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VIEWPOINT

The Activities of the Italian Coast Guard in the Field of Airborne Remote Sensing and the Eventual Use of Satellite Platforms in Marine Pollution Abatement Activities

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The Italian Coast Guard Corps operates twelve fixed-wing airplanes, type Piaggio P 166 DL3, for the performing of tasks related to the survey of marine environment. Three of them are fully equipped with a remote sensing system.

This system, including a bispectral scanner system Daedalus AA 2000 and a multispectral scanner system Daedalus DS 1268, can make a quick and effective survey both of the shoreline and large areas offshore and process and interpret real time data. Environmental (oil pollution erosion, coastal assessment) and policing purposes (identification and appraisal of illegal releases, prevention and repression of unauthorized building) are supported by such surveys.

Satellite platforms (ERS-1, ERS-2) can be utilized for surveillance duties, although, in the case of operational activities, a comparison with the data available from airborne remote sensing system must be made. The planning of such a programme cannot be carried out without a keen cost–benefit evaluation. © **1997 Elsevier Science Ltd**

Background

The Italian Coast Guard Corps is a branch of the Italian Navy and gives support to the Ministry of Transport and Navigation. It is a highly professional and specialized organization carrying out, besides specific activities of a military nature, maritime policing activities in cooperation with various national Administrations. It operates in the following fields:

- search and rescue at sea;
- environmental protection and response to marine pollution;
- control of harbour traffic;
- harbour security;
- ship security;
- on and offshore maritime policing;
- regulation and surveillance of fishing activities;
- control of the merchant fleet
- control and policing of pleasure craft;
- maritime certificates;
- protection of pipelines and offshore oil platforms in the exclusive economic zone;
- coastal patrol;
- archaeological patrimony and underwater surveillance;
- support to anti-immigration patrols at sea; and
- participation in maritime operations in cases of natural calamity or national emergency.

The Italian Coast Guard deploys a variety of marine

REMOTE SENSING SCANNERS

(a)

- DAEDALUS AADS 1268

	CZCS	ATM
No. of Wavebands	11	11
Spectral Range (μm)	0.42 - 13.0	0.42 - 13.0
IFOV (mrad)	1.25, 2.5, 5.0	1.25, 2.5, 5.0
Focal length (cm)	15.2	15.2
Scan width (°)	86°	86°
Weight (kg)	140	140
Wavebands (μm)	Centre Width 1) 0.443 0.02 2) 0.490 0.02 3) 0.520 0.024 4) 0.560 0.034 5) 0.605 0.05 6) 0.670 0.064 7) 0.765 0.1 8) 0.885 0.11 9 - 11 As ATM	1) 0.42 - 0.45 2) 0.45 - 0.52 3) 0.52 - 0.60 4) 0.605 - 0.625 5) 0.63 - 0.69 6) 0.695 - 0.75 7) 0.76 - 0.90 8) 0.91 - 1.05 9) 1.55 - 1.75 10) 2.08 - 2.35 11) 8.5 - 13.0

(b)

- DAEDALUS AA 2000

	SEA VERSION	LAND VERSION
No. of Wavebands	2	2
Spectral Range (μm)	0.32 - 14.0	3.0 - 14.0
IFOV (mrad)	2.5, 5.0	2.5, 5.0
Focal length (cm)	15.2	15.2
Scan width (°)	87°	87°
Weight (kg)	109	109
Wavebands (μm)	1) 0.32 - 0.38 2) 8.5 - 14.0	1) 3.0 - 5.5 2) 8.5 - 14.0

Fig. 1 Remote sensing scanners.

craft, including 60 long-range vessels, 140 short-range boats with various features, 137 coastal short-range boats and 13 anti-pollution craft. Resources available include 12 fixed-wing patrol aircraft, type Piaggio 166 DL3, and four helicopters, type Augusta AB 412, the number of which is expected to increase to 21 in the future.

Remote Sensing Activities

The evolution of national legislation concerning the protection of the marine environment has made the specific responsibility of the Coast Guard Corps even greater in activities such as the control and abating of man-induced pollution and the management of protected marine environments. For this reason, development within both operational and professional areas of the Coast Guard is necessary and the importance of remote sensing has grown.

Remote sensing can be utilized by the Italian Coast Guard for surveillance of both the marine and coastal

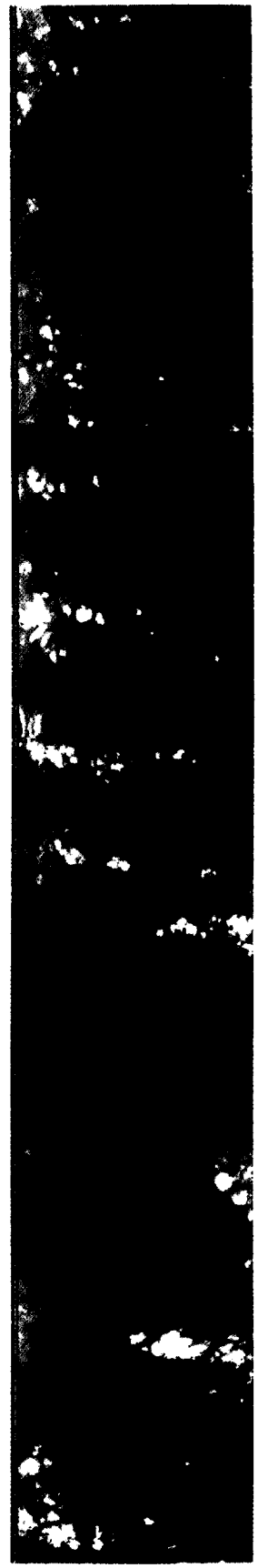

Fig. 2 Daedalus scanner image of the Adriatic Coast, Northern Italy, between Marina Romea and the mouth of the River Po (Volano). In this false colour composite of channels 7–5–3 (red–yellow/green–blue), the visible band does not reveal any important feature on the sea surface, due to cloud cover.

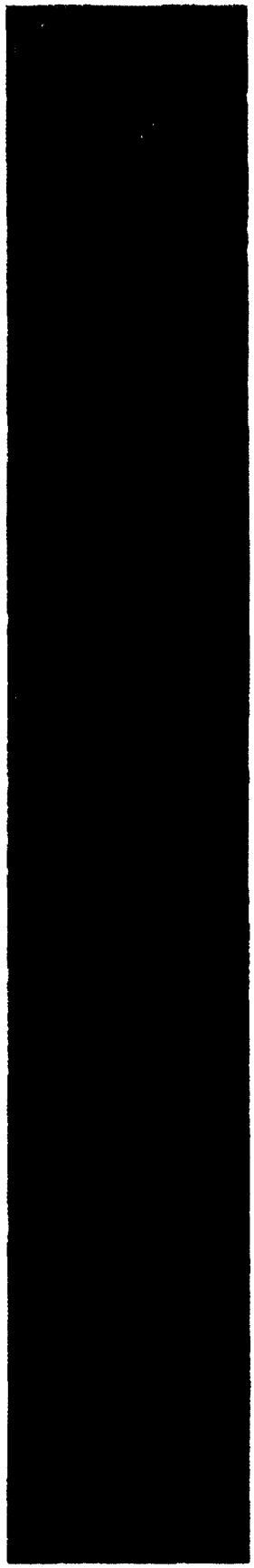

Fig. 3 Thermal infrared image of the Adriatic Coast, Northern Italy, between Marina Romea and mouth of the River Po (Volano). It is a false colour processing of Daedalus scanner, channel 12, data showing marine areas with different temperature. Some of the intensity levels in the spectral response have been cut, to allow easier interpretation of the phenomena. Low temperatures ($< 12°C$) in blue; medium temperatures (12–14°C) in green; high temperatures ($> 14°C$) in red.

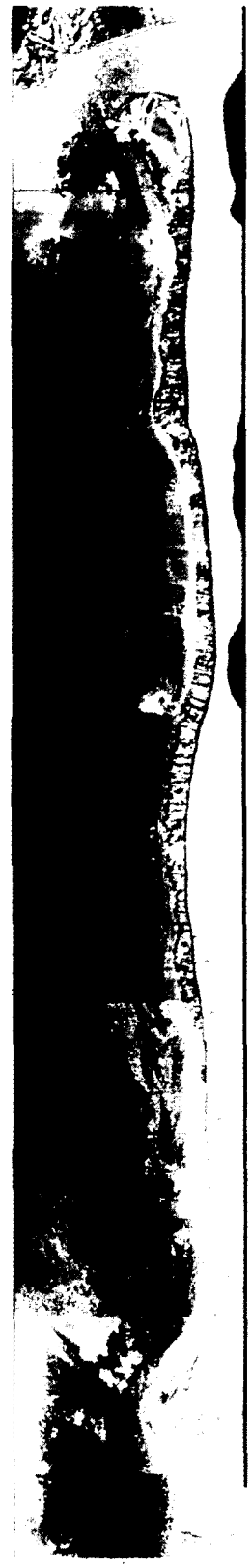

Fig. 4 False colour image of the Adriatic Coast, Northern Italy, between the southern part of the Venice Lagoon (Malamocco) and Chioggia. One can see the island off Pellestrina. Yellow colour filters have been applied to the processing of Daedalus scanner, channels 1 and 11, data in order to evidentiate the presence of hydrocarbons.

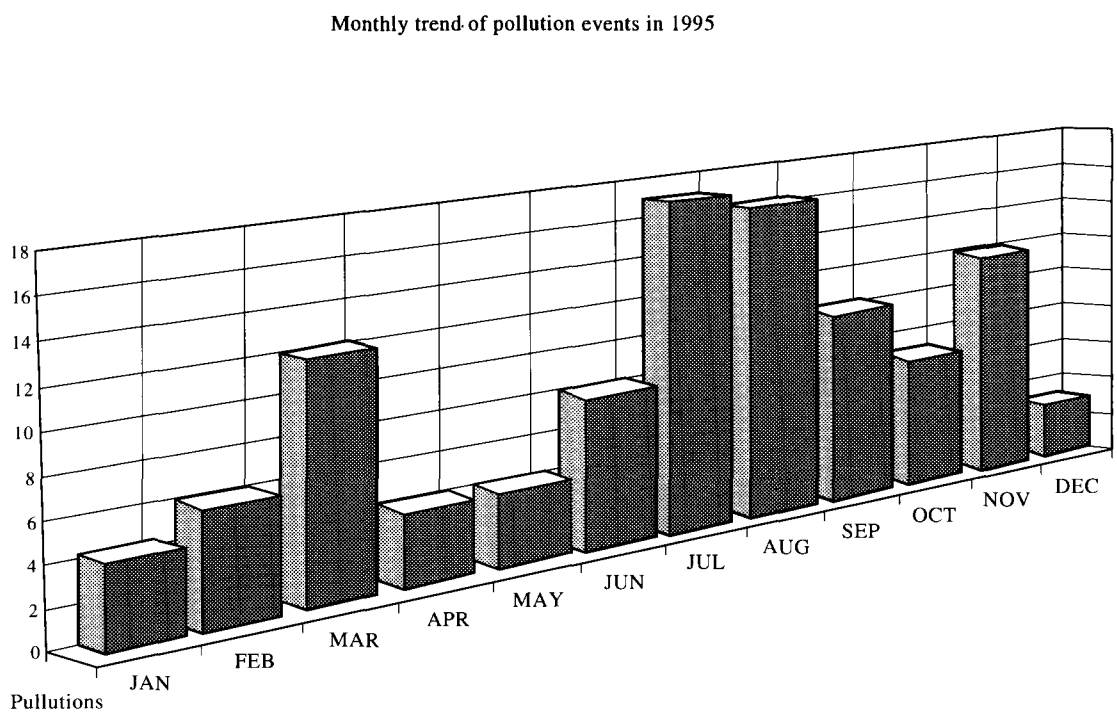

Fig. 5 Monthly trend of pollution events in 1995.

environment, in particular in the following areas of concern:

- ecology (oil pollution detection and sea health);
- geology (erosion, territory set up); and
- policing (control of unlawful waste, prevention and repression of unauthorized building).

Airborne remote sensing

Description of airborne remote sensing system. Fixed-wing aircraft have been equipped with a variety of sensors to perform, at low cost, the rapid monitoring of large marine areas and extended strips of land. The Piaggio 166 DL3 is equipped with:

- **Vinten 618.** An aerial camera system made up of two 70 mm cameras installed on the port side of the aircraft. Their axis are oriented 80° and 40° 30′ in relation with the surface, to allow side-taking and nearly vertical images. The film speed can be selected by the operator in order to cope with the specific task of the mission and with the aircraft speed and altitude.
- **Daedalus DS 1268.** A multispectral scanner system which detects and registers electromagnetic energy emitted by earth; it works on 12 recording channels which split up the electromagnetic spectrum into 12 intervals in the visible, near infrared and thermal infrared. Imagery is digitized on high density magnetic tapes, then converted into CCT tapes to

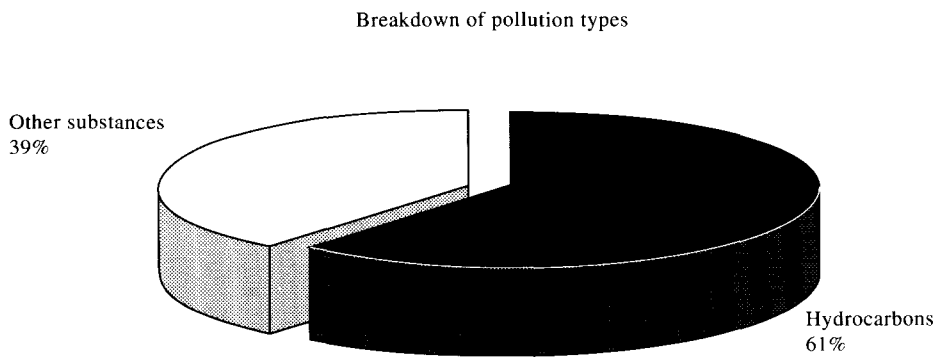

Fig. 6 Breakdown of pollution types.

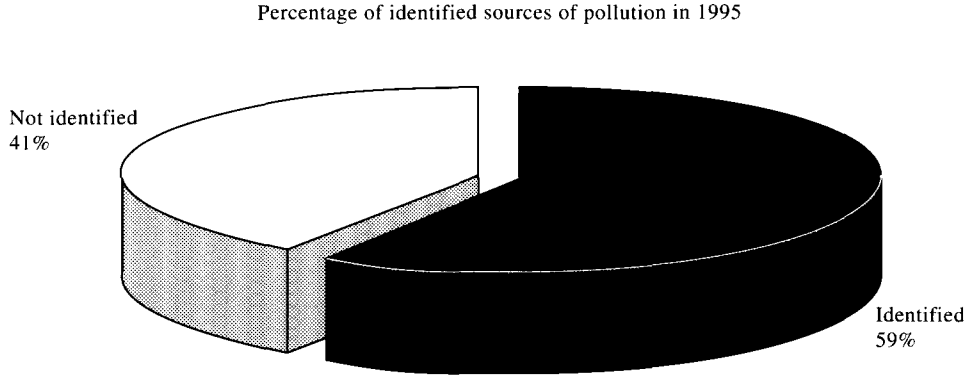

Fig. 7 Percentage of identified sources of pollution in 1995.

be processed by special software for the utilization of the required information. The processed imagery shows, in false colours, some physical parameters (temperature, radiance, reflectance) and gives the opportunity to analyse the features of the observed sea stretch.

- **Daedalus AA 2000**. A bispectral scanner system which works on two channels in the infrared and ultraviolet bands, with a 86° digitized field of view and a 5 mrad geometric resolution. It was especially designed for the surveillance of coastal zones affected by oil spill pollution. Oil slicks can be detected easily thanks to their high reflectance in the ultraviolet band. Also, a difference of emissivity between adjacent healthy and polluted surfaces can be seen in the infrared band. Daedalus AA 2000, in contrast to Daedalus 1268, was not intended to perform the digitization of imagery; it produces a hard copy image directly onboard (Fig. 1).

The remote sensing service—S.T.A.I. (Servizio di Telelevamento Ambientale e Istituzionale). For the rational use of remote sensing systems, the S.T.A.I. (remote sensing service) was established at the Italian Coast Guard Headquarters. This service arranges and schedules remote sensing missions carried out by Coast Guard aircraft and processes and reads the data which are the source of important information for the defence of the marine environment and the surveillance of all activities in- and offshore.

In addition to the above, S.T.A.I. is responsible for the standardization of remote sensing procedures, operational issues and the familiarization of airborne teams with procedures to maintain the efficiency of equipment and sensors.

A number of missions have been managed by S.T.A.I. in co-operation with the Civil Protection Department and the Ministry of Environment. In November 1994, when floods affected the Po Delta, the processing of imagery acquired by the Daedalus 1268 produced relevant information about both agricultural crops and built-up areas and about warp shifting due to tides in proximity to the shoreline (Figs 2 and 3).

In December 1995, in co-operation with the Ministry of Environnent, Coast Guard aircraft monitored the Lagoon of Venice, from Malamocco harbour to Chioggia harbour for an evaluation of the effects of oil pollution originating from a break in a pipeline. Data processing showed the spreading and the thickness of the oil slick and proved to be a valid tool for the allocation of anti-pollution resources coordinated by the Harbour Masters Authority of Venice (Fig. 4).

Coastal environmental monitoring programme using combined airborne/satellite platform data

The Italian Coast Guard, in co-operation with the Aerospace Engineering Department of La Sapienza University in Rome, are directing an experimental project incorporating airborne and satellite remote sensing for the monitoring of the sea surface close to the Italian coastline. The project is giving encouraging results, despite some bureaucratic obstacles.

The programme is based on data collected by the ERS satellites' SAR sensors (synthetic aperture radar) and imagery acquired by the airborne remote sensing system Daedalus AA 2000 and DS 1268 installed on board Italian Coast Guard aircraft.

The programme consists of:

- periodic surveys by Italian Coast Guard aircraft equipped with a remote sensing system, for the evaluation of coastal water quality and the detection of pollution in marine waters;
- the implementation of systematic detection of potential oil slicks by SAR sensors mounted on the

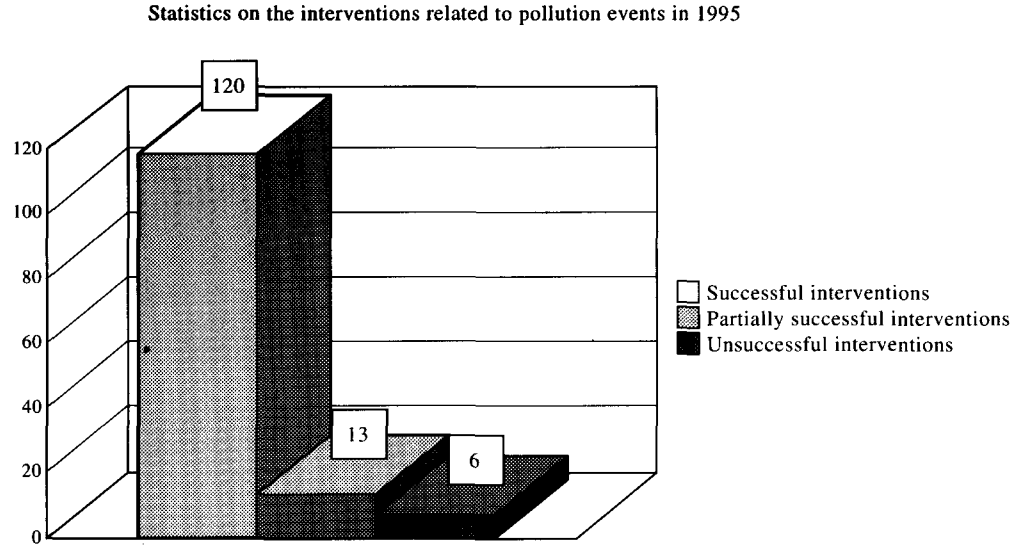

Fig. 8 Statistics on the interventions related to pollution events in 1995.

ERS satellites (through the study of quick look images available shortly after the satellite pass);

- *in situ* missions by Coast Guard aircraft and marine craft aimed at a detailed analysis of waters affected by possible oil slicks detected from ERS satellite quick look images (Figs 5, 6, 7 and 8).

Periodic aircraft surveys

Coast Guard aircraft equipped with sensors are particularly useful for periodic missions (for example, twice a year, to collect data before summer and in autumn) for the evaluation of coastal water quality. Calibrated algorithms, from a previous algorithms calibration mission, may be used in order to estimate the presence of chlorophyll. suspended sediments and suspended organic particles. These surveys can detect waste water discharges by means of the Daedalus AA DS 1268 CZCS sensors in the thermic infrared band.

In the first year of the programme, with development at an experimental stage, surveys are aimed only at the monitoring of chlorophyll α along the Italian coastline. In the future, surveys are to be carried out for the evaluation of organic particles (this second stage needs a calibration campaign of water quality parameters).

Systematic utilization of ERS satellite remote sensing information for oil slick detection and support of* in situ *missions

In the near future the operation of an ERS imagery acquisition system with a quick look delivery system is envisaged for the Italian Coast Guard. It would be similar to the operational marine pollution monitoring system established by the Norwegian Coast Guard.

Based on a delivery of ERS data with 3 h of acquisition, the system could process and make available in almost real time quick look imagery of the observed sea surface with a resolution below 100 metres for the stretch of sea observed. Immediately after the quick look is generated an analysis would be performed in order to verify the existence of oil slicks corresponding to dark areas in the image.

In the system configuration described above the operational stage starts whenever a potential oil slick is detected at sea. When this occurs an aircraft, type P 166 DL3, is assigned to verify the presence of pollution in the area suggested and perform a better evaluation of the slick *in situ*, for its abatement. Being able to rely on the Daedalus AA 2000 UW/IR is of great advantage. As soon as an oil slick is detected, the information is immediately released to the specialized staff on board the aircraft.

In the case of low ceilings the aircraft has to fly at lower altitude to check for the presence of pollution. The use of satellite SAR information is vital in this situation, as it is not dependent on weather conditions and can direct the aircraft to where potential pollution has been detected and needs to be verified.

In the event of an ascertained oil spill, updated information on its evolution is required continuously to enable a prompt response time and to modify strategies as the emergency develops. The spread of oil in the sea depends largely both on weather conditions and different external dynamic agents, and on the specific components of each single hydrocarbon. In addition, experience shows that even the most elaborate mathematical forecast models, need confirmation through a continuous and systematic monitoring of the scenario.

Further satellite imagery acquisition can track the shifting of slicks for many days and shows the full extent of the coastal waters affected. It can also enable the Coast Guard to control the dispersal of a slick on a scale, sufficiently large, to ensure that the entire oil slick has been abated. However, unless satellite platforms are available for the monitoring of the affected area within restricted time parameters (such as a revisit time of less than 12 h), the optimal surveillance is provided by aircraft equipped with radar and optic sensors. These considerations are confirmed by the Norwegian experience using a system based on frequent satellite observations.

Conclusions

The satellite and airborne coastal monitoring system described above is based, essentially, on tools and sensors operating presently. It is meant to make a more extensive use of information derived from satellite platforms, but at present is unable to offer a solution to some of the operational constraints that remain:

- infrequent satellite revisiting times;
- lack of satellite electro-optic sensors providing a ground resolution suitable for significant studies of water quality;
- strong disturbance caused to airborne electro-optic sensors by ceilings and fog.

The last difficulty can be overcome, because, thanks to sensors independent cloud cover such as ERS SAR it is possible to direct an aircraft to the area affected by pollution. Water quality evaluation, on the other hand, cannot take place using microwave sensors.

Poor temporal repetitiveness of satellite passes and low ground resolution of satellite electro-optic sensors is a major constraint. The objective to set up an operational, efficient coastal monitoring system in the Mediterranean Basin, capable of detecting oil slicks, to deploy immediately all available resources and eventually to succeed in abating the pollution is difficult to achieve. To be able to do so, an increased frequency in satellite passes would be required, together with an improved information content of the satellite imagery.

The system suggested has to be carefully evaluated in terms of cost–benefits. As a result of a cost–benefits analysis it might be discovered that, presently, satellite imagery is too expensive. A solution could be to benefit from international co-operation, whereby, Mediterranean Basin communities could subscribe to an agreement for mutual utilization of the system. By concentrating the efforts, financial and scientific, of all Mediterranean countries towards the protection of marine environment, the cost of satellite data could be considerably reduced.