consultation, to be able to satisfy real user needs by the development of the UT and the LCS.

A specific methodology for user requirements capture was developed; users played an important role on the methodology definition and their inputs were fundamental as key representative stakeholders.

The main results of this work package were included in three deliverables:

- *D1.1 State of the Art document* which includes the findings on the state of the art of the research study performed,
- *D1.2 Functional Requirements,* containing the list and analysis of the functional and technical requirements identified thanks to a methodology developed and a close collaboration with experts from the maritime and inland community.
- *D1.3 Technical Requirements*, including the list of the technical requirements identified and analysed.

Results aforementioned were a consolidated base of the ARIADNA project, providing inputs for others work packages, specially feeding WP2 as consecutive action.

3.2. WP2: System Engineering

The main challenge of this WP was to define a congruent solution, technically feasible, that really satisfied end user's needs previously identified in WP1. In order to achieve this goal, this activity defined the main system components, including the description of their functionality, performance and analysis of alternative physical solutions, evaluating research and implementation results in relation with defined research goals.

In this context, first of all there was a plan of the future development of ARIADNA, to provide the formal requirements definition used by design engineers to develop the design concepts in the early phases and the preliminary and detail designs in the development phase.

Second activity was to set both, the Preliminary and Detailed Design to provide the product capabilities and architecture for the corresponding Design. The Design established a conceptual design for the System according with the System Specification. ARIADNA architecture was considered for several scenarios: channels, rivers and ports, so some subsystems had a different behaviour depending on the scenario.

The final activity was to set the Integration and Test Plan. This plan provided the basis for review and evaluation of the effectiveness of the Assembling Integration and Validation program, describing the approach, methods, procedures, organization, resources and schedule to assemble, integrate and test a product in line with its verification plan.

Results of this work package were included in the following deliverables:

- *D2.1 System Specification*, containing the Functional Specifications which establish the intended purpose of the system, its associated constraints and the environment, the operational and performances features and the permissible flexibility and Technical Specifications that the ARIADNA system had to accomplish, its associated constraints and the environment, the operational and performance features and the permissible flexibility.

- *D2.2 Preliminary design,* including the Preliminary conceptual design for the System according with the System Specification,

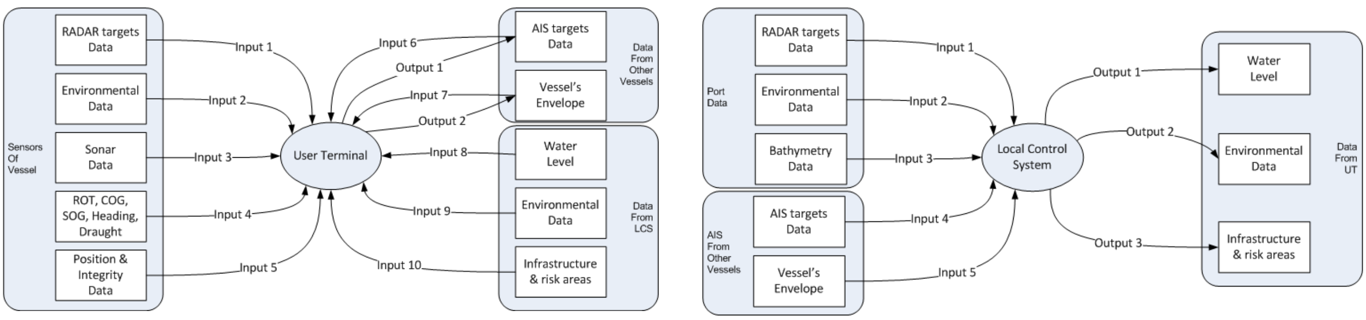


Figure 3-1 UT and LCS Logical Architectures

- *D2.3 Detailed Design,* including the specifications, detailed architecture and the design of the different subsystems considered in the ARIADNA architecture,

- *D2.4 Integration and Test Plan*, outlining the approach, methods, procedures, organization, resources and schedule to assemble, integrate and test the product in line with its verification plan.

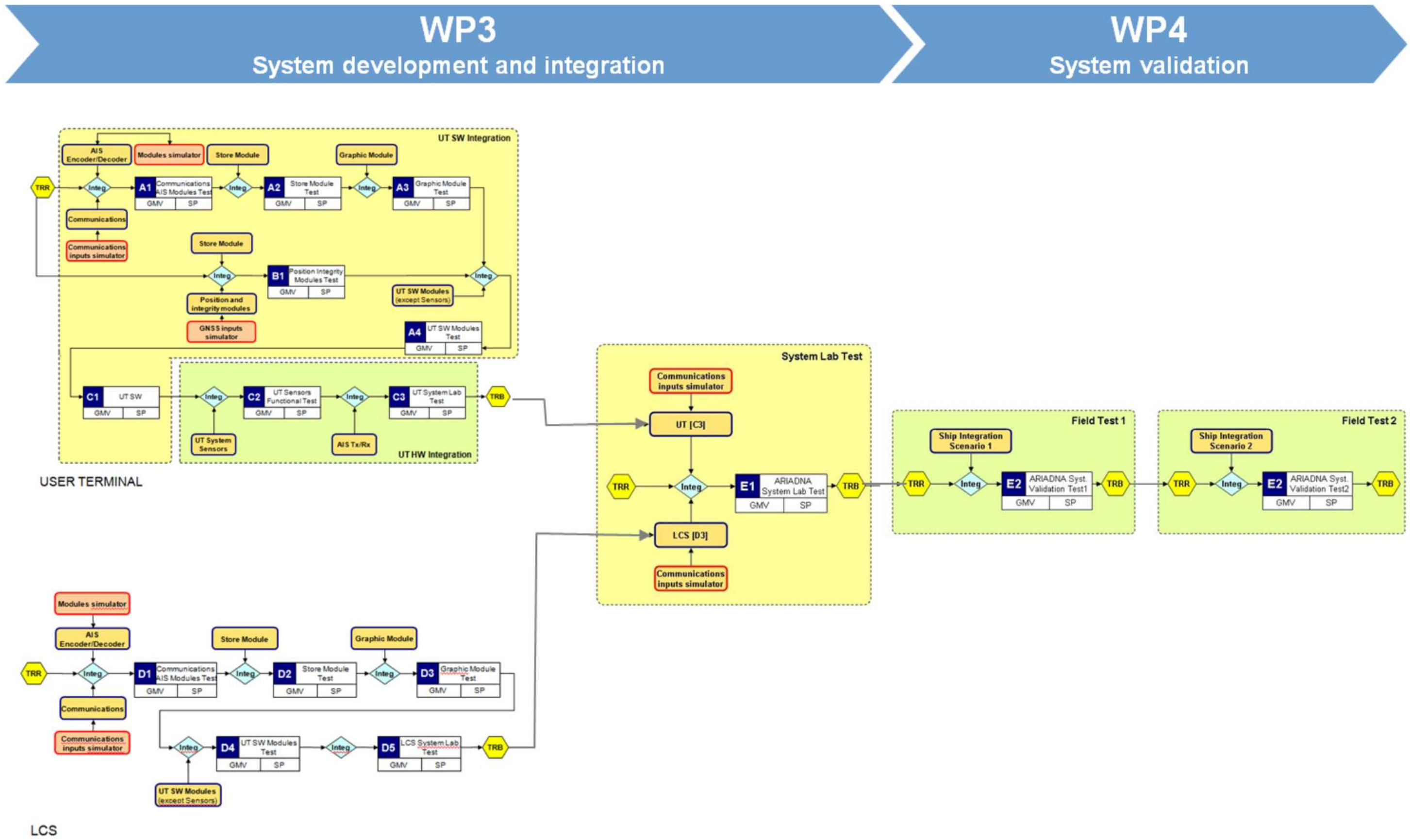


Figure 3-2 ARIADNA complete Integration and Test Flow

3.3. WP3: System Engineering and Integration

Regarding **WP3 System Development and Integration**, the three developed deliverables contained the main results.

- *D3.1: ARIADNA Local Control System (LCS) design, integration and Validation*

  The LCS is an onshore system similar to UT which includes information with renewal data on Port Databases such as bathymetry, weather conditions (wind included), water level, etc. It also generates volume of risk areas and broadcasts all this information in the surrounding area in order to enhance the volume generated by UT and monitor a specific area.

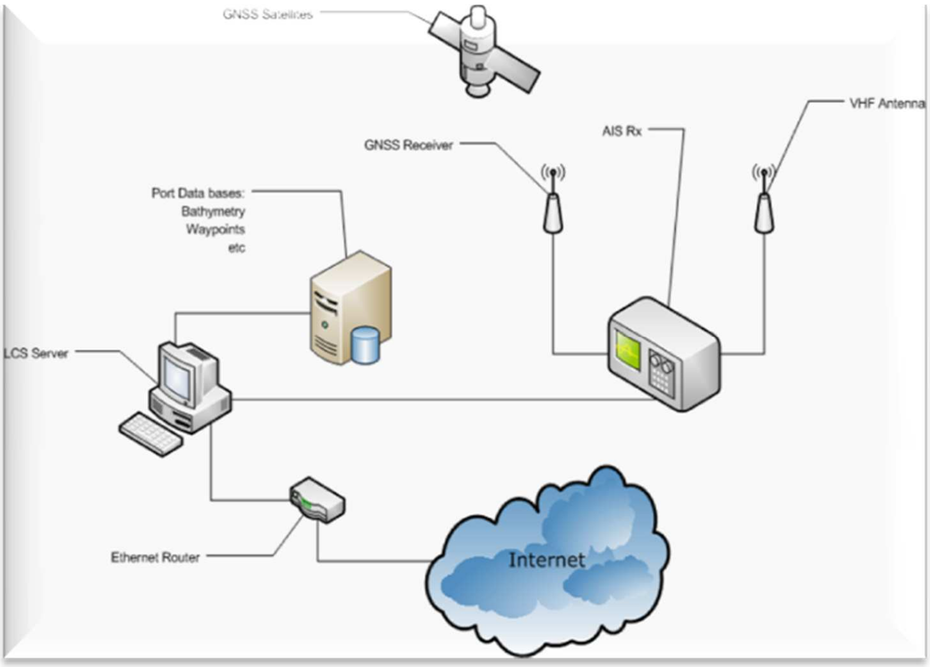


Figure 3-3 LCS Physical Architecture

  This deliverable defined a plan for ARIADNA LCS system development, assembly, integration and validation, as well as its implementation in order to guarantee that the development system is compliant with the defined requirements and specifications.

- *D3.2: ARIADNA User Terminal (UT) design, integration and Validation*

  The second deliverable of WP3 was the implementation of the User Terminal (UT). The UT is the system allocated inside the vessel whose main functionality is to build ARIADNA's volume with information about the own ship, weather conditions, surrounding ships (traffic) and data received from the LCS.

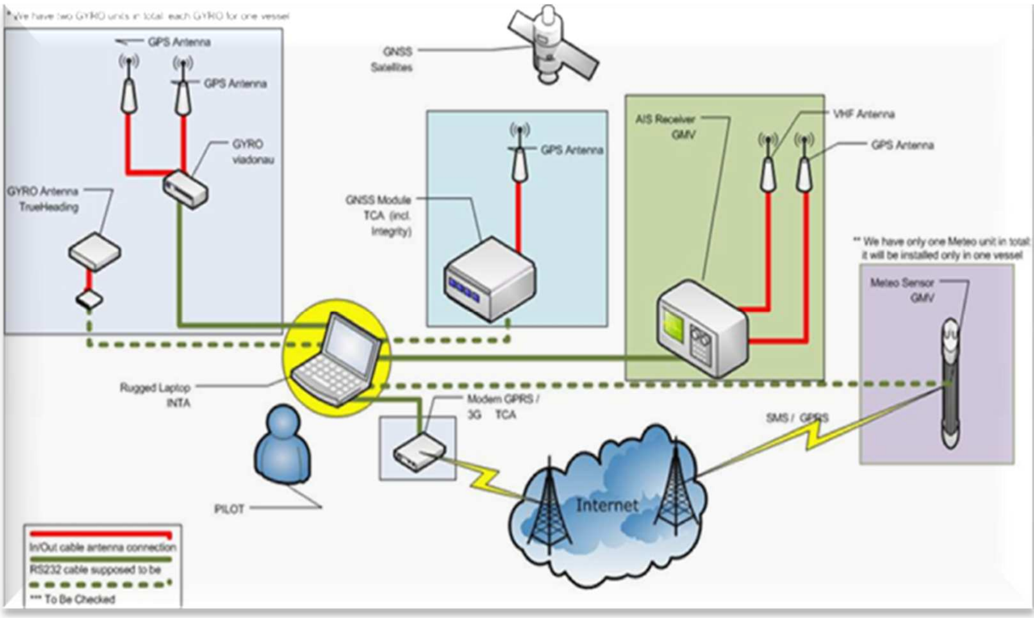


Figure 3-4 UT Physical Architecture

This deliverable defined a plan for ARIADNA UT system development, assembly, integration and validation, as well as its implementation in order to guarantee that the development system is compliant with the defined requirements and specifications.

- *D3.3: ARIADNA prototype system integration and validation*

The third and last deliverable of WP3 was ARIADNA prototype system integration and validation. This document includes a description on the prototype user interface for LCS and UT as well as the necessary configuration parameters to ensure the correct functioning of the whole system. This description completed the design provided in the previous deliverables 3.1 and 3.2. It also provided a prototype interface to potential users of ARIADNA system so that the fulfilment of the requirements was ensured. Factory Acceptance Test reports obtained from the individual modules testing were included as well.

3.4. WP4 System validation

WP4 System validation results were shown in three deliverables.

- *D4.1: Test and Validation Plan*

This one was in charge of the test and validation plan. The purpose of this document was the definition of the plan in order to test and validate the ARIADNA pilot system. This document was the base to study the behaviour of ARIADNA's system stressed by means of field tests carried out in a real-life environment and normal operations conditions.

- *D4.2: Field Test Report*

Both field tests, the inland waterway and the maritime test, were necessary to evaluate and validate the performance of the ARIADNA system under normal operational conditions. Additionally, several stakeholders and interested people from different European countries participated on the validation, which served as demonstration of the system too provided feedback for potential usefulness, which was taken into account in WP5 deliverables.

Field tests were carried out in sequential order where the focus of the first demonstration aimed at the configuration and adaptation of the ARIADNA system for inland waterway use and in a maritime environment.

It was important for both field tests that the ARIADNA system could be installed independently from the navigation devices available on board. To keep the influence to existing navigation devices as little as possible, it was installed separately.

The ARIADNA field tests scheduled into the plan, and later executed were:

- **Field Test 1 in the Austrian Danube**. This trial demonstrated the performance of the ARIADNA system in an inland waterway environment. The focus lied on providing navigation support to skippers to reduce the risk of collisions.

Figure 3-5 Demonstration vessels "Kaiserin Elisabeth II" and "Dienstboot Abwinden"

Since the inland waterway test was the first one, where the overall system was tested, some bugs and minor discrepancies of the hardware and software were detected and internally documented. The results of the inland waterway tests show that in this field of navigation, especially in the vicinity of infrastructural buildings like bridges and locks, the system offers its advantages. Mainly due to the draft information together with the gauge information, accidents like bridge collisions and grounding can be avoided.

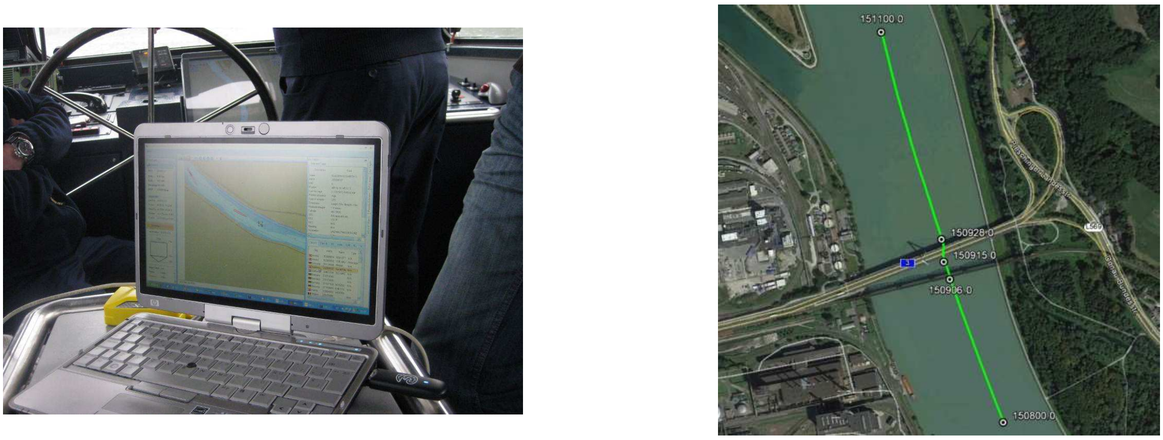


Figure 3-6 ARIADNA UT2 Laptop - Position track during bridge interaction sequence (© by Google)

The system showed very clearly that potential collisions such as collisions with bridges, port infrastructure, and other vessels can be avoided due to the additional information, which the boat master receives. Well, some parameters where adjusted, such as the risk factor, which was not available during inland waterway test. The captain of the vessel can change the risk factor depending on the situation between low risk, moderate risk, and high risk. Furthermore, the maximum prediction interval of the future position can be set according to the needs of the application.

- **Field Test 2 in the Strait of Gibraltar, Spain**. The location for the maritime test was chosen very well since the port of Algeciras is located in a geo-strategic area of the Gibraltar Street, one of the most frequented navigable waterways in the world.

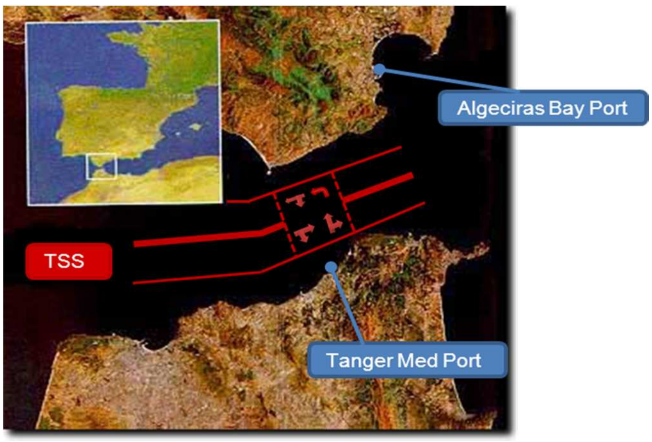


Figure 3-7 Strait of Gibraltar with special mention to Tanger Med and Algeciras Bay Ports

This demonstration validated the performance of the ARIADNA system in a port environment. The focus lied on providing navigation support to ship officers for port approach, port entrance and the navigation inside the port TSS. The goal was to improve safety of navigation and improve shipping and port infrastructures efficiency (i.e. reducing waiting time at entrance and during manoeuvring). Enhancements in the ARIADNA software resolved the bugs detected during inland waterway test.

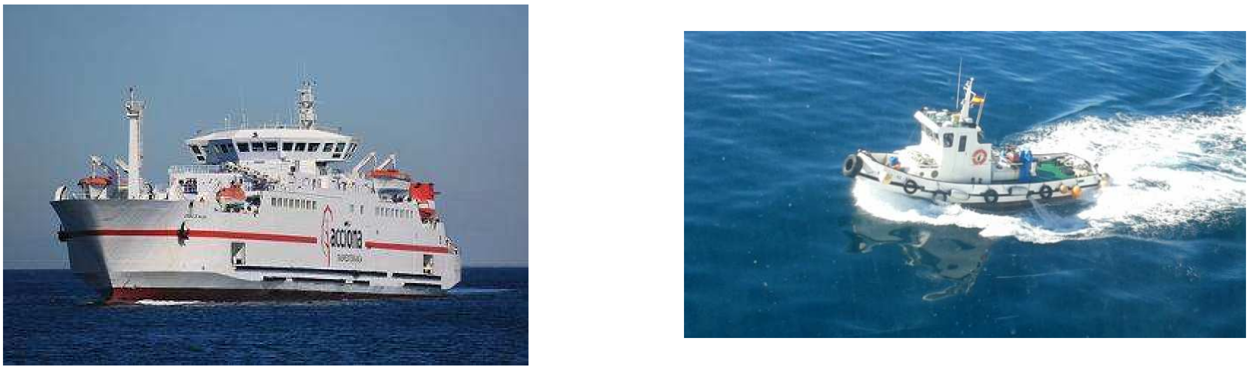


Figure 3-8 Demonstration vessels "Ciudad de Málaga" and "Calima"

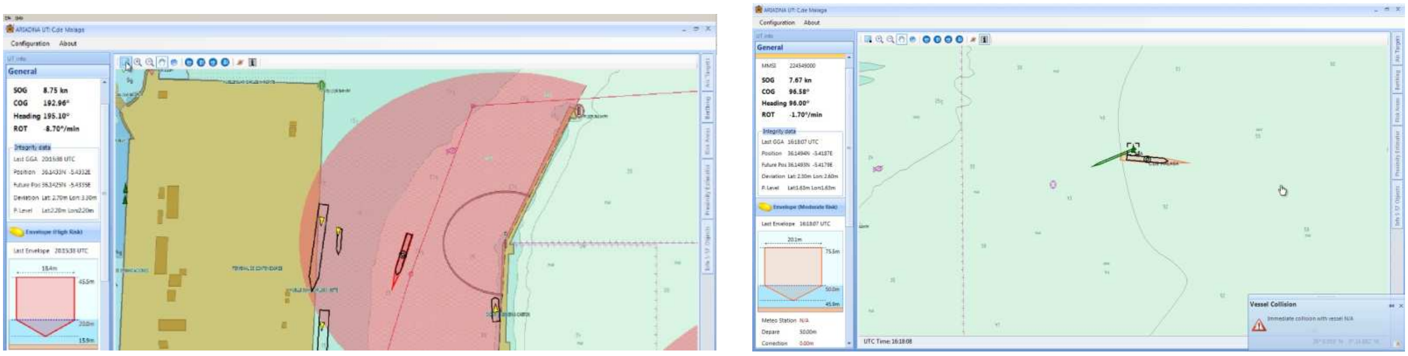


Figure 3-9 ARIADNA interface

- *D4.3: Validation of System Performance,*

The ARIADNA system contains of several different hardware and software modules. This document shows very well the performance of the system in the fields of inland waterway and maritime navigation. Analyses of the different contributing modules showed the behaviour of those modules.

The communication module, responsible for handling all incoming and outgoing communications, performed well during all validation exercises during the inland waterway and maritime trial. Minor problems occurred in the maritime trial due to roaming issues in the case of 3G/GPRS connection. As main communication method, a 3G/GPRS connection and an AIS link were used.

The AIS Encoder/decoder, responsible for en- and decoding all the used AIS messages, was used for all validation exercises. Since the ARIADNA envelope and risk areas have to be interchanged between LCS and UT, an AIS format based on ITU-1371, IALA-126 and IMO Circ289 was used. The decoding at both sides performed fine. In the case of the usage of two UTs, both envelopes were visible all the time. LCS information, especially risk areas, were encapsulated into AIS format and transmitted. The AIS Encoder/Decoder decoded all the information in all validation exercises.

The RADAR Module from the software side of view was prepared. In both trials, it was not possible to integrate the on-board RADAR into the ARIADNA system. However, GMV as developer of that module has tested the RADAR module during laboratory tests.

The AIS targets manager is directly connected to the AIS Encoder/Decoder. Every time if new data from a vessel arrives, the decoder informs the AIS targets manager, so an updated list of the surrounding AIS targets is available in the ARIADNA system. For all validation exercises, this module worked properly. Vessels in the vicinity of the User Terminals, equipped with AIS, were detected. The detected vessels were visualised, together with all their information send through AIS.

The Manoeuvring Inside Port module, also denoted as Berthing module, was not used in the inland waterway trials. However, it was applied for the maritime trials. A validation exercise, the E24, was designed for the validation of this module. It was checked while the Algeciras Port was approached with UT1. The UT operator requested a berthing track from the LCS. After the LCS received the request, empty berthing points was assigned and send back t the UT. This information was included into the route information of the UT. ARIADNAs ability to support the skipper with secure and adequate berthing information is one of the major advantages of the system. The LCS can handle more UTs at the same time, which enhance the timing and scheduling of vessels in harbour areas.

A very important module is the Graphic Representation. It is responsible to fuse the ARIADNA produced information (envelopes, risk areas, etc.) with existing ENCs. A separate layer was developed for that issue. Furthermore, the module is responsible to display the current berthing points, the AIS targets, and the infrastructures of the port or channel, the nautical charts ant its parameters and the water level changed related to nautical charts. For all tests, the module was checked and valuated as working properly.

The environmental influences such as currents, wind, and the sea state are important parameters for envelope calculation. For the inland waterway trials, the sea state was not used, only in the maritime trial. Furthermore, the wind module is only working if the vessel is equipped with a wind sensor. This was in both measurement campaigns not the case with UT2. However, the wind data received from UT1 was well applied to envelope calculation.

The calculation of the own waves produced by the vessel worked fine for the conducted exercises. This module has to be adapted to the corresponding dimensions and flow behaviour of the vessel. Performance and results of the wave module was for all tests as expected.

Calculation of possible collision risks with different objects (infrastructure, bridges, locks, restricted areas, safety envelopes of other vessels) is the task of the proximity estimator. A permanent comparison of all objects in the vicinity of the UT has to be performed, and possible collisions have to be announced by the proximity estimator. Furthermore, it manages the warnings for the vessel. All warnings that occurred are stored in the store module. This is important to have a data recovery in cases of accidents. The warnings of the proximity estimator are stated graphically and acoustically. During the validation exercises where two UTs and risk areas were used, this software module performed excellent and did not miss any possible collision warning.

Responsible for introduce new water levels of rivers, channels, or ports and provide them to the User Terminals is the bathymetry module. The bathymetry module uses depth, extracted form ENCs, and water level information from AIS. Especially for the visualisation of the 3rd component of the envelope, the bathymetry module is essential. That was shown during the inland waterway trial in Linz. It achieved adequate results for this trial.

A key enabler of the ARIADNA system is the position of the vessel. This position is derived by the means of GNSS. The term GNSS is used, because not only GPS is used for position determination, although EGNOS as augmentation service contributes to positioning by the means of quality enhancement. Important information that is not available at the majority of COTS GPS receivers is the integrity of the position solution. ARIADNA provides beside the accuracy also the integrity of the GNSS position. This module was analysed very detailed in the previous sections. The result is that GNSS as position giving source performs well.

The future position as valuable parameter was computed together with the position and integrity, using a dynamic model for short time prediction. The results in section 6 shows that this quantity can be estimated very well, assuming a constant dynamic behaviour of the vessel.

The manoeuvring module is one of the components of envelope calculator, providing the shift in longitudinal, transverse directions and heading. It checked that the speed is an important input in order to know the effect of this module. During locking manoeuvre sequence, the effect of manoeuvring module effect was very low due to low speed. However, during cross path sequence, the transverse shift, and heading shift was in the expected direction. This module provides an important component in order to know the behaviour of the intention of movement of the vessel.

The store module, available for storing all necessary output parameters of different software modules into a database, was used during both trials. It worked as expected, the information is available for post-analysis.

The main task of the sensor module is the handling of incoming data from ARIADNA sensors such as the wind sensor, the heading device providing the heading and rate-of-turn, and the GNSS integrity receiver. Different connection types (serial, Ethernet, USB) were handled by this module and performed well during validation trials.

3.5. WP5 Implementation

In regards of WP5 Implementation, the work package was in charge to assess and facilitate the implementation of ARIADNA results on products and services, assessing economic potential, anticipating possible gaps, and facilitating administrative and customer acceptance.

The results were included in four deliverables.

- *D5.1: Report on integration of ARIADNA on navigation systems and regulations,*

The first one was the report on integration of ARIADNA on navigation systems and regulations. It reported on how the ARIADNA system could be implemented and used in existing regulations and how the process would be to get full acceptance and promote the implementation of an ARIADNA like system either in the maritime or inland environment, where several ideas and developments from the ARIADNA project could well be implemented as ideas into existing systems.

The most likely approach and fastest as well would be to approach the E-Nav developments currently ongoing in the maritime environment and the River Information Services (RIS) developments in the inland one.

- *D5.2: Standard service and interoperability specifications,*

The second one was the report on standard service and interoperability specifications. It developed the product and service specifications for main potential users groups as: inland waterways and locks; port accesses, entrance channels and traffic; sea traffic separation on channels and congested routes; traffic control users; adaptation to HNS carriers traffic; recreational craft and port market; and specific critical cases (general approach).

- *D5.3: Acceptance, gaps and limitations,*

The third deliverable of WP5 was about acceptance, gaps and limitations of the ARIADNA system. The purpose of this document was to analyse, and discuss the ARIADNA acceptance issues for the potential end users after identifying and assessing the ARIADNA products gaps and limitations after validation exercises, that may impair the acceptance in short, and long term unless fixed on post-ARIADNA follow up. It also included the economic potential and impact of ARIADNA deployment considering an ARIADNA final product after solving the gaps remaining at the end of the project and obtaining the administrative and user's acceptance.

- *D5.4: Roadmap and implementation of ARIADNA,*

The last deliverable of this work package was in charge of the development of a roadmap to extend ARIADNA system full acceptance and promote the system implementation.

4. Potential Impact, Main Dissemination Activities and Exploitation of Results

4.1. Potential Impact

4.1.1. ARIADNA in the global transport economy

The ARIADNA objective of increasing the efficiency of the navigation infrastructures has its input on facilitating traffic flow and traffic density without the need of enlarge or build new infrastructures.

The importance of the port infrastructures has been evidenced recently by the publication of the World Economic Forum Competitiveness indexes where the "Quality of Port Infrastructure" is considered one of the 12 economy pillars.

The Global Competitiveness Index (GCI) of the World Economic Forum (WEF). The 2012-2013 WEF ranking appeared last September. Switzerland is on top, moving ahead of Singapore. The WEF ranking consists of over 100 ranked items, classified in 12 pillars. For each pillar, some rankings are survey based, while others are based on actual data. Through the provision of cost-efficient, reliable and frequent connections to overseas and inland markets seaports play an essential role in facilitating trade and in increasing the competitiveness of a nation or region. It is no surprise that Pillar 2 of the GCI dealing with infrastructure includes a component on the 'Quality of Port Infrastructure'.

Additionally ARIADNA facilitating the navigation flow in high density areas contribute to the efficiency of shipping. Indirectly the efficiency of shipping involves the reduction of fuel consumption and the carbon footprint of the inland and maritime transport, and the emissions of noxious and GWG gases.

Additionally safe navigation reducing the number of groundings and collisions most of them accompanied by oil spills and sometimes by ship and cargo loss, reduces the impact of transport on the marine environment.

4.1.2. Benefits for the Society

Benefits for the society and the maritime world are related in general to human life, assets (ships and cargo) and the environment; it is no needed to mention almost all maritime accidents are accompanied by spills.

Looking at the Allianz Global Corporate&Specialty Shipping Review 2013, shipping losses (ships over 100GRT only, not including fishing and recreational) have been 106 the year before November 25 2012, with and increase 15 over the same period of the previous year. East Mediterranean is identified as the area with more frequent occurrences.

The causes of losses from the same report on the period 2001-2012 are lead "Foundered" with 669 separated with "Wrecked/Aground 294 more. The group of collision (162) and allision (20) totals less than one fifth of the grounding related accidents. Reduce grounding risk implies that the under keel clearance, the vertical dimension of the ARIADNA volume is also of prime importance as grounding may be also cause of wreckage with loss of life, loss of the ship, and oil spill together. Of those risks is difficult to value (insurance companies do) and usually involve human error, so the cost-benefit of ARIADNA on contributing to avoid maritime accidents is even more relevant.

4.1.3. Potential End Users and Scenarios

ARIADNA has been designed and developed as a general purpose navigation support system without addressing specific potential end users and needs, scenarios or infrastructures. ARIADNA started from addressing general targets of infrastructure efficiency and safe navigation, at inland and maritime scenarios. Main targets have been:

- supporting safe speed optimization and closer distances on narrow navigation channels and approaches under controlled risk
- providing to the ship complete information for manoeuvre efficiently and safely on restricted waters
- providing a decision support system for a two ships combined collision escape manoeuvre
- providing port control to ship information on the best time slots for direct entry on port, or on lock

It considers the following potential end users and scenarios:

4.1.3.1. Inland waterways scenario

- Inland Vessels (and tug-barge trains)
- Traffic control systems
- Lock control

Inland vessels with manoeuvring characteristics much better than conventional ships, share the waterways with barge assembles pushed by a tug that having small manoeuvring capability even with a side-thrusters on the front barges. Inland waterways have many narrow passages where the ARIADNA volume (beam) must be reduced to avoid to frequent warnings. Heading devices are no compulsory in inland and this reduces the ARIADNA functionality. Most inland ports are open, ships berthing shore side.

The comments of attendants during the inland validation confirmed that an Inland dedicated ARIADNA should be needed, focused on the inland navigation peculiarities.

Inland traffic control systems are in homogenization phase, and EMSA the European Maritime Safety Agency, that waives its role on maritime safe navigation (by participating in IMO wider UN dependent organization). EMSA could be useful for providing clues for potential implementation of a dedicated ARIADNA on future inland navigation control.

The application for locks is not a safety application but a queuing avoidance application, similar to the port entrance application, but alone is not sufficient to justify ARIADNA on inland

The expert groups on Inland navigation are different than IMO

- European RIS platform and RIS Committee

  - Main goal: To promote the harmonised implementation of RIS in Europe
  - The technical work of RIS is organised in four working groups:
    - Tracking & Tracing Expert Group
    - Notices to Skippers Expert Group
    - Electronic Reporting International (ERI) Expert Group
    - Inland ECDIS Expert Group

Other regulating commissions for Inland Navigation

- PIANC Inland Navigation Commission (InCom)
  - International association concerned with these technical aspects of navigation
- Inland Navigation Europe (INE)
  - European platform for inland navigation linking waterway freight promotion bodies and national waterway managers
- River Commissions
  - Central Commission for Navigation on the Rhine (CCNR)
  - Danube Commission

4.1.3.1.1. Potential Inland ARIADNA end users

Inland vessels may use ARIADNA as collision warning system provided that the ARIADNA volume can be adjusted to be coherent with the navigation channel width. Overtaking is not quite common but crossings could be quite frequent as well as turns for berthing and change of navigation direction. Inland vessels often have twin rudder-propellers allowing a complete 180% turn on the same position.

Long barge trains pushed by a single tug (although the front barge may integrate a side trust), that may be two parallel barge wide, may benefit of ARIADNA although the turning characteristics of the tug-barges assembly must be incorporated to the ARIADNA volume.

Traffic control systems may use ARIADNA for extending they shore to ship communication and traffic control mapping. Locks may use ARIADNA messages to provide short time availability information and reduce queuing and waiting times (and so reducing fuel consumption too)

As heading devices are not compulsory on inland ships, ARIADNA use may require an upgrade on the navigation equipment. Inland ships dock mostly riverside and navigation and waypoints are mostly visual.

Currents may be near 10km/hour and vessels have nowadays twin 360º propellers which give maximum manoeuvring, and stopping capabilities.

The River Information Service RIS used on the donau river and developed and operated by via donau, partner of ARIADNA is likely one of the best opportunities to develop and ARIADNA Inland Implementation (specific and adapted to the end user needs and requirements)

The fact that the European Maritime safety Agency (EMSA) includes inland navigation on his mission, may provide a clear regulatory frame, more quick and easy than IMO that requires the acceptance by the representatives of all UN maritime countries.

4.1.3.2. Maritime scenario

ARIADNA maritime initially identified the following main application fields:

- Ships
- Recreational craft
- Pilots
- Ports
- Traffic Control
- Risk assessment, administrations, revision of Col_Regs
- Training and simulators (including on board)

From the first port contacts with Barcelona and others it appears that Pilots are performing their activities, on close connection with the ports and using tools agreed by each Port Pilot Association.

Traffic control application was clearly justified on the Maritime Validation, but could not be specifically addressed on ARIADNA development.

ARIADNA concentrates on ships (UT) and ports local control stations (LCS) as main clear application fields.

From the maritime application field the following specific scenarios were identified:

1. (Open sea navigation)
2. Port approach and entrance and coastal navigation
3. High density traffic areas
4. Transit on straits and sea channels
5. Manoeuvring and docking in port
6. Port access channels (is similar to inland waterways but with sea-going ships)

Navigation in open sea where no navigation channels or infrastructures exist is not intended for ARIADNA that may not provide added value to long range existing navigation warnings.

Port approaches and entrance is one of the best applications for ARIADNA: port approach is done through one or more navigation channels, where traffic includes small recreational and service vessels, anchoring areas, and draft restricted areas. Currents and sea state may make difficult the entrance and even close the entrance.

ARIADNA can help on the decision of closing or not closing the port based on ship to ship case and support the entrance manoeuvre accounting for the effect of the wind and currents. But this requires very precise and update meteo-information and accurate position data not all available in the current ARIADNA development status.

ARIADNA is not much useful on port manoeuvring as the ships must navigate close to infrastructure ends, and the manoeuvre is governed by the ship turning characteristics and known response, and is often assisted by tugs. ARIADNA however can provide additional information to the pilot plugs as it is used on some Baltic ports.

The information on the available slots for crossing the port entrance avoiding waiting by the priority given to big cruise ships, LNG and products carriers etc is of prime interest for ferries as indicated by ACCIONA TRASMEDITERRANEA, but this information depends on the port organization and communications policy and ARIADNA cannot improve on this but could host the messages if available.

The information for berthing even in the case of a ship calling a port first time is not likely to be an ARIADNA added value as the berth must be prepared well in advance of ship arrival and the ship agents and services prepared on site so the berth assigned is well known in advance and transmitted to the ship through normal VTS services sufficiently proved.

4.1.3.2.1. Potential Maritime ARIADNA end users

Ports as LCS providers have been identified as strong potential end users. On the way to e-navigation the ports may provide information to ships through ARIADNA using the AIS open message channels, and ARIADNA can contribute to its standardization. Internet and satellite communications may support also the information of interest for ships approaching, but the port direct information may prevail locally. The Pilots convey part of the port information and should be closely linked to the LCS. Some big ports subcontract the control tower functions to the local Pilots Association.

Ships may use ARIADNA alone without LCS support or link to the port. Anyhow ships call always two ports as minimum and its ARIADNA must be able to operate without LCS (same when at sea out of LCS reach).

Ship operators having central control of their fleets may use ARIADNA for optimizing its operations, and for additional control of the ships.

Recreational craft may use simplified versions of ARIADNA as apps of the current navigation appliances.

Simulators may benefit from incorporating ARIADNA as risk related training tool.

Ship-owners and ship-operators may have their own personal practice and collision avoidance exercises on board with simple simulators incorporating ARIADNA.

4.1.3.3. Additional scenarios

There are other scenarios which are not included in DoW and added along the project:

- Passing under bridge (air gap)
- Information for berthing (assignation of berth)
- High speed ship induced waves (i.e. containerships over 20kn)

Under bridge clearance (air gap) depends on the information received from the river services, the accuracy of the ship data (dimensions and maximum draft), the accuracy of the bathymetry update, and in the maritime case the water salinity (density) and the ship movements, and ARIADNA may do the computation too but not compete with the current practice of ships on the maximum bridge allowance range, and occur on responsibilities on accidents produced by inaccuracy or miss of the data managed.

The usefulness of the information for berthing depends case by case on how the information for berthing is being provided without ARIADNA.

The ship induced waves (usually over 20kn) was considered useful by the representative of the European small craft association for advising the recreational craft on not getting close to the containers or cruise ships when at speed but lately this application was disregarded. The waves induced by the ship do not affect his safe navigation, and cannot substitute the effect of the sea waves on the ship course and safety.

4.2. Main dissemination activities

During the execution of the Project different dissemination activities were planned in order to broadcast the project outcomes and achievements to stakeholder, facilitate networking for the project participants and gather feedback from stakeholders.

The dissemination activities included workshops, scientific papers, articles, posters, presentations for conferences and fairs of the transport and GNSS sectors, promotion videos, flyers, a website, etc…

4.2.1. Workshops

Three workshops were organized for dissemination and exploitation among the relevant stakeholders

The first ARIADNA workshop was held in Vienna at via donau premises on 3rd and 4th March 2010. This workshop mainly dealt with the establishment of user requirements supported by the maritime and inland stakeholders and users.

The second workshop was held after prototype development in the Port of Algeciras where the validation of the ARIADNA system in a maritime scenario was taken into account on a live trial.

Figure 4-1 2º Workshop – Port of Algeciras, Spain

The third workshop was held at the end of the project taking advantage of the audience of the European Navigation Conference 2013. It was a great opportunity in order to disseminate the results of ARIADNA to the interested parties (stakeholders and user groups).

4.2.2. Scientific Papers

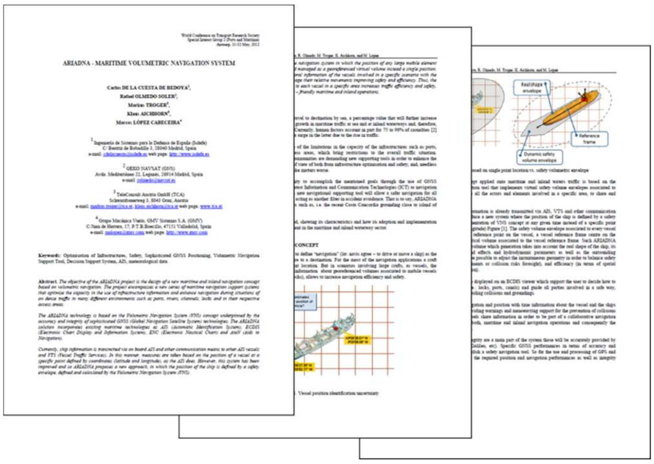
In this regard, during the whole project, but mainly in the second phase, different papers were submitted and accepted for publication in a wide range of scientific conferences with peer reviewing, as the following:

- M. Troger, K. Aichhorn, P. Berglez, C. de la Cuesta, M. Lopez, J. Nemeth; Maritime Volumetric Navigation System (ARIADNA) accepted for the European Navigation Conference, Vienna, Austria, 23-25 April, 2013.

- R. Olmedo, C. de la Cuesta, J. Nemeth, K. Aichhorn, M. Lopez, N. Andrés; "*ARIADNA: a volumetric Navigation System implementation for maritime applications*" accepted for the 6th ESA Workshop on Satelite Navigation Technologies Navitec 2012, Noordwijk, The Netherlands, 5-7 December 2012.

- K. Aichhorn, C. de la Cuesta, P. Berglez, M. Lopez, M. Troger, A. Kementinger; "MARITIME VOLUMETRIC NAVIGATION SYSTEM" accepted for ION GNSS 2012 conference; Nashville, Tennessee USA 17-18 Sep, 2012.

- C. de la Cuesta, R. Olmedo, M. Troger, K. Aichhorn, M. Lopez; "ARIADNA – MARITIME VOLUMETRIC NAVIGATION SYSTEM" accepted for WTRC World Conference on Transport Research Society Special Interest Group 2 (Ports and Maritime); Antwerp, 21-22 May, 2012.



ARIADNA - MARITIME VOLUMETRIC NAVIGATION SYSTEM

Carlos DE LA CUESTA DE BEDOYA[1],
Rafael OLMEDO SOLER[2],
Markus TROGER[3],
Klaus AICHHORN[3],
Marcos LÓPEZ CABECEIRA[4]

Figure 4-2 Extract of the WTRC paper

- A. kemetinger, K. Aichhorn, M. Troger, C. de la Cuesta, M. Lopez, J. Nemeth, R. Olmedo,; "ARIADNA – MARITIME VOLUMETRIC NAVIGATION SYSTEM" accepted for European Navigation Conference GNSS; Poland, 25-27 April, 2012

4.2.3. Articles, Conferences and different Media News

In addition, different articles were published in international conferences and journals such as:

- French magazine "Navigation, ports & intermodalité" specialised in the inland navigation published an article about ARIADNA.

- F. Bellido R. Olmedo; "*ARIADNA: Maritime Volumetric Navigation System*"; publication in the "Satellite Navigation applications in the NEREUS Region" prepared by the NEREUS GNSS Working Group, April 2011.

- Publication in the "HSVA Newswave" 2010 by G. Ernst (HSVA).

- Spanish Merchant Marine Association ANAVE published an article about ARIADNA, May 2010

- European Navigation Conference 2013. Poster and presentation of the ARIADNA Project, Vienna Austria; April 2013.

Different presentations and supporting documents as posters were prepared by all the partners of the ARIADNA project during the difference conferences events, pointing out the 13th e-NAV Committee of IALA (Paris, France; March 2013) and theTransport Research Arena 2012 (Athens, Greece; April 2012).

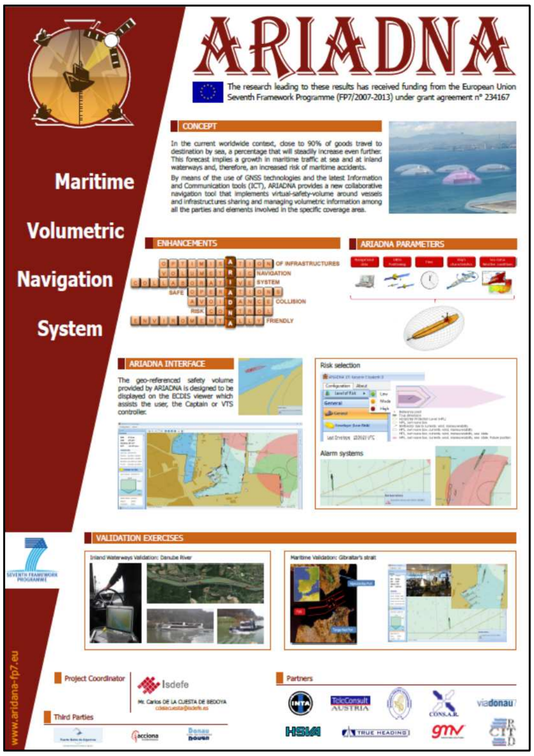


Figure 4-3 ARIADNA poster

Moreover, the last validation activity performed in the Strait of Gibraltar had an important repercussion in the local newspapers and even radio programmes that show their interest in the project requesting different interviews with the Project Coordinator, Mr Carlos de la Cuesta.

Un gaditano desarrolla un sistema de control para la navegación

El terreno de Visteon saldrá a concurso a final de mes

EuropaSur

Prueban en Algeciras un nuevo sistema de ayuda a la navegación

EuropaSur

Fecha: 15/02/2013

Sección: MARITIMAS

Páginas: 24

El 'Ciudad de Málaga' prueba los equipos del proyecto Ariadna

Isdefe presenta en la sede de la APBA el nuevo Sistema Volumétrico de Navegación

El 'Ciudad de Málaga' prueba los equipos del proyecto Ariadna

Isdefe presentó en la sede de la APBA un nuevo Sistema Volumétrico de Navegación

Figure 4-4 Different local newspapers including information about the ARIADNA project

4.3. Exploitation of Results

ARIADNA has a number of aid-to-navigation applications in the maritime environment and water inland environments including optimization of maritime and inland waterways infrastructures, collision avoidance, vessel traffic services, maritime safety, aid-to-navigation and accident avoidance and investigation. The strengths of this system are based upon AIS communications (ARIADNA basis) robustness and the system provided additional functions to the capacities provided by other navigation instruments. This robustness yields to a higher safety level in navigation. The wide range of different operational scenarios allowed by ARIADNA, the ship-to-shore and shore-to-ship possible communications and the radar & other Aid-to-Navigation (AtoN) complementarity the system is able to provide are main ARIADNA strengths.

The outcomes of the ARIADNA project are very valuable for all the partners into their daily work in their activity fields and several opportunities arise related to the possibility of developing future capacities in order to promote volumetric navigation system and new navigation applications with high level safety requirements.

The commercial exploitation of the single modules in their current standing is unlikely. No patents or software has yet been identified for IPR exploitation. Regarding a full license or product, it is doubtfully that the partners can benefit from the current ARIADNA product or license. Only a qualified navigation equipment provider can be credited for license and exploitation. Unfortunately no bridge equipment provider has been included on the ARIADNA partnership, and no one of those contacted along the project has been interested, possibly due to the limited time for demonstration and validation up to the end of the project.

However, for some individual partners there are current and future business activities related to the project as the following:

- A simplified application of ARIADNA to recreational craft may provide a return for one of the partners who is already involved in AIS antenna business and offers recently a "SEA PILOT" product.

- The Spanish ARIADNA major partners involved in Naval and civil maritime systems and also civil aviation systems may benefit for a pilot contract with the Ports National Authority or a single port or a Navigation Control area for developing an ARIADNA based system. Also for a 2D application on airport surface flights and service vehicles planning and surface control.

- One partner is already involved on a blind person's navigation project.

- One partner backed by a major ship-owners group previously participating in navigation projects offered his support and interest, on the final workshop for a new proposal spin-off from ARIADNA.

- One ARIADNA partner with maritime background and expertise, which current business is consultancy plan to address some of his contacts risen along (or before) the project trying to develop further product development and research.

- The Inland Navigation partner is already involved on a TEN project that may incorporate some ARIADNA inputs.

- The two partners operating towing tanks may benefit from the need of using hydrodynamic inputs development that is necessary for acceptance of ARIADNA, accounting for the effects of sea waves, currents, wind, squat, and manoeuvrability and ship movements.

4.3.1. Hypothetical calculation for a Commercial Exploitation of Results

The commercial exploitation of an integrated approach by a single provider would be more efficient than a commercial production module by module.

The ARIADNA product consists mainly of software, and a commercial-professional computer, needed to run the software(s) and provide the outputs. Therefore, the costs of the ARIADNA modules from the end of the project, and taken into account most of the sensors are included on board the vessel, have been estimated around 2.000€ for producing and testing one module (that consist on the software).

The software cost for a potential customer is just the license, the connection with the on-board equipment (today some brand new equipment has Wi-Fi and Bluetooth outputs, so the cost of connexion could be almost zero except may be for the radar(s), and only the integration test, the training and manuals could implicate costs, and this will depend on the number and similarity of the lot.

Then the costs to incur for a commercial exploitation of ARIADNA, including standardization and fitting to specific customers, and acceptance by IMO and Classification Societies are much larger than the cost of the existing ARIADNA package.

We can identify the following costs before commercialization:

1. Obtain agreements with a complete set of bridge equipment manufacturers to provide their on board equipment outputs and adjust the respective module and software for calibration, self-adjustment, and for failure of data transmission and error warning

2. Qualify ARIADNA for maritime standards and IMO and country homologations. As ARIADNA may be reduced to software, no electronic equipment rules may be applicable, but some qualification and demonstration of no interference with shipboard equipment will be need or even to be included on some of the shipboard equipment qualifications, and for compliance with the communication standards and communication channels occupation rules. The cost for IMO, Classification Societies and country homologations and acceptance cannot be quantified, without more detailed study and consultations with IMO, and national authorities, and pilots and ship-owners associations and P&Is. This cost must be balanced with the costs charged to the potential users licenses on the first years of commercialisation

3. Obtain the hydrodynamic model of the ship well a ship series or one by one (can cost up to 30.000€). Similar cost if ARIADNA is to be used for port access; the hydrodynamic model of the port should be supplied by the port, or subscribed by the ARIADNA user

4. Cost of compliance with customer specifications, including training to bridge crew, validation and delivery tests, and cost of the after sales warranty

The above mentioned costs may rise due to delays and times spend on approvals and administrative barriers.

ARIADNA outcomes depend also on the quality of the input data that depends on the source and on the data selection and calibration by the end user. Therefore liabilities that could increase the cost calculation, cannot be assumed and applications not related to safety shall be preferred.

The cost of high standard ship navigation equipment depends on the quality and performances of each equipment, sonar, radar(s), AIS, ENC and its proper calibration and maintenance, and also depends of the integration with the equipment and tests. As the high performance navigation equipment are derived from advanced military developments is not possible to estimate the cost of a supersized 18.000TEU containership or cruise ship navigation equipment. The main issue is that modern navigation equipment has safety and warning subsystems that may left ARIADNA maximum performances may not add much value, and credit to outperform current warning aids.

Then the cost application of ARIADNA on advanced navigation systems cannot be considered a new cost for the ship-owner but a small cost increase for the complete navigation system package offered by the provider, who may decide (with the ship-owner) to include or not ARIADNA on the navigation package, and the main cost of that is the integration of ARIADNA on the complete system with all data. Then all data may be already available from the ship and from AIS and ECDIS, but the whole ARIADNA software may need to be reconstructed for the specific ship case.

We must consider that modern radar equipment at a cost of aprox. 3000$ include software that provide very good safety navigation and warning options: Radars have software options for display and tracking. Provide free software for RADAR is common practice. A MDS-8-2Kw 20" radar with ranges from 1/8 to 24NM,4.7º Horizontal Beam Width, Direct Ethernet connection, costs no MDS box required costs $2,999 including the software free of charge.
ARIADNA integration with radars must consider the link with the manufacturer provided software. Also ARIADNA being a software may be expected to be provided “free of charge” and therefore the ARIADNA first customer and end user is the navigation equipment provider.

The application of a simplified ARIADNA to recreational craft may be reduced to an APP for a modern pilot system, or even an Android or iOS. One of the ARIADNA partners has launched a new SEA PILOT software that may start bottom up a potential line of ARIADNA low cost applications.

On recreational craft, depending of the “modules” included and on the data inputs available, and of the display the cost may be a per cent over the AIS software. ARIADNA as App may be a marketable product.

5. The Address of the Project Public website

As part of dissemination activities, a website was designed by TCA and Isdefe which link is indicated below. The website was managed for general dissemination purposes and it was used as internal communication tool within the consortium.

www.ariadna-fp7.eu

Figure 5-1 ARIADNA logo and website address

The web page provides a short overview about the objectives and the achievements of the project to interested parties, such as user groups, experts, scientists, potential users, and R&D projects. The main page of the project web page is depicted in the following figure.

Figure 5-2 ARIADNA web page: Overview & Objectives and Video sections

The reader gets an overview about ARIADNA in a compact modality. A project plan provides information about the different work packages and the milestones. In a separate section, the project partners are presented shortly. Also the role of the different partners in the project is published. Furthermore, it is possible to download different conference papers, presentations and videos as well as ARIADNA contributions in different journals in a download area. This ensures technology transfer.

A main achievement of the web presentation has been to keep the web page up-to-date. It has been a continuous process, so that new information about ARIADNA has been available as soon as possible.

The major sections of the internet presentation are:

- Overview & Objectives.
- Concept & Approach.
- Project Team.
- Events.
- Links.
- Contact.
- Internal.

5.1. Contact Details

Goals of the project were addressed for a European competitive consortium, led by Isdefe, whose expertise and wide experience in different ARIADNA activities guaranteed the success of the project.

The list of all beneficiaries with the corresponding contact names is herewith included:

Organisation	Contact details	
	Name	Email
Isdefe Ingeniería de Sistemas para la Defensa de España	Carlos DE LA CUESTA	cdelacuesta@isdefe.es
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Table 1 – ARIADNA Consortium – Contact details