ENVISYS
Environmental Monitoring Warning and Emergency Management System

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1. Informative Summary

The Mediterranean Sea is a well frequented sea route allowing access to Southern Europe, North Africa, the Middle East and the Black Sea. The result of this extensive marine traffic is a high risk of oil pollution, both intentional and accidental. In addition to the obvious ecological risks associated with such pollution in a closed sea area, it is in the interest of all nations bordering the Mediterranean to protect their coastal zones on which they depend for tourism, fishing and other activities.

Changes in our environment are strongly tied to the capabilities of human resources to mitigate their effects, with the use of new technologies, equipment, and methods. The minimization, if not elimination of the considerable political, economical and environmental repercussions and the need to seriously address these repercussions have been widely recognized for many years now. The ENVISYS Project provides a telematic framework, where appropriate counteraction means can be undertaken, taking into account that different types of hazards have different evolution and control times.

2. The ENVISYS Project

Recently started ENVISYS is an international cooperation project, partly financed by EU DG XIII in the framework of the Telematics for the Environment Programme. Its primary objective consists of creation of a complete system for early detection of oil-spills, monitoring of their evolution and provision of support to responsible Public Authorities during clean-up operations.

ENVISYS consists of a set of separate modules that together constitute the integrated monitoring and management system. The project, therefore, provides a basis for several independent, commercial products that can also be used separately in other contexts. The primary source of data is satellite data. The availability of large amounts of satellite data should be emphasized as this enables the applied research results of the project to be transferred

from the domain of R&D to the domain of commercial exploitation. Because of that, the project has identified a User Reference Group (URG) with more than 400 organisations interested in the ENVISYS approach. The project is building demonstrators in three European countries (Spain, Norway and Greece) by integrating existing remote sensing techniques (based on Synthetic Aperture Radar Imagery), communication tools, Geographic Information Systems, Data Bases and multimedia tools. The demonstrators provide automatic detection of oil-spills, based on intensive research work realised during the preparation phase of a relatively pre-operational service in Norway by the Norwegian Space Centre, the Tromso Satellite Station, the Norwegian Computing Centre and the Norwegian Pollution Control Authority. The demonstrator is being tested and verified in two Mediterranean regions, the South Aegean Sea (Cycladic Region) and Gibraltar area, as well as in the Finisterre Region (Galicia, Spain).
In this way, the knowledge and experience acquired during the Norwegian experiment, can be transferred to and tested in South European areas selected due to the frequent incidence of oil pollution and characterised by different difficulties and operational requirements.

3. Project Objectives

The objectives of the ENVISYS project are the following :
To integrate into a fully operational system existing remote sensing, communication and software intensive technologies, as well as existing public infrastructure
for sea monitoring;
detection of oil spills due to human activities;
issue warning to responsible public authorities;
and
provide decision support to the said authorities during clean up operations.
To investigate the cost effectiveness of chosen techniques and solutions in the selected geographic regions, which present different weather conditions, sea current patterns and coastlines.
To investigate the applicability of similar concepts and techniques in other physical disaster phenomena, most notably forest fires and floods.

4. Expected results

The project aims to detect a very high percentage of all slicks created during the demonstration, constrained only by satellite coverage of the area in question (in terms of time). As 24 hours satellite coverage is anticipated in the imminent future the achievement of this aim could demonstrate the system's potential to be used, on a daily basis, as a very powerful tool for public agencies in this field.

Apart from the direct monitoring functions, the existence of a sea monitoring system, has a clear preventive action, by marketing and exploiting the satellite surveillance factor. It is observed and generally accepted that a major part of sea pollution comes from oil dumping in open seas.
The users of ENVISYS technology are regional, national and international authorities responsible for enforcing national & international law for marine environment. Secondary users are organizations and industry taking part in verification, assessment, and clean-up activities. The ENVISYS project focuses on providing assistance directly to the Environmental Authorities, enterprises and institutions involved in the environment protection.

5. Basic technologies used

ENVISYS creates a platform integrating the following techniques:

5.1 Remote sensing techniques

Remote sensing techniques are the principal components of the ENVISYS technology. In the case of oil-spills, detection by SAR (Synthetic Aperture Radar) is based on the dampening effect oil has on capillary and short ocean surface waves. In order to discriminate from "look alike" phenomena, (which currently prevent the development of automatic tools) higher-level analysis based on special characteristics for oil-slicks has been tested to a limited degree, and has shown promising results. The necessary development of automatic oil-slick detection in this project will draw heavily on these results. Main sources are the ERS-1 & 2 data as well as other non European satellite data as soon as they become operational.

5.2 Geographical Information Systems

Geographical Information Systems (GIS) are a principal tool for presentation purposes and decision support. In particular, ENVISYS is interested in modelling the developments of oil slicks (based on data for sea currents and prevailing winds in the region where the disaster occurred) in order to support agencies conducting clean up and monitoring these operations. Currently, commercial GIS systems provide very powerful modelling tools which make such tasks feasible and quite practical.

5.3 Data bases

In order to support public authorities in their clean-up operations, various types of data (images, maps, statistical data etc.) mainly related to the demonstation areas are stored in data bases. Examples of useful data include:
Historical data from previous oil pollution events (images, photos, maps, damages etc);
Detailed sea maps (bathymetry, sea currents, coastlines, coast types etc.);
Thematic maps (sea, coast and land use, fishing and sea cultivation, areas of ecologic importance, under-water flora, touristic regions);
Chemical products used in clean-up operations asoociated with oil type and oil-spill characteristics (dimension, depth etc.);

5.4 Telecommunication services

The early detection of oil-spills depends on the timely delivery of satellite imagery at near real time (i.e. within few hours from the satellite passing). This requires fast data communication links from the satellite ground stations to the system operations site. The ENVISYS project uses high speed leased lines of up to 2Mbits/s for this purpose. Today, such infrastructure is available in - and between - every EU member state. Therefore the availability of the telecommunications infrastructure seems to be assured, and only the question of operational costs in the case of a future permanent operation have to be examined, related to the possible use of new broadband telecommunications links (e.g. ATM networks) .

5.5 Likely developments

The types of emergency situations covered by ENVISYS are totally dependent on frequent remote sensing data from appropriate parts of the electromagnetic spectrum. The remote sensing sector is steadily growing, and there is no doubt that access to remote sensing data will increase thanks to the presence in orbit of ERS-1, ERS-2 and Radarsat. The large European remote sensing platform Envisat will follow in the late 1990's, and there are plans for numerous other commercial remote sensing satellites within ten years. This ensures satisfactory data access and frequent coverage, which strongly supports the potential for ENVISYS to be an important tool for environmental emergency monitoring in the future.

6. System characteristics

The system contains the following features:

Synthetic Aperture Radar (SAR) remote sensing data collection and processing (a typical image product will cover an area of 100 km x 100 km).

Automatic oil slick detection in the radar imagery.

Emergency assessment. The extent of the emergency will be assessed and the resulting information will function as a basis for planning of actions.

Emergency information for local and central pollution authorities, fishery authorities and the public in near-by coastal areas.

Emergency management support, including the forecast of spill direction and the continuous monitoring of the oil spill evolution.

6.1 Functionality

The ENVISYS system will contain two main parts: a core system and a set of additional modules. The core system will be of general applicability for all kinds of environmental emergency monitoring based on remote sensing. The additional modules will be application specific.

6.2 The core system

The core system will consist of five modules. Four of the modules will represent different operation types or modes of the system, while the fifth module is a toolbox. The four modes of the system will be:

Monitoring. The objective is to detect and indicate possible environmental emergency situations. Remote sensing data from the geographical area of interest is analyzed as the data enters the system. If a possible emergency is

detected, the remotely sensed data is put into a geographical context and presented to the operator for manual evaluation.
Assessment. If the operator can confirm a possible emergency situation, the system is switched to the assessment mode. The objective of this module is to verify the emergency situation and assess how serious it is. The system integrates geographical, meteorological and ancillary information, and applies GIS & multimedia tools to efficiently inform the operator of the situation assessment.
Information. This module contains an information report generator for the system operator, and the authorities responsible for the verification of the oil-spill and the clean-up operation, the professionals of the interested sectors (tourism, fishing) and the public.
Management. This mode is for management of an operation to reduce or eliminate the emergency situation and its environmental consequences. It includes two-way communication with the field operation and tools for continuous planning of the operation. Among the planning tools is a simulator for different scenarios of the emergency development. The simulator makes it easier to make strategic decisions for operations trying to limit the emergency.
Basic tools. The toolbox contains functions that are used by more than one of the primary modules. This will include at least a geographical information system (GIS), multimedia functions and report generators.

6.3 The application-specific modules

A series of application-specific modules are connected to the core system.
External remote sensing system. ENVISYS is linked to an external remote sensing system. The external system consists of one or more operational remote sensing satellites, a ground station, and possibly a remote sensing data preprocessor.
Emergency detection. The emergency detection module receives remote sensing data from the preprocessor. Image analysis methods are used to screen the data for possible emergency situations.
Data integrator. The data integrator combines other relative information, e.g., wind data from selected meteorological stations and the current location of emergency aircrafts with other data in the system.
Information report generator. This module uses templates to generate recipient specific reports (e.g. to pollution authorities and the general public).
Communication, planning and simulation. This is a set of sub-modules supporting the management module in the core system.

7. Methodology

The ENVISYS project draws heavily on currently existing techniques in processing of radar imagery and in emergency assessment and management systems. In addition, it is totally dependent on the timely availability of such imagery.

In general, all the basic technology necessary to develop ENVISYS exists. Parts of the system can be based on commercially available tools, and other parts can be based on experiments and methods previously developed in related activities. Hence, the main development activity necessary is integration of available methods and techniques.
The methodological approach taken consists of the following steps :

7.1 ***Collection of user requirements***, in particular current practices and problem areas, historical operational data and time related patterns of oil slicks, legal environments and future directions in conformance with national and European directives. This is considered as part of the User Requirements based on the ENVISYS user/partners and also on the ENVISYS User Reference Group (URG) in order to produce the User Requirement Specifications (URS). Also, an assessment of the suitability of the existing work for incorporation in the final system is being conducted. In addition, a detailed report of currently available satellite imagery products shall be produced in relation to the demonstrator sites.

7.2 Given the necessities for satellite imagery collection and processing, as well as the user requirements, a ***detailed system architecture*** is being designed together with the functional specification of each module. It should be noted that the communication requirements (satellite ground station to operator's site) differ from one demonstrator to the other. In addition, the functional design specifications (FDS) allows the incorporation of ready modules, in addition to off-the-shelf tools.

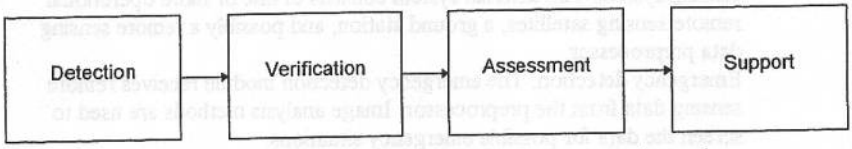


Figure 1: The four main functionalities of ENVISYS. The arrows shows the logical connection of the functionalities, and the direction of the arrows shows the typical processing development

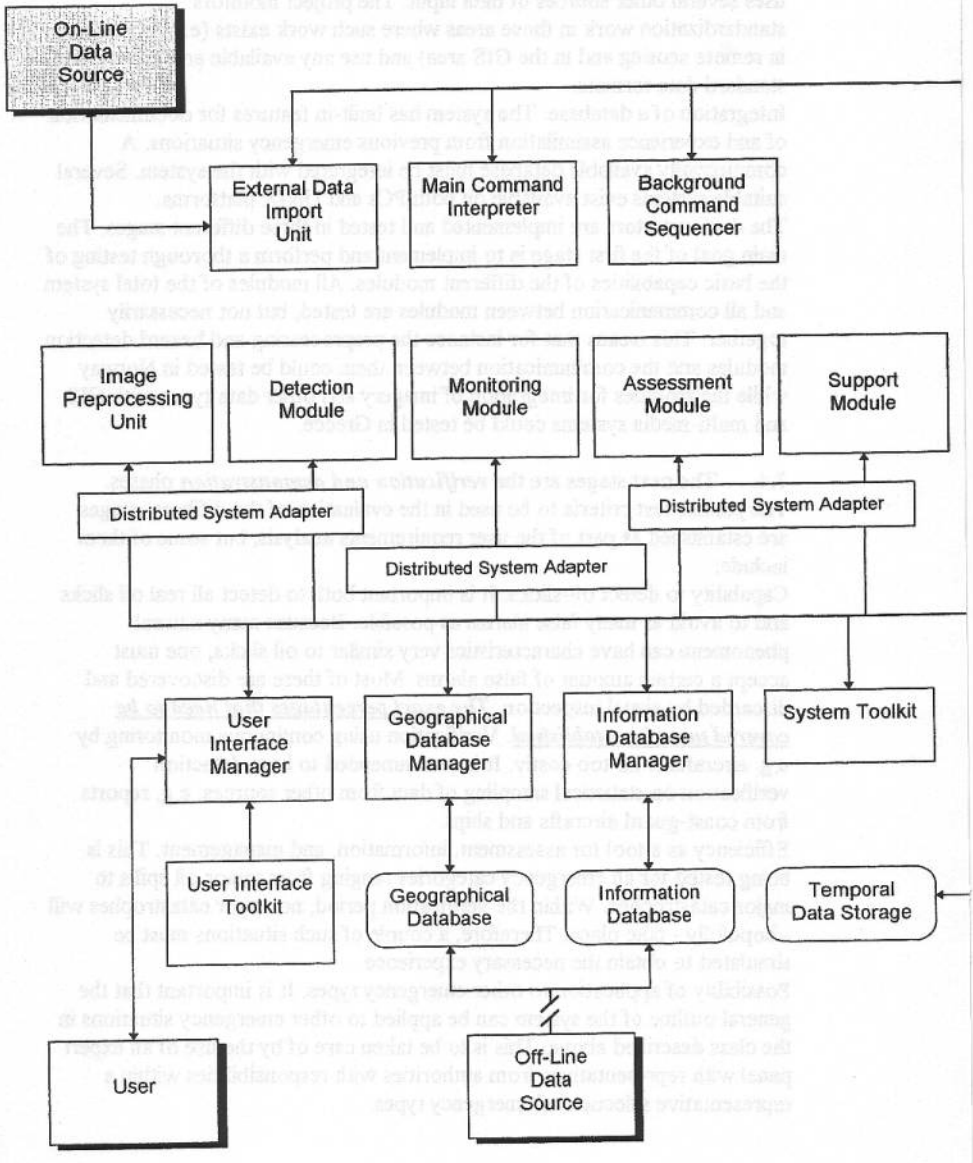
7.3 The next step is the ***Demonstrator implementation***. In this context, the main tasks are the following:
Oil-slick detection. Basic image analysis techniques have been developed for automatic oil-slick detection (Weisteen et al. 1993). However, the current techniques have been tested on a very limited amount of Remote Sensing data. The results were quite good and demonstrated that oil-slick screening is possible, but the results also indicate that the methods must be refined, tested on larger data volumes and made more robust to avoid unnecessary manual inspection.
Integration with GIS. A commercially available GIS tool is an integrated as part of the system. The GIS tool is available on different types of platform

(i.e. PCs and UNIX workstations), and integrated with a window manager suitable for a multi-media environment (e.g. Microsoft Windows or Motif).
Integration of image data and GIS system. The GIS system selected has this facility already built-in.
Integration of other data types. In addition to satellite imagery ENVISYS uses several other sources of data input. The project monitors standardization work in those areas where such work exists (e.g. in imaging, in remote sensing and in the GIS area) and use any available and appropriate standard data formats.
Integration of a database. The system has built-in features for documentation of and experience assimilation from previous emergency situations. A commercially available database must be integrated with the system. Several suitable systems exist available on both PCs and UNIX platforms.
The demonstrators are implemented and tested in three different stages. The main goal of the first stage is to implement and perform a thorough testing of the basic capabilities of the different modules. All modules of the total system and all communication between modules are tested, but not necessarily together. This means that for instance the preprocessing and hazard detection modules and the communication between them could be tested in Norway while the modules for integration of imagery and other data types with GIS and multi-media systems could be tested in Greece.

7.4 The next stages are the ***verification and demonstration*** phases.
The precise test criteria to be used in the evaluation of the different stages are established as part of the user requirements analysis, but some of them include:
Capability to detect oil-slicks. It is important both to detect all real oil slicks and to avoid as many false alarms as possible. Because many natural phenomena can have characteristics very similar to oil slicks, one must accept a certain amount of false alarms. Most of these are discovered and discarded by visual inspection. ***The exact percentages that need to be covered must be established***. Verification using continuous monitoring by e.g. aircrafts is far too costly. It is recommended to base detection verification on statistical sampling of data from other sources, e.g. reports from coast-guard aircrafts and ships.
Efficiency as a tool for assessment, information, and management. This is being tested for all emergency categories ranging from minor oil spills to major catastrophes. Within the verification period, no major catastrophes will - hopefully - take place. Therefore, a couple of such situations must be simulated to obtain the necessary experience.
Possibility of application to other emergency types. It is important that the general outline of the system can be applied to other emergency situations in the class described above. This is to be taken care of by the use of an expert panel with representatives from authorities with responsibilities within a representative selection of emergency types.

User friendliness. This is an extremely important aspect of the system and is taken into account both in learning to use the system and in using it once it is there.

ENVISYS main functional architecture.



8. User Requirements

ENVISYS has developed a pan-European approach towards the user requirements and a specific methodology to support it. The project has initiated contacts with main users, service providers, intermediate interests and the research community in addition to various international cooperations. Within even the first months of the project's life cycle, a list with more than 400 organisations and interested parties has been available for the continuous and future involvement and exploitation of the ENVISYS approach and the Telematics Programme itself. The groups have been stratified, according to their needs and requirements, such as Governmental Bodies, Associations, Ministries, Coast Guards, Civil Authorities, Research Centres, Meteorological Institutes, Environmental and Health Organisations, Pollution Fighting Companies (public and private), Chemical Industries and Associations, Shipping Companies and their Associations, Ports and Terminals, etc. A number of countries such as Spain, United Kingdom, Norway, Sweden, Germany, The Netherlands, Italy, Greece and Malta, have been involved in this process.

The analysis of the current situation within the User Group of the ENVISYS consortium, as well as within the overall User Reference Group, that the project has established, provided the following recommendations:

maximise covering area, using high performance technologies and satellites cartographic support for the detection and the evolution of the spill (use of GIS)

performant telecommunication, for fast alarm triggering and for data transmission

early (near real-time) detection and efficient cleaning-up strategies

information and techniques exchange between organisations and involved countries (collaboration)

legislative harmonisation, needed for penalties for causing sea pollution

flexible and expandable system (i.e. for possible application in other Environmental Emergency situations)

cost effective system

ENVISYS thoroughly investigated the international, European, national and regional legislation, agreements and recommendations in order to provide developments through appropriate frameworks.

It is worthwhile to mention that there are certain developments within the industry which make the ENVISYS approach a well based potential alternative for the near future, by utilizing advanced technologies in a mature fashion. In addition, existing service providers are positively considering ENVISYS integrated management approach, and it is evident, even though premature, that future satellite sensor based systems are being staged within the European space, proving the particular interest of the undertaken approach.

ENVISYS collaboration with the European Space Agency (ESA ESTEC and ESA ESRIN) and the support of the SATEMA project have been

considered valuable for the success of the project, in order to provide a proper response to some of the user needs identified.
The detection of environmental hazards through SAR and other satellite images is still under very careful investigation by a number of scientists in that area, with numerous European, national and regional interests.
ENVISYS does not intend to provide "another new vehicle on the road", but to base its validation on the most sound scientific approaches, utilizing the new technological innovations in this field, as well as in the Telematics field and to provide a generic decision support tool for management of emergency situations.
ENVISYS focuses on oil spills in European waters and on the approaches for different seas which are under careful consideration, based on the prescribed needs. The overall outcome of the ENVISYS project is not only considered to be the detection of the spill, but also the identification of the ship, which illegally generates the spill, in order for the appropriate penalties to be imposed. The near real time ENVISYS tool can lead to the above outcome, since the integrated approach deals also with the proper identification of the ships through the National Competent Authorities (NCA) based on the latest HAZMAT Directive and EUROREP Directive of the Commission.
In addition and in order to satisfy the needs of special geographic areas (protected areas, lagoons, regions of high tourist and fishing interest etc.) the ENVISYS system will provide a risk managing index for all the implicated areas, where the system will be validated.

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