# An Intelligent Robot System to Respond to Oil Spills: the EU-MOP Project

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**Abstract**
This paper introduces a new EU research project called EU-MOP, which involves the design and evaluation of an intelligent robot system to respond to oil spills. The paper defines the objectives of the project, presents the underlying concept and discusses some preliminary results.

## 1. Introduction

The purpose of this paper is to present the concept of an intelligent robot system to respond to oil spills, in the context of the so-called EU-MOP project. EU-MOP stands for “Elimination Units for Marine Oil Pollution” and is a research project co-funded by the European Commission, Directorate General for Research and Technological Development, in the context of the 6th Framework Programme. The project started in February of 2005 and has a duration of 3 years. The EU-MOP consortium is coordinated by the National Technical University of Athens (Greece), and also includes as partners the University of Glasgow and Strathclyde (UK), Sirehna S.A. (France), Instituto de Soldadura e Qualidade (Portugal), BMT Ltd (UK), Cetemar S.L. (Spain), Environmental Protection Engineering S.A. (Greece), Aurensis S.L. (Spain), the University of Oxford (UK), Consultrans S.A. (Spain), Bureau Mauric S.A. (France), the Institute of Shipping Economics and Logistics (Germany) and IPA Fraunhofer (Germany).

Although this project is on-going, in this paper we shall present the underlying concept and a few preliminary results. To that effect, the rest of this paper is structured as follows. Section 2 provides some background on the problem. Section 3 describes the objectives of the EU-MOP project. Section 4 discusses oil spill scenarios and statistics and Section 5 talks about operational specifications, preliminary design and robotics. Finally Section 6 outlines future plans.

## 2. Background

Oil pollution, arising either from marine accidents or from routine ship operations, is one of the major problems that threaten the equilibrium of the marine environment. Only estimates can be given on the quantity of oil that finally ends into the sea, from all possible sources (maritime transport, fixed-shore installations etc.). Table 1 gives a picture of oil spills in Europe from 1990 to 2004.

| Year | Number of Spills | | Total Number of Spills | Total Spilled Quantity >7tons (tons) |
|---|---|---|---|---|
| | 7-700 tons | >700 tons | | |
| 1990 | 14 | 5 | 19 | 9,000 |
| 1991 | 7 | 2 | 9 | 147,000 |
| 1992 | 11 | 3 | 14 | 76,900 |
| 1993 | 10 | 3 | 13 | 91,300 |
| 1994 | 9 | 3 | 12 | 47,000 |
| 1995 | 5 | 0 | 5 | 499 |
| 1996 | 3 | 1 | 4 | 73,100 |
| 1997 | 5 | 2 | 7 | 8,210 |
| 1998 | 5 | 1 | 6 | 3430 |
| 1999 | 5 | 3 | 8 | 23,100 |
| 2000 | 2 | 0 | 2 | 550 |
| 2001 | 3 | 1 | 4 | 2640 |
| 2002 | 1 | 1 | 2 | 62,700 |
| 2003 | 2 | 1 | 3 | 1300 |
| 2004 | 2 | 2 | 4 | 10,400 |

**TABLE 1: Number of European spills by size (source: ITOPF, as reported in Vergetis et al. 2005)**

The efforts in protecting the environment after an oil spill (through an anti-spill operation) could cost in billions of euros in cleanup and damage costs and often produce questionable results. The most expensive oil spill in history was the one caused by *Exxon Valdez* (Alaska, 1989). Cleanup alone cost about US$2.5 billion and total costs (including fines, penalties, claims settlements, etc) are estimated at US$9.5 billion. The *Amoco Cadiz* spill in France (1978) reportedly cost about US $282 million, of which about half was for legal fees and accrued interest. Claims are still being processed for the *Erika* spill in France (1999), and are likely to considerably exceed the US$ 180 million which is available under the 1992 Civil Liability (CLC) and Fund Conventions. It is obviously early to accurately estimate the total cost of the *Prestige* oil spill, but it is again likely that it will reach up to hundreds of millions of euros (ABS alone has been sued by the Spanish government for more than US$800 million).

The issues of oil marine pollution and oil spill confrontation have attracted increasing research efforts over the past 25-30 years. The preservation of the marine environment is of extreme importance and therefore all possible dangers-problems that threaten it must be dealt with determination and efficiency. In this context, the MIT Oil Spill Project has contributed significantly in the areas of strategic and tactical planning, that is, through the optimization of an effective anti-pollution network and of tactical and straregic response management (Psaraftis and Ziogas, 1985, Psaraftis et al. 1986). Additionally, innovative structured approaches concerning the causes, the escalation phase and the impact (consequences) of oil spill accidents are in position to enhance the scenario analysis and reveal useful trends and practices that should be dealt with extreme caution. Moreover, the integration of this problem with safety techniques (e.g. fault trees, event trees, risk contribution trees, HAZOP etc) presents the necessary potential to compose an efficient operational framework in terms of danger awareness, spill prevention and adequate pollution confrontation (Ventikos, 2002).

The International Convention on Oil Pollution Preparedness, Response and Co-operation provided a framework for international co-operation for combating major oil pollution incidents and places various obligations on signatories. The mandatory requirements of the Convention include Articles on Oil Pollution Emergency Plans, National and Regional Systems for Preparedness and Response, and International Co-operation in Pollution Response. Also, the European Maritime Safety Agency is very active in this area, and has developed an appropriate Action Plan (EMSA, 2004).

The key factor for efficient clean-up operations is to develop an adequate structure focusing on the confrontation of oil when this is floating into the sea. This means that a well-planned operation should try to confront the oil when this is still into the sea and diminish its possibilities to impact the nearby coasts.

## 3. Objectives of the EU-MOP project

All the above converge to the fact that there is an existing and direct need for a continuous renovation of the relative anti-pollution methodologies and equipment, always striving for the minimization or the elimination of the adverse effects an oil spill has on the environment. Such a goal must be incorporated in all hierarchical levels, taking at the same time all necessary legislative and surveillance measures to prevent the emergence of oil spills in the first place. However, it is an undisputed fact (and something that maritime history repeats explicitly), that as long as oil-carrying vessels sail the seas, tons of oil will eventually end up in the seawater. In effect, and taking into account the increase of oil-related traffic of recent years, (a trend that is expected to continue), efficient operational, *in situ*, techniques that allow for the control and the elimination of observed oil spills, are imperative.

The specific objectives of the EU-MOP concept are to:

1. Develop innovative intelligent robot technologies for oil spill management;
2. Design and set the basic principles of these novel technology devices for oil spill confrontation;
3. Formulate an integrated structure for oil spill management and logistics at both the strategic and tactical levels;
4. Introduce an advanced structure (dissemination) concerning oil pollution response policy.

There are a number of elements concerning this research that make it particularly appealing for the maritime industry and for the environmental balance of the marine environment:

- The research is multidisciplinary and encompasses areas of particular technological innovation. Below are some of the technological challenges involved and possible routes that the research could propose to face them are briefly outlined:

    - *Energy source and propulsion*.
    - *Sensors, electronics and Artificial Intelligence*.
    - *Vessel design*.
    - *Robotics*.
    - *Oil processing*.

- Environmental efficiency and friendliness. The EU-MOPs aim to represent a versatile, efficient, cost-effective, and manageable technique to combat oil spills. They carry no side effects, no dangerous materials on-board and no possibility of harmful action. They would significantly save on the labour costs of cleanup.
- Oil pollution emergency (crisis) management. The project formulates an advanced approach for spill management issues for both the strategic and the tactical level (confrontation, strategic survey, logistics etc). Thus it presents an integrated solution-chain concerning the overall framework for the mobilization and application of anti-pollution means.
- Industrial appeal. The envisioned units will be designed and assessed (proof of concept), assembled from inexpensive materials. This surely makes them, in the long run, an appealing challenge for the industry, since they will be efficient, patentable, and will allow for an adequate profit margin.

In the sections that follow we give a very limited sample of the results of the EU-MOP project thus far, by focusing only on a few of them.

## 4. Oil Spill Scenarios and Statistics

As a baseline for the project, in Morrall et al (2005) a comprehensive overview of the legislative framework and available tools, methodologies and areas of future development for clean-up and oil spill response is presented. In addition, Mamaloukas-Frangoulis (2005) addresses the marine oil spill scenarios that are incorporated in the EU-MOP project. The common characteristics of different oil spills and their respective response operations are grouped into a limited number of scenarios involving the use of EU-MOP units. Scenarios selected have been drafted in order to define, at a preliminary stage, the spectrum of operational demands for the EU-MOP units.

The report in Vergetis et al (2005), draws from a multidimensional list of potential oil spill data sources, such as state maritime authorities, international organizations, EU-MOP partners, and others, highlights and furthermore elaborates on significant pollution related statistical data in order to develop a state-of-the-art baseline regarding operational and strategic aspects of pollution confrontation and control.

We have identified other similar approaches such as the ones originated form ITOPF, Clarksons, EMSA, and others, but to our knowledge none of them achieves the depth of detail or the specific application of risk driven methodologies as it is the case with the above report. Several sources of information have been tapped, including (but not limited to) ITOPF, EMSA, REMPEC, HELCOM, the Bonn Agreement, SASEMAR, ACOPS/MCA on oil spill data, the EU 'Eurowaves' project on wave and other environmental data, and a variety of sources on maritime traffic data. As a result of this analysis, ten (10) priority areas in Europe have been identified and presented under the umbrella of the geographical position of each broader region. Figure 1 depicts these risk areas, superimposed on a map also showing previous oil spill locations, as well as the main oil traffic lanes, ports and refineries in Europe.

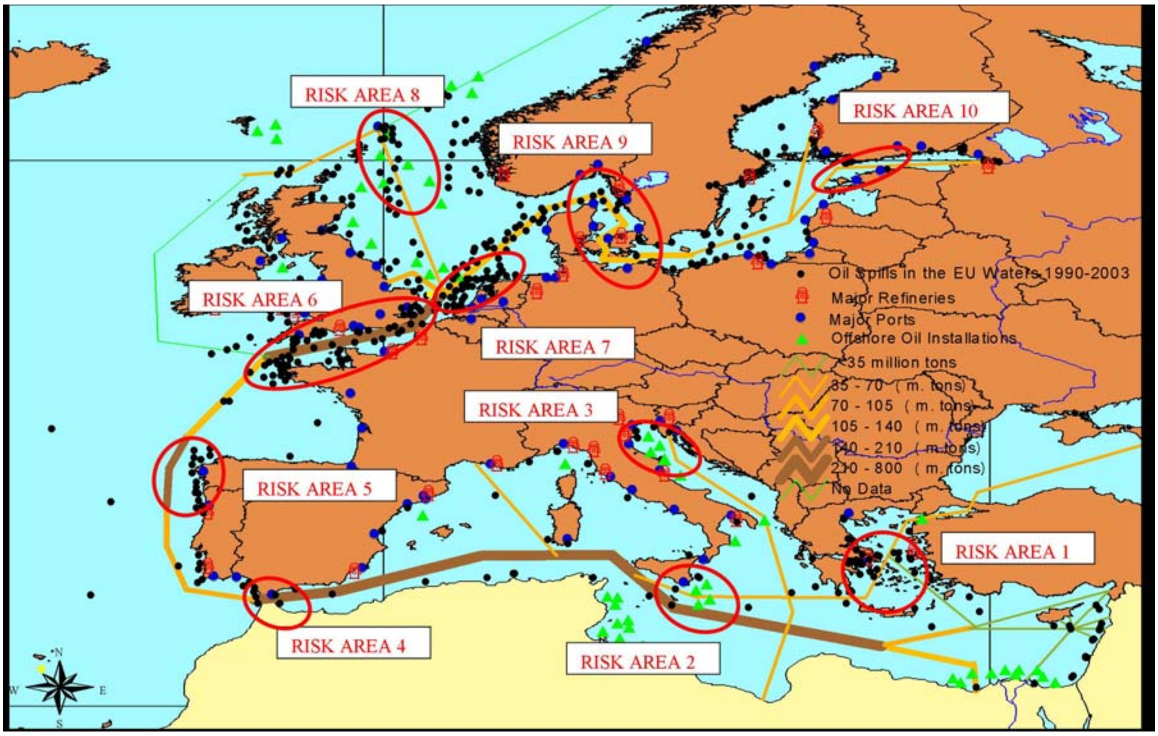


**FIG. 1: European Oil Spill Risk Areas (Vergetis et al., 2005)**

Spcifically, the risk areas are broken down as follows:

<u>Mediterranean Sea</u>
Risk Area 1: **The Aegean Sea**;
Risk Area 2: **The Southern Region of Sicily (Straits of Sicily)**;
Risk Area 3: **The North Adriatic Sea**;
Risk Area 4: **The Straits of Gibraltar**.

<u>Atlantic Front (European Atlantic)</u>
Risk Area 5: **The Galician Coast NW of Spain**;
Risk Area 6: **The English Channel** (e.g. its approaches).

<u>North Sea</u>
Risk Area 7: **Off the Coasts of the Netherlands and Belgium**;

Risk Area 8: **The UKCS and the Area of Offshore Oil & Gas Installations, NE of the UK**.

Baltic Sea

Risk Area 9: **The Kiel Canal & the Entrance to the Baltic Sea**;
Risk Area 10: **The Entrance to Gulf of Finland**.

Sea state and other weather variables are also very important when examined in conjunction with various aspects of oil pollution. For instance, bad weather conditions are a significant causal factor for many marine accidents; many of them leading to oil spills. The break-up of the tanker *'Prestige'* was accelerated by bad weather. Also, the rate at which the oil spreads is strongly determined by the prevailing conditions such as local temperature, water currents, tidal streams and wind speeds. The more severe the conditions are, the more rapid the spreading and breaking up of the oil is. Last but not least, clean-up operations and their success (or failure thereof) are strongly dependent upon weather conditions, especially in the open sea. Some key questions are: (a) is there a connection between the recorded oil spill incidents and the prevailing weather conditions? (b) where and under which environmental conditions (wave height, wind speed, direction, currents, etc) is the EU-MOP concept capable of operating?

With respect to the first question, and even though as noted above bad weather conditions certainly increase the risk of an accident that can lead to oil spillage, none of the oil spill data sources in our disposal had an explicit connection to and adequate explanation of the weather conditions prevailing at the time of the spill. If anything, there was only an oblique (and certainly not fully explained) connection between spill volume and time of the year that the spill occurred, with large spills not likely to occur in the July-September quarter.

With respect to the second question, it is obvious that the sea state and other weather and environmental variables are important for at least the operational specifications and the design criteria of the EU-MOPs. To that effect, a comprehensive statistical analysis of such variables was performed for European waters (see Vergetis et. al (2005) for more details). As an example, Figure 2 shows the seasonal distribution of wave direction (away from shore versus toward the shore) for a point in the Eastern Mediterranean. Knowledge of such information is obviously very important for oil spill contingency planning.

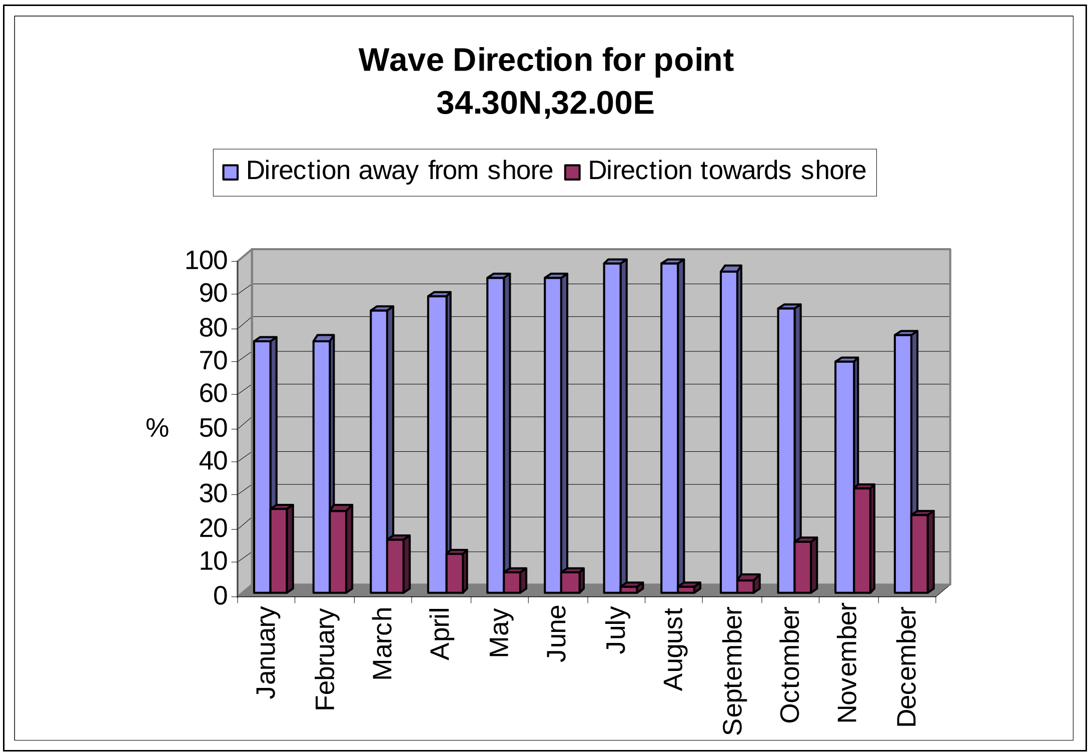


**FIG. 2: Distribution of Wave Direction for Point 34.30N, 32.00E (Vergetis et al., 2005).**

## 5. Operational Specifications, Preliminary Design and Robotics

In Mamaloukas-Frangoulis et al (2005), an EU-wide current inventory regarding marine oil pollution response units and equipment is reviewed, along with a description of the advantages and disadvantages of each type of antipollution equipment in order to point out eventual deficiencies of the existing antipollution systems during clean-up operations.

In Ventikos et al (2005), the necessary operational specifications regarding the adequate development of the EU-MOPs are presented. The report covers specifically important constituents such as artificial intelligence and robotics, and the oil processing properties and capabilities of the proposed units.

In Kakalis et al (2005), a preliminary design of the EU-MOP vessels is presented. Three alternative sizes have been examined, all designed to fit into a standard 20-ft or 40-ft ISO container, to facilitate transportation to the spill site. Their preliminary specifications of the Catamaran version can be summarised in the Table 2 below.

| **EU-MOP** | **Large** | **Medium** | **Small** |
|---|---|---|---|
| Power autonomy (hrs) | 24 | 24 | 24 |
| Transit speed (knots) | 5 | 4 | 3 |
| **Dimensions** | | | |
| Length (m) | 3.00 | 2.00 | 1.00 |
| Height (m) | 1.625 | 1.08 | 0.72 |

| | | | |
|---|---|---|---|
| Width (m) | 2.30 | 1.55 | 0.90 |
| Demi-hull width (m) | 0.66 | 0.44 | 0.22 |
| Draught – fully loaded (m) | 0.93 | 0.62 | 0.31 |
| Hull separation (m) | 1.00 | 0.67 | 0.34 |
| Displacement (tons) | 3.60 | 1.60 | 1.07 |
| **Storage** | | | |
| Storage capacity (m3) | 2.0 | 1.4 | 0.7 |
| Weight (kg) | 1993.2 | 1395.24 | 697.62 |
| **Electronics** | | | |
| Weight (kg) | 20.44 | 20.44 | 20.44 |
| Volume (m3) | 0.06 | 0.06 | 0.06 |
| Power needs (kW) | 0.62 | 0.62 | 0.62 |
| **Oil processing** | | | |
| Brush width (m) | 1 | 0.67 | 0.34 |
| Nominal capacity (m3/hr) | 30 | 20 | 10 |
| Effective capacity (m3/hr) | 27 | 18 | 9 |
| Oil recovery | 95% | 95% | 95% |
| Recovery speed (knots) | 1.0 | 0.7 | 0.4 |
| Weight (kg) | 180 | 120 | 60 |
| Volume (m3) | 2.00 | 1.34 | 0.67 |
| Power needs (kW) | 2.50 | 1.67 | 0.84 |
| **Propulsion** | | | |
| Hull weight (kg) | 150 | 100 | 50 |
| Total weight (kg) | 278 | 180 | 80 |
| Volume (m3) | 0.40 | 0.30 | 0.08 |
| Power at thrust (kW) | 24.08 | 5.42 | 0.96 |
| **Energy system** | | | |
| Power asked (kW) | 27.20 | 7.71 | 1.82 |
| Weight (kg) | 773.10 | 322.48 | 132.85 |
| Volume (m3) | 0.84 | 0.46 | 0.17 |
| **Total requirements** | | | |
| Weight (kg) | 3245 | 2038 | 981 |
| Volume (m3) | 5.3 | 3.6 | 1.6 |
| Power needs (kW) | 27.20 | 7.71 | 1.82 |

**TABLE 2: Preliminary specifications, EU-MOP cataman version (Kakalis et al., 2005).**

In Lemesle et al (2005) alternative Monohull, Catamaran and "Monocat" concepts are further analysed with criteria based on volume, weight, skimming device integration potential, load carrying potential, speed performance, and stability, bearing in mind the given technical requirements.

Last but not least, in Fritsch et al (2005a), a short analysis of the state-of-the-art of robots in marine environments is presented. Afterwards an analysis of the state-of-the-art of sensors for autonomous mobile robots has been conducted. These are sensors for positioning, oil detection, collision detection and avoidance, navigation, communication, and internal status of units. Furthermore, possible sensor systems for these purposes have been identified and sensor configurations have been developed on the basis of the sensor classification matrix. The overall artificial intelligence structure is developed in Fritsch et al (2005b), see also Figure 3.

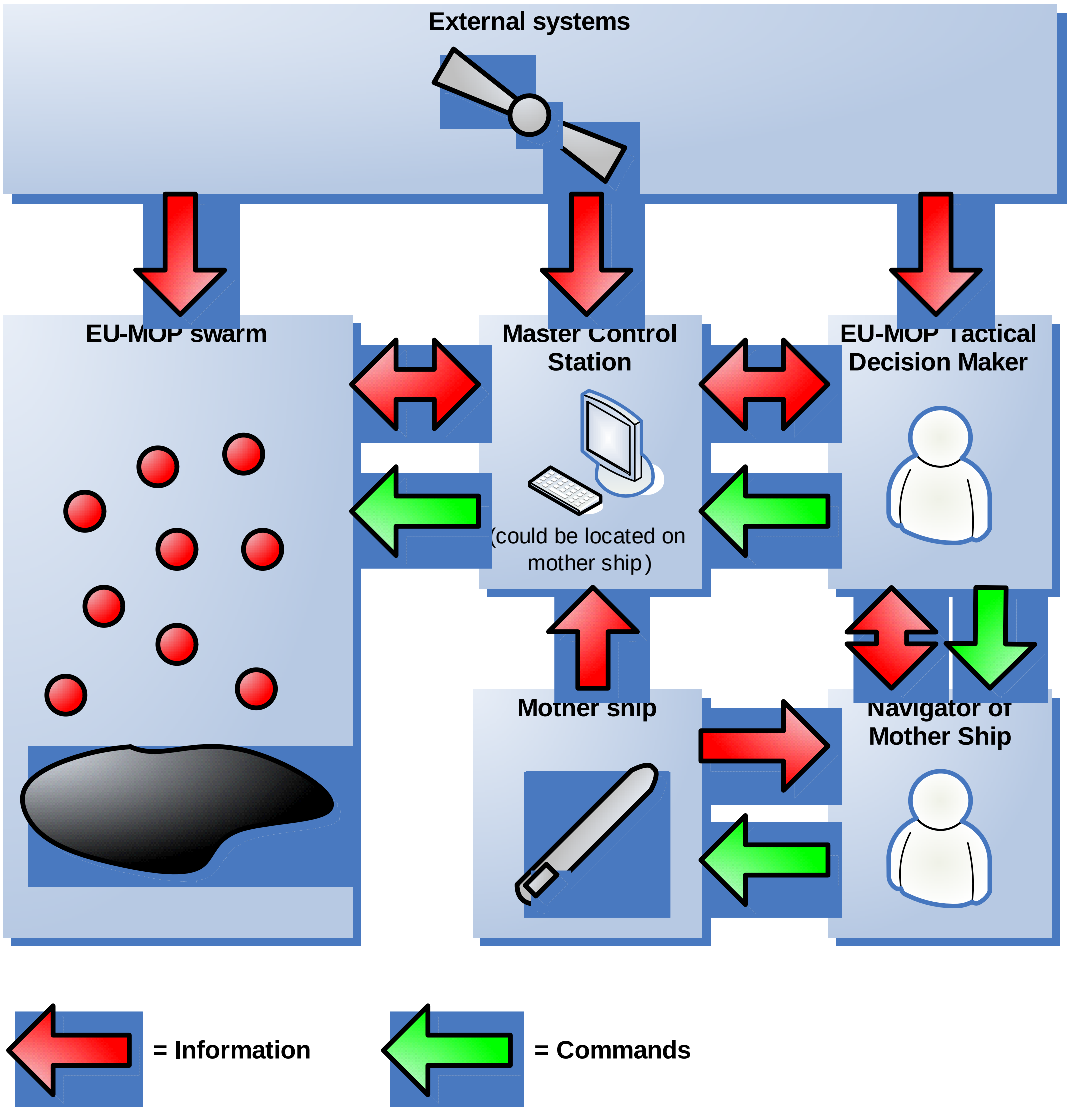


**FIG. 3: EU-MOP Command and Information Flows (Fritsch et al, 2005b).**

**6. Plans ahead**

Work ahead includes further development on the design of the unit, on the artificial intelligence unit, on the oil processing scheme, on cost-benefit analysis and on response logistics at the strategic and tactical levels. With respect to the last issue, the project is formulating an advanced approach for spill management issues, including mobilization, application tactics, strategic management, logistics, etc. Emphasis will also be given on the logistics and support chain of the EU-MOP concept and operation: the implemented logistics and the corresponding techniques are properly assessed in terms of efficiency, functional facilitation and continuous service enhancement. In this way, the emergency response management component will acquire a realistic structure and consequently provide the best possible protection of the marine and coastal environment. Progress on all these issues will be reported in future publications.

## 6. Acknowledgments

Project EU-MOP (contract no. TST4-CT-2004-516221) is funded in part from the European Commission, Directorate General RTD. The contribution of all EU-MOP partners is gratefully acknowledged.

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