EUROPEAN COMMISSION
D G III INDUSTRY

INDUSTRIAL RTD PROJECT 20874

REMOTE MAINTENANCE for FACILITY EXPLOITATION

INFORMATION PACKAGE

March 1997

INTRODUCTION

Increasing the competitiveness of the European industry is the main challenge the countries of the European Union have to face up in the late 90's.

Since the world-wide competition is expanding in all domains of industry, managers have to reduce production costs without reducing product quality.

A margin of operation cost reduction exists at the level of asset maintenance in manufacturing and process industries.

Fault diagnostic assistance and preventive maintenance are becoming strategic challenges and many R&D projects in this area are now supported and funded by the European Commission. The REMAFEX project is placed at the core of this challenge.

This information package provides a summary description of the project's contribution to this techno-economical objective.

After a synthesis of the state-of-the-art of typical tools available on the market for maintenance assistance, the maintenance is brought into the framework of the CMMS (Control Maintenance and Technical Management) model.

The REMAFEX approach is described next, in particular the methodological aspects of capturing the industrial needs. Innovative solutions to improve condition based monitoring are proposed.

Then, the R&D work programme and the demonstration of the project expected results are described. The consortium layout and the summary of the contribution of each partner close the paper.

REMAFEX OBJECTIVES

The REMAFEX project (acronym Remote Maintenance for Facilities Exploitation) is a collaborative R&D project supported by the Directorate Industry (DG III) of the European Commission in the framework of the ESPRIT, phase IV (1994-1998) programme.

Launched in February 1996, with a 7 Mecus budget, 50% funded, it has a duration of 3 years.

REMAFEX wants to propose a strategic approach to reducing the load of the corrective and planned maintenance in favour of the predictive and the condition based maintenance. It is a complementing (not competitive) approach to technical solutions for maintenance assistance available on the market.

REMAFEX attempts to define an appropriate methodology for overall modelling of the maintenance activity and to assemble an inventory of industrial needs for the information system dedicated to the maintenance assistance.

The REMAFEX objectives are based on the survey of the state-of-the-art in maintenance management and condition monitoring systems. Starting from an overview of the maintenance needs, REMAFEX is intending to identify what is typically lacking in existing systems.

STATE OF THE ART AND REMAFEX POSITION

Two types of information system addressing maintenance issues are currently available on the market :

- maintenance management systems

- condition monitoring systems

- maintenance management systems

These systems are designed by companies that are either software houses or maintenance services suppliers. Maintenance management systems cover a wide range of functionalities : technical management of assets, finance, spare parts, purchases, resources and maintenance actions scheduling and management, etc ...
They are used to help in planning preventive maintenance programmes which are based on average statistical data related to « normal » equipment rather than « real » equipment. They cannot host real time functions of dynamic monitoring of maintained equipment.
These systems are widespread and REMAFEX as open system will be able to exchange data with them.

- condition monitoring systems

These systems initiate maintenance by monitoring technical aspects of real operating conditions of equipment, by processing physical measurements captured either manually or automatically. Their purpose is early detection of malfunctions and anticipation of failures. Priority is given to equipment protection rather than to preventive maintenance.

Condition monitoring systems are designed to deal with specific types of equipment of which typical physical properties are monitored. Because of the preponderance of mechanical assets, the most known in the process industry are those dedicated to vibration monitoring of rotating machines.

REMAFEX will also be able to exchange data with them.

- REMAFEX position

REMAFEX objective is to create a system which will fill some gaps in maintenance management and condition monitoring systems. Our approach, in comparison with existing products, will start with expressions of user needs and will identify priority functions, develop these functions and assemble them in the REMAFEX foundation platform. Preventive maintenance is considered through needs for diagnostic and decision support, focusing on the most critical equipment of the installation. According to user needs, the REMAFEX platform must be able to :

- host existing condition monitoring systems, regardless of their age,

- integrate specific new functions when these are not available in existing condition monitoring systems,

- co-ordinate the monitoring functions around a knowledge database of the equipment under consideration.

PREVENTIVE MAINTENANCE

Maintenance terminology is included in standards IEC©50 (191) and NFX 060-010. It allows to chart the different maintenance activities as shown in figure 1.

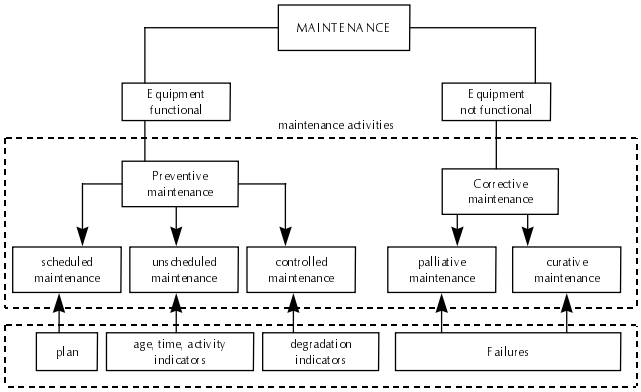

Figure 1 : Maintenance activities and indicators

An efficient maintenance system must include a tool that allows optimising the initiation of maintenance activities in such a way that the operator can anticipate failures and prevent as many of them as possible by just-in-time preventive maintenance actions.

Maintenance-triggering events correspond to more or less complex indicators that must be monitored continuously. Usable types of indicators are the following :

- scheduled maintenance

Maintenance actions are planned in advance according to management decisions : maintenance management system alert, inspection, overhaul, supplier's recommenda-tions,... This is often referred to as calendar-driven maintenance.

- unscheduled maintenance

Maintenance actions are triggered according to the state of an item, which may take into account the time in some ways. Commonly used indicators to monitor the state are :

- age indicators, i.e. the time elapsed since the appearance of a pre-defined event : last tuning, last repair,...
- time indicators, i.e. the accumulated time in which the item is in given conditions : accumulated time in hostile environment, in rotation, ...
- activity indicators, i.e. the number of appearances of a given event : number of starts,...

This is also referred to as predictive maintenance.

- controlled maintenance

Maintenance actions are triggered when some malfunctions are observed.
The target is to minimise preventive maintenance and to reduce corrective maintenance.
Typical indicators are : vibration, bearing overheating, performance degradation,...

This is also referred to as condition based maintenance.

Tools to aid in preventive maintenance must be able to :

. capture automatically the diagnostic measurements and status of critical equipment,

. analyse such data in real time according to the 3 types of indicators listed above, trend and record them,

. supply complementary services to fill in the knowledge database and maintain or even develop the corporate preventive maintenance expertise.

The REMAFEX project aims at developing a data processing platform for to this tool.

FUNCTIONAL ARCHITECTURE OF MAINTENANCE

When considering the set of maintenance activities, it appears a comprehensive information system should be designed at 3 functional levels :

- the first level, dedicated to necessary field data acquisition and short term processing to provide operators with aids for corrective and preventive maintenance. It includes elementary functions as : equipment state monitoring, operator alerts, basic diagnostic aid, support for intervention, ...

- the second level, dedicated to subsequent data exploitation in order to provide a knowledge database in which the corporate expertise is stored. It includes advanced analysis functions and multifunction diagnostic aid. At this level, a data warehouse can be incorporated to provide the company with technical data inquiry facilities.

- the third level, that consists of the maintenance management.

REMAFEX covers levels 1 and 2. The geographical distribution of functions of the 3 levels depends on the organisation of maintenance in the company, as well as on the topology of the installations. So the configuration of the REMAFEX platform must be highly flexible.

CONFORMANCE TO CIM MODEL

The European ESPRIT projects DIAS(EP2172 Distributed Intelligent Actuators and Sensors) and PRIAM (EP6188 Prenormative Requirements for Intelligent Actuation and Measurement) now successfully completed, had dealt with the CIM (Computer Integrated Manufacturing) and have demonstrated the soundness of the CMMS (Control, Maintenance and Technical Management System) model in the manufacturing and process industries.

The CMMS model allows on the one hand to express the overall user needs for a shop floor information and automation system, and on the other hand to design the appropriate functional architecture to cover the control, maintenance and technical management of the installation.

The CMMS model is shown in Figure 2. It is designed on a four levels basis :

- Level 0 includes the process and the I/O devices,
- Level 1 includes automatic processing functions of data captured by level 0 devices,
- Level 2 includes functions that support operators in charge of the installation, respectively the control, the maintenance and the technical management of equipment,
- Level 3 : it includes company's management functions.

REMAFEX wants to deal comprehensively with the maintenance according to the CMMS model, covering in a coherent way the total set of company's needs for maintenance.

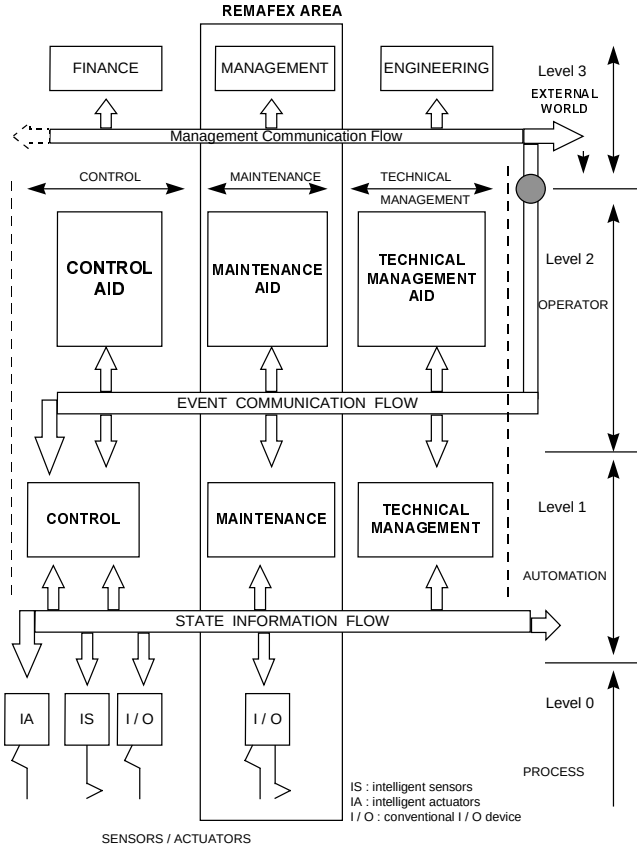

Figure 2 : REMAFEX functional architecture

Figure 3 shows an example of REMAFEX application designed for a typical installation, according to the CMMS model.

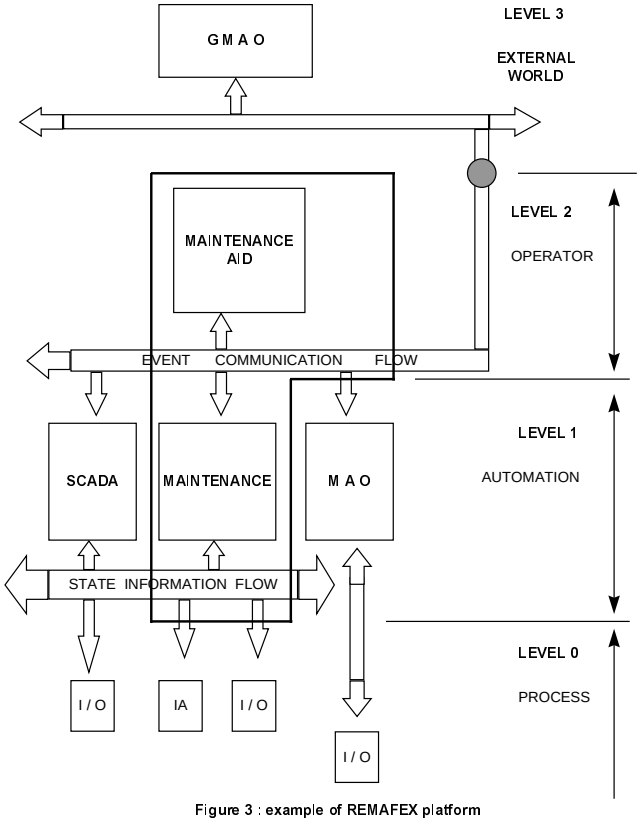

Figure 3 : example of REMAFEX platform

In this example, the REMAFEX application includes existing condition monitoring systems (vibration monitoring) with their own I/O devices and specific functions. REMAFEX and condition monitoring systems exchange data through the Level 2 communication channel. Depending on their required type and performance, functions are incorporated either in level 1 or in level 2.

The (off-line) maintenance management application is separated from the REMAFEX application, through they both can exchange necessary information through the level 3 communication channel.

In this, the REMAFEX concept benefits from the CMMS advantages resulting from the global approach of the whole information system in the CMMS framework :

- the assurance of data consistency among control, maintenance and technical management islands,

- the availability of a technical database at level 2, including real-time and historical data and diagnostic aid functions dedicated to the maintenance.

METHODOLOGY

The objective is to identify the complete set of user needs in a consistent and structured way which an information system dedicated to maintenance must support.
Leading to the objective is an approach which provides users with a methodological framework for expressing their needs.

This approach consists in :

- considering the industrial installation in its external environment,
- studying the installation internally by means of the functional analysis (top down) or the physical architecture (bottom up) to establish a structure in terms of functions, sub-functions, equipment, devices (example : power station, generating unit, turbine, bearing, sensor, ...).
- at each level, identifying all requests to and reports from the maintenance system by using sustained methods (FMEA, risks and costs analysis,...) and a maintenance focus area.

These needs, coherent with the systemic points of view that cover operation, engineering and technology, address :

- the primary maintenance activities that yield directly the final maintenance information (example : faults location, analysis, diagnostic,...) : these are the functional needs,
- the secondary maintenance activities that emerge from the primary ones and are related to the maintenance organisation : these are the non functional needs,
- the constraints imposed on the information system which supports the primary and secondary activities : they characterise each of the functional and non functional needs (validity, performance,...).

The maintenance focus area or the final maintenance reference model, formalises the set of activities and guides the users in expressing their needs.

The users are guided through each activity and asked to follow the links between activities to ensure both consistency and completeness. When this phase is completed, the development cycle will develop the functional architecture, the operational architecture (the REMAFEX platform) and the physical architecture (the REMAFEX platform customised for a field application).

WORK PROGRAMME

To meet the objectives assigned to the project, the work programme includes the following tasks :

- definition of an integral approach to the maintenance activity as an integrated part of the future Intelligent Production System, according to the CIM model,

- modelling of this activity with the support of the methodology described above, according to the corporate strategy both technical and economical,

- expression of user needs for the maintenance information system compatible with the CMMS model,

- gathering of data necessary to help in preventive maintenance of critical equipment which requires continuous monitoring,

- identification and development of innovative diagnostic functions which will be validated on trial installations,

- development of the REMAFEX technical platform by using the best-in-class information technologies available to guarantee both openness and expandability,

- validation and demonstration of the added value of the REMAFEX platform on two industrial installations provided by two consortium partners.

REMAFEX OPENNESS

At the beginning of the project, the consortium partners launched in their own countries a survey into the industrial needs for support for preventive maintenance.

The objective was to capture generic needs in this domain and to select those which will lead to priority developments and integration into the REMAFEX platform.

Among the results of the survey, we identified the necessity to provide users with the following:

- appropriate methodology to identify user needs and to design the system specifications,

- integrated database storing status and trends of equipment behaviour and operator's expertise,

- technical data warehouse with user friendly navigation facilities into technical information,

- flexible hardware (PC) and software (Windows NT) structure so that the REMAFEX configuration could be made according to installation topology,

- open system to plug and play :
  - protocols for data acquisition from existing information systems
  - advanced processing functions (modelling, algorithms, expert systems,...) for diagnostic and decision making.

The REMAFEX platform is to be considered as an umbrella over existing control and condition monitoring systems, which support advanced functions while preserving existing investments.

TRIAL SITES

The functions developed in the project are as generic as possible. However, the intention to validate and to demonstrate the usefulness of the REMAFEX platform on two different industrial sites has led to the selection of pilot sites where the added value of REMAFEX could be demonstrated within the allocated budget limit.

Ideal characteristics of field installations that contribute to the REMAFEX promotion are :

- necessity of networking REMAFEX with existing monitoring and control systems. Interactions between control and maintenance must be possible,

- high level of automation so that both local and remote access to operating conditions of critical equipment is possible and pertinent diagnostic can be made before intervening on site,

- presence of complex machinery that justify the development of advanced diagnostic functions,

- possibility to incorporate into the REMAFEX application the existing condition monitoring systems that can contribute to supply of technical data to the maintenance data warehouse.

Power generation plants and generator units from hydropower plants are well suited to the REMAFEX trials. The two trial sites are :

. Soutelo hydro power plant in Spain,
. France-Covas hydro power plant in Portugal.

EXPANDABILITY AND DISSEMINATION OF PROJECT RESULTS

Power plants and co-generation installations, off-shore platforms and large airports are typical installations of interest to the consortium partners.

Beyond the energy and transport sectors, the expandability of the REMAFEX concept and tools for other industrial sectors (chemical industry, steel manufacturing, paper mills, ...) will be studied by the user reference groups supported by the European Commission.

Intermediate and final results will be described in a tutorial available to the public. It will be also accessible on the WEB site the Commission has created, to help disseminate the results of funded R&D projects.

PARTNERS IN REMAFEX CONSORTIUM

The consortium includes three types of organisations : users, developers and R&D organisations.

USERS

- **IBERDROLA (S)**
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  IBERDROLA is the leading private power utility in Spain. Its principal role in REMAFEX is to identify user needs for power station maintenance, to provide the Soutelo site for pilot application trial and to validate the trial results.

- **E D P (P)**
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  Electricidade de Portugal is the Portuguese enterprise responsible for generation, transmission and distribution of electrical energy. Its main role in REMAFEX is to contribute to identification of user needs, to provide the France-Covas site for pilot application trials and to co-ordinate dissemination of project results.

- **LYON-SATOLAS INTERNATIONAL AIRPORT (F)**
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  LYON INTERNATIONAL AIRPORT is in charge of studying the expandability of the REMAFEX concept and results to critical equipment of large airports.

EUROPEAN COMMISSION

- **DIRECTORATE GENERAL INDUSTRY**

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  The European Commission, represented by the DG III, is in charge of the co-ordination of all applied R&D projects related to the CIM area, to which REMAFEX belongs.

DEVELOPER

- **Sema Group (F)**
  Energy Division
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  Sema Group is the leader in information system integration in Europe. Its first role in REMAFEX is to manage the project. Its second role is the software platform design, prototyping and integration.

R&D ORGANISATIONS

- **E F I (N)**
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  EFI, Norwegian Electric Power Research Institute is part of the SINTEF group. Its principal role in REMAFEX is to develop advanced diagnostic and decision support functions and to study the expandability of the REMAFEX concept and results to oil and gas offshore platforms.

- **CRAN (F)**
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  CRAN, the Laboratory of Automation of the University of Nancy, is in charge of all the methodological aspects of the project, including the documentation supporting the dissemination of REMAFEX results.