THE INTEGRATED INFORMATION PLATFORM OF THE ISTITUTO IDROGRAFICO DELLA MARINA

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1. Introduction

Since the beginning of the 1990s, the Hydrographic Institute of the Italian Navy (IIM) has increasingly found itself up against two complex and competing problems: on the one hand, the gradual decrease in human resources and, on the other, the more and more urgent need among mariners and the scientific community for a vaster range of high quality services and products.

Against a background of swift technological development, the IIM decided to carry out a radical overhaul of its production processes, investing a large share of its available human and economic resources, first, on identifying the basic prerequisites for and, secondly, on the implementation of the "Integrated Information Platform of the Istituto Idrografico della Marina".

The Platform is an ensemble of "technical tools and organisational solutions", some of which take the form of software, others hardware, others again procedures, rules and guidelines. Operating in concert, they allow the acquisition, harmonisation, standardisation, exploitation and, finally, the management of the vast amount of data required by the modern HO.

The "touchstones" of project are simplicity, flexibility, modularity, hardware downsizing (extensive use of PCs), a combination of specialised software tools, a precise pin-pointing and synchronisation of work flows and, finally, a perfect integration of the results achieved with each flow.

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The development of the Platform is the result of collaboration with a private sector company and is based on the resources afforded by "Ambiente Pangea", developed by Pangea S.r.l. .

This article begins with a brief review of previous IIM experiences matured over the years. It then goes on to list the Platform's project goals in the light of the outstanding technical features of "Ambiente Pangea". Before concluding, it will also illustrate one of the main areas in which the Platform is now operational, providing an account of the entire IIM process of hydrographic surveying, carried out according to the Italian methodology based on IHB recommendations.

2. PREVIOUS EXPERIENCES IN AUTOMATION AT THE IIM

In the early '70s, the onslaught of the information technology boom led to an awareness that many technical problems might be solved with the aid of computers.

The IIM set up a Data Processing Department to investigate the possibility of automating operations which, as well as requiring high precision results, also necessitated time-consuming, complex calculations. The earliest results were obtained in the field of chart making, with the automating tracing of borders and graduations, sea cables and other symbology. In the field of nautical publications, research was performed with the aim of automating complex algorithms for the compilation of Nautical Almanacs and Tide Tables; other efforts were made on the front of automatic acquisition and processing of oceanographic parameters.

At the same time, studies were begun on ways of employing computers in the acquisition and analysis of hydrographic data. Working in collaboration with private sector companies, such research led to the development of a complex system for automatic data capture and the production of survey sheets. The IIM then tried to come up with tools for cartographers seeking support in automatically tracing isobaths from soundings. For a number of reasons, none of the systems allowed the achievement of any significant results, partly due to over-optimism on the part of IIM and, partly, to a lack of honest pragmatism in the technical consultants engaged, whose job was to assist their hydrographer clients to bring their expectations within more reasonable bounds.

Towards the end of the 70s, automation options were again discussed, resulting in the decision to purchase an American-built system, which was subsequently installed on the survey vessel PIOPPO. Working reasonably well at the out-set, thanks largely to the presence of the producer's technicians, it soon ran into problems, giving rise, among other things, to the need for expensive modifications. After a great deal of work, the system was judged to have no cost-benefit and the project was eventually ditched.

The early '80s heralded the arrival of mainly Anglo-American systems for automated hydrographic surveying and computer-assisted cartography. The IIM, like many other HOs, decided to adopt "turn-key" systems: a hydrographic one on the survey vessel AMMIRAGLIO MAGNAGHI, and another for chart production, both of

which called for substantial capital out-lays and a tortuous amount of red tape. However, in the medium-term they required numerous software modifications (always very expensive and frequently unsuccessful) in order to bring them into line with national standards and procedures.

In spite of numerous difficulties, the two systems were utilised for over ten years, during which time the cost/benefit ratio continued to decline.

In the meantime, after substantial investment and many years of joint effort with the private sector, progress was achieved in dealing with nautical information for use in compiling Notices to Mariners, a system that remains in operation.

2.1. Description of the IIM scenario at the outset of the Platform Project

In the late 80s when the project got underway, the IIM was bogged down by a series of heterogeneous, unharmonised procedures and methodologies, most of them dependent on manual intervention. Thus, the effort to guarantee the quality and reliability of the product continually came up against the following obstacles:

- high management costs, long work processing times, the need for repeated revisions (incurred by the presence of traditional procedures);
- the impossibility and/or difficulty of using the increasing reserve of data already available in diverse digital forms;
- the growing need for personnel specialised in the single stages of the various production processes, at a time of serious, long-term shortages in specialised staff.

In addition, the period in question was characterised by two concomitant situations:

- the build up of a huge and increasing amount of survey sheet back-log, still waiting to be examined on account of the entirely manual methods adopted during the various production phases;
- a mass exodus of specialised IIM staff, who had previously guaranteed the performance of survey planning activities, data analysis and control within a reasonable time.

This combination of factors provided the impetus for getting down to work on the Platform development. The first phase involved outlining the overall design of the project, which gave priority to the Survey Department, facing in sequence the problems arising from survey planning - and production of the related technical outputs - data validation and data acquisition at sea.

The details of data base design and set up and digital product automation were left for a later step.

3. IMPLEMENTATION OF THE PLATFORM

In view of past experience and bearing in mind the need to fulfil its HO responsibilities, the IIM was greatly encouraged from the very out-set to model the Platform on existing Institute traditions, hydrographic experience and organisational structures.

In particular the quest for an original, customised solution contemplated a number of cardinal points:

- *a priori* exclusion of the "turn-key" solutions available on the market, an option that might impose radical changes in IIM organisation;
- identification of specialised private sector partner(s), to serve as an operative support in the overall development and the solution of computer-related problems. This approach allowed the merging the hydrographic experience and tradition with the opportunities offered by information technology [4];
- recuperation and harmonisation of all existing digital data;
- IIM's central role as the controller, supervisor and verifying agent, in order to ensure that the development of the Platform was tailored towards its own specific needs and to suggest new development and research activities;
- development of the Platform through a series of carefully planned successive steps, starting from the present, to move into a transitional phase that would gradually lead to its full implementation;
- step-by-step elimination of all manual procedures that could be performed automatically, with a view to:
  - doing away with repetitive operations and helping the detection of errors;
  - reducing the amount of work required to obtain results;
  - creating conditions for an increase in production volumes;
- progressive extension of the project to cover all production departments.

3.1. Choice of partner

Towards the end of the 80s, a public competition was held among numerous companies specialised in dealing with geo-referenced data. With the gradual passage of time, an increasingly close relationship was to evolve between the IIM and the analysts of Pangea, whose ability and growing interest in entering into and interpreting hydrographic issues greatly facilitated their integration within the "operative fabric" of the Institute, which also drew significant benefit from the knowledge obtained by Pangea during its simultaneous involvement in the Digest VMap data production project.

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[4] The strategic fusion of innovation and tradition finds an emblem in the presence in the Institute of 19th-century engraved copper plates, eloquent testimony of the IIM's chart making experience.

Early positive results went on to become highly satisfactory and, especially in the light of the previously outlined technical and organisational situation, provided and continues to provide the catalyst for further progress.

4. FEATURES OF THE PLATFORM

We summarise here the main technical characteristics of the Platform based on "Ambiente Pangea".

4.1. Hardware Platform

The entire system has been designed to maximise the cost/performance ratio and minimise maintenance expense. This target was achieved by the choice of downsizing, with the wide-scale introduction of PCs connected on-line. The network arrangement facilitates data exchange and peripheral device sharing, as well as simplifying human-computer interaction.

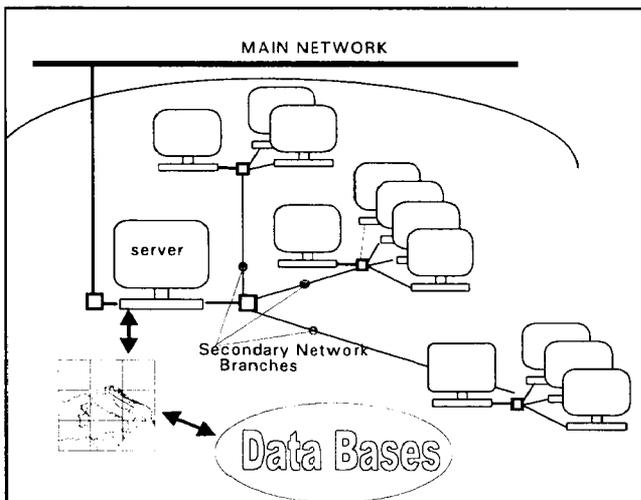The diagrams illustrate the structuring used to optimise efficiency and flexibility.
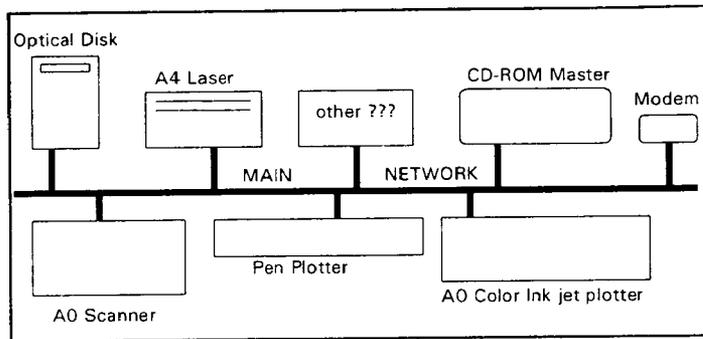

FIG. 1 – Hardware architecture.

FIG. 2 – Shared peripheral devices.

4.2. Communication system

Communication is one of the pivotal concepts underpinning the system as a whole: it allows information exchange and interaction both among the various elements of the Platform itself and between the Platform and the "external world". In general, communication[5] takes place via the "open system approach", exploiting the "import-export" tools provided by "Ambiente Pangea":

- the *internal communication system* currently addresses the problem of numerical data exchange among the various departments of the Institute;
- the *external communication system* addresses the problem of digital data transfer according to international data transfer standards.

Moreover, it should be emphasised that the "import-export" tools have allowed the recuperation and reutilization within the Platform of all digital data already existing at the IIM in other formats and/or other systems.

4.3. Commercial software packages

The operating system is currently undergoing a transition from DOS to Windows (version 95/NT). In addition, the Platform carries office automation tools, network software and a Computer Aided Design package used by "Ambiente Pangea" for graphics requirements and management[6].

4.4. Application software Platform

The Application software Platform is based on *"Ambiente Pangea"*, which has proven to have the technical and structural characteristics required for the setting up and implementation of the Platform.

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[5] Communication has been used since the beginning of the project as a powerful tool to facilitate automated exchange of data.

[6] The CAD provides two graphic monitors where the user can chose up to eight synchronised windows working simultaneously on the same data set, a feature that is especially useful in acquisition and verification processes.

"Ambiente Pangea" is made up of a "computational nucleus" flanked by a series of software tools specifically designed to cope with the high degree of complexity inherent in geographical data management. The nucleus has two principal functions: one the one hand, it integrates all the activities carried out by the single software tools, which are thus transformed into "geographical operators" co-operating according to protocols; on the other, it manages the interface with the user, thus simplifying and standardising human-computer interaction.

By combining typical GIS software with tools for dealing with hydrographic problems, "Ambiente Pangea", has allowed us to:

- create a close correlation between the applicative function to be performed, and the software tool utilised;
- deal with any work process (in which raw data becomes information) as a flow, divided into a series of steps, where the user employs a set of software tools, according to his requirements;
- adopt a single common Platform (from data acquisition at sea through chart production), which ensures maximum structural homogeneity. It therefore provides three major advantages:
- it eliminates the difficulties and time involved in integrating systems based on different philosophies, data formats etc.;
- it permits the reutilization of all previously developed software tools;
- it drastically reduces the time involved in the training of technical personnel.

The standard CAD package eliminates the costs involved in the development and maintenance of all graphic capabilities, as well as making available some libraries of functions for use during the development/customising phase.

The types of data managed come under the following categories: *raster data* (black and white, grey tones, true colours), *vector data* (2-D and 3-D), *geographically referenced alphanumeric data* and *grid referenced data*.

Data structures employed can be roughly subdivided into three categories: (1) *data layering* support tools, (2) data structures able to deal with "*objects*" and (3) *metadata* management support tools.

Classification of software tools: they can be classified in structural terms (operative / support) or according to the activities in which they participate (data acquisition, analysis and control, processing, storage, cartographic representation). Of particular interest are the following:

- RASTER management: allowing the management of raster files of any size for which it is possible to perform precision geo-referencing using any number of points for the software digital stretching phase, each point exactly corresponding to the set coordinates;
- 3D MODELLING: comprising 3D management functions;
- CONTOURING: allowing various procedures for the parametric production of isobaths, starting from any kind of traverses. In particular, it also incorporates a "maximum hydrographic safety" mode, which automatically

takes into account the morphology of the sea bed in tracing the contour lines;

- MORPHOLOGICAL analysis: allowing a series of 3D data analyses, making it possible to obtain automatically the main morphological features (point, line and area objects) of the sea floor;
- BOOLEAN operators: providing user support in performing Boolean operations (intersection, union, difference) among layers of digital geographical data;
- HYDROGRAPHIC DATA CONTROL AND ANALYSIS: supporting the user through the entire hydrographic data verification process, from the first control step to delineation.

5. ACQUISITION AND VALIDATION OF HYDROGRAPHIC DATA

As previously mentioned, there follows an outline of the acquisition and validation of hydrographic data performed by the Survey Department, where the Platform is currently fully operative.
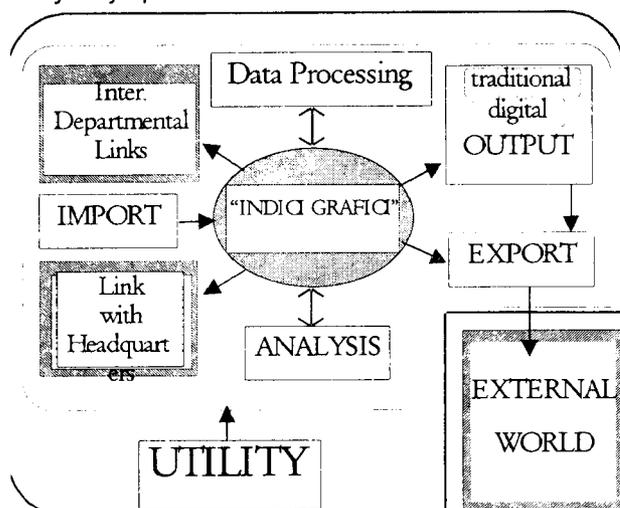

FIG. 3 –Layout of acquisition and validation procedures.

The flow of operations involved may be divided into five major phases:

1. **Survey planning;**
2. **Data acquisition at sea;**
3. **Data control and analysis;**
4. **Traditional and digital production;**
5. **Data storage.**

With the exception of data acquisition, which has to be performed at sea, these operations can all be performed either at the Institute or in the field, using the same software modules, albeit at different layers of application.

The next section provides an outline of the methodologies and software tools used in each of the operative stages, highlighting the differences in applicative level according to the modules used.

5.1. Survey planning

5.1.1. National Charting Scheme

In order to plan the survey, use is made of the National Charting Scheme, i.e. information dealing with chart characteristics and priorities for publication. It takes into account the age and therefore reliability of the charts currently in force as published by the IIM.

This regularly up-dated data base provides the background for decision as to which surveys should be performed.

Standard use: At the Institute

5.1.2. Geographical Index of Survey Sheets

The data base "Indici Grafici" (Geographical Index of Survey Sheets) provides a further important tool in survey planning. It records all the basic information concerning all the survey data and supports the user to automatically manage it. Very briefly, they are:

- survey number;
- area surveyed;
- scale (data density);
- archive number;
- survey period;
- technical characteristics;
- survey vessel;
- expedition director.

The geo-referencing of the information is performed on the basis of the survey boundaries reported on "Serie 900"[7] charts. During the first phase of the project this data was digitised using specialised software tools.

As a first step, the problem of managing the data relative to each survey was resolved by creating special "objects" that are able to store, manage and query all metadata concerning the survey.

Once the porting of the Platform into Windows 95/NT is complete, it will be possible to deploy such "objects" also using office automation tools, such as MS Access, MS Excel, MS Word, for data base management, statistical analysis and either traditional paper or digital production.

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[7] The "Serie 900" is a collection of 1:250,000 nautical charts covering all Italian waters.
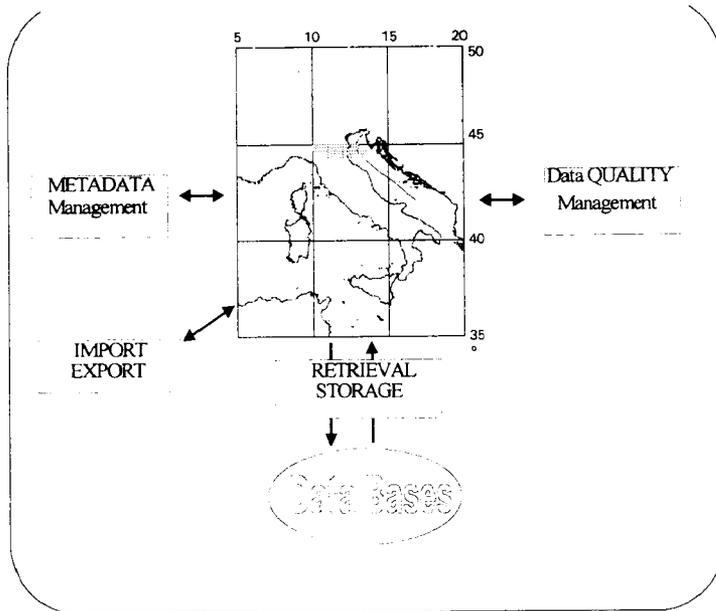
FIG. 4 – Geographical Index of Survey Sheets management system.

At present, the operative procedures follow the main steps outlined below:

- <u>vector drawing of areas using raster background</u>
The geo-referenced raster showing the charts in force is used as a background against which to draw the survey area, thus eliminating the need for digitisation tables.

To speed up the overall process, the normal design tools of the commercial CAD are flanked by software tools specially designed to perform many operations dealing with the properties of objects in order to facilitate digitising activities.

Standard use: At the Institute

- <u>topological control of elements</u>
A series of specialised software tools is available to ensure correct topological relationships among all the areas and lines, as the user may make digitising errors. The tools will alert the operator in the presence of one of the following situations: 1) for lines: isolated nodes, terminal nodes, multiple nodes, self-intersections, self-superimposition, intersections, superimposition and intersections on nodes, 2) for the area: open lines, superimposed areas, "implicit" areas, adjacency between areas, repeated centroids in different areas, different centroids in the same area, areas with no centroids and centroids with no area.

Standard use: At the Institute

- <u>filling in of survey metadata</u>
When the survey area has been defined, the technical information pertaining to the survey data are filled in to create a preliminary survey "object", basis of the data base management, that is quickly identifiable by survey number and scale.

Standard use: At the Institute

- <u>data base consultation / survey time estimates</u>
Pre-defined standard queries can be used by the operator for data base management and consultation. In particular the user can perform parametric estimations of required survey time, taking into account the speed of the vessel, number of hours per day devoted to sounding activities and other corrective parameters deriving from experience (eg. foreseeable number of bad weather days). This is a support tool to assist in decisions on how to allocate available resources in the most suitable way.

Standard use: At the Institute

- <u>production of guidelines for use in the field</u>
The information generated are stored and ordered in a series of documents for use in the field during detailed survey planning.

Standard use: At the Institute

- <u>detailed survey planning</u>
The computer-assisted generation of survey lines is carried out using the survey planning information (in particular, survey boundaries and scale) transferred to the field by the IIM. The data resulting from this phase is in turn transferred to the Institute by means of the same software tools.

Standard use: at sea.

5.2. Data acquisition at sea

The monobeam automatic survey system is another element of the Platform based on "Ambiente Pangea"; it allows the operator to integrate in-progress data acquisition with the run-time analysis and checking of navigational information and hydrographic raw data. Such operations are greatly facilitated by the two synchronised graphic monitors.

In particular, the conceptual three-dimensional vector model used provides a visual representation of space, where the survey vessel appears in the form of a moving computer symbol, which is able to interact with the "virtual" model of the real world. This facility is an extremely useful navigation aid and a powerful tool in the process of data acquisition and analysis.

5.3.   Data control and analysis

The data captured undergoes a series of control procedures that employ the method of "successive generations": this means that the data pertaining to each phase are stored unaltered, allowing subsequent analysis of the various work phases at the Institute, to check that the surveys have be performed correctly and evaluating their conformance to the standards listed in the Special Publication No 44 of the BHI (S-44).

Data control is performed following the procedure outlined below:

- Interactive 3D graphic editing and elimination of spurious data
  This step employs a series of software modules for the 3D graphic editing of data, automatically recognising isolated spikes, groups of spikes and constant value intervals.

  Any data the system considers to be incorrect are compared by the user with those recorded on the traditional paper plot and, if needs be, corrected or eliminated, creating new files of clean data.

  The "new generation" files are then corrected for sound velocity and tide.

- Delineation
  Delineation permits the computer-assisted selection of the most significant hydrographic raw data, at the same time maintaining as far as possible the uniformity of spread. The processing is performed through a succession of looping convex hulls along the points of the survey line. The mathematical algorithm ensures that no point between any two delineated ones is shallower than the level of the two points in question.

  The resulting set of discreet data is used for the generation of the 3D model of the sea floor, according to Delaunay's triangulation.

  Standard use: at sea

- Generation of the 3D model of the sea floor and control of data congruence
  The model is generated excluding the survey control lines; their values are used to monitor "raccordi interni" (internal link up points), when they are projected onto the model to analyse any deviations according to the limits established by international rules (S44), marking any that exceed the limits.

  The operator is assisted by the system to evaluate the degree of error automatically found.

  The same procedure is employed to check the congruence of the "raccordi esterni" (external link up points) of the data pertaining to adjacent surveys; this is achieved by projecting every single sounding on to the model built using the data of the adjacent survey.

  Standard use: at sea/at the Institute (during the validation phase)

- <u>Analysis of the 3D model of the sea floor</u>
  The analysis tools of the 3D model have led to the development of work methodologies that are entirely new for the IIM.

  One very interesting result has been the employment of CAD rendering functions to highlight data positioning problems in certain areas of the survey, a particularly pronounced phenomenon in steeply sloping areas.

  The morphological analysis yields crucial information that is currently under study in order to try to identify the areas requiring greater data density in order to ensure the safety of navigation.

  Standard use: at sea/at the Institute (during the validation phase)

- <u>Isobath generation</u>
  The specialised software module for generating isobaths allows the parameterisation of the smoothing criteria; in particular, it employs the specially developed "maximum hydrographic safety" algorithm, which automatically takes into account the morphology of the sea bed in tracing the contour lines.

  Standard use: at sea/at the Institute (during the validation phase)

5.4. Traditional and digital production of survey sheets

Traditional and digital production are supported by "standard GIS software modules" (conversion of coordinates and ellipsoids, automated generation of cartographic borders, utilities for text management, plotting etc..)

Standard use: at the Institute.

5.5. Data storage

This step involves the computer assisted storage of all the information with the corresponding up-date of the "Indici Grafici" data base.

Standard use: at the Institute.

5.6. Results

The system developed during the early 1990s became fully operative in the Survey Department at the end of 1995. Up to then, the validation of surveys was performed manually, with the new Platform tested on a sample basis to verify its functionality.

During this period, the considerable increase in surveying work at sea, coupled with specialised staff shortages, resulted in a huge backlog of surveys pending verification, (about 160 fair sheets that correspond to an ara of nearly 32,000 km² -

nearly 34,000 km of lines surveyed), in spite of a routine production of 100 survey sheets per year.

At the beginning of 1996, it was decided to implement fully computer-assisted verification, using the system set up with the help of Pangea for the validation of digital data. With the resources made available by the Platform, the Survey Department was able to eliminate the backlog completely by the end of 1996, simply using three work stations.

6. Conclusions

In view of the above remarks, it can be affirmed that the Platform has provided the IIM with a integrated body of specialised software tools, which have allowed it to abandon traditional working methods, in favour of a flexible approach where the user is free to choose the most appropriate solutions and methodology for the problem at hand. In this context, the Platform offers two major advantages:

- extendability of the Platform: new problems can be dealt with simply by introducing a new specialised tool based on the same Platform;
- the capacity to keep apace of arising requirements without imposing the need for producing completely new expensive *ad hoc* software.

The Platform has proven to be a valid support both in the work of specialists, with a large amount of experience, and in operations entrusted to less expert users. In the former case, the specialist defines the work flow and employs the software tools according to its objectives; in the latter, the user follows the pre-defined, tried and tested standard flows.

Thus, with the single group of homogeneously integrated tools in the Platform, it is possible to carry out sophisticated analyses without recourse to *ad hoc* applications, as well as employ less specialised personnel while guaranteeing good results.

Thanks to the developmental approach, the Platform always ensures the maintenance of at least one previous production level, as well as the recuperation and harmonisation of all data already available in digital form.

The fully integrated character of the Platform, has permitted:

- the reduction of the overall complexity of the system, being easily used also by less expert staff;
- the reduction in training and work processing times;
- increased flexibility of deployment of technical staff;
- the reutilisation of the Platform's tools for different tasks;
- the standardisation of work procedures, as well as a reduction in development and implementation costs;

The integration of the Platform with office automation software, the extensive use of the open system approach and the widespread employment of PCs has simplified many operations and led to a spontaneous involvement of the staff.

7. Bibliography

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