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REMOTE MAINTENANCE for FACILITY EXPLOITATION

D E L I V E R A B L E   8 . 2

Maintenance Reference Model: REMAFEX solutions to an expandable DMS Architecture

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CONTENT

1. EXECUTIVE SUMMARY

The REMAFEX project aims at defining and proposing new IT solutions with **Distributed Maintenance System** (DMS) which manages the **global maintenance activity for industrial facilities.**

The **Distributed Maintenance System** has to help maintenance operators to take the right decision at the right place on the right time, by the right people in order to manage continuously all maintenance activities and to replace in a stepwise fashion the current maintenance actions (corrective and scheduled preventive) by more advanced ones (predictive and condition based).

At the end of this project, REMAFEX Consortium can be proud of the work achieved, the results obtained are fully in the line with the expected results.

Project results, documented in different deliverables are today available to the maintenance European Community on the REMAFEX Web-page address:

http://www.gsip.cran.u-nancy.fr/wp9_remafex/index.html.

This deliverable D8.2 is designed to be a guide to new and external maintenance actors (users, vendors, operators):

- to fully understand the REMAFEX results
- to be able to understand the new added value of such REMAFEX results
- to be able to use in the next future the REMAFEX results

This deliverable D8.2 is written to give readers a brief understanding of the REMAFEX concept and REMAFEX results. These readers may be people coming from companies outside the project and from different industry sectors, coming from maintenance groups or maintenance organisations, who want to evaluate if the REMAFEX concept and result also may be a solution to be used in their own company.

The aim of this deliverable is therefore to give the reader a brief understanding and introduction to:

- the current status of **"Maintenance Reference Model"** in section 2.
- what was the **"REMAFEX way of working"** in section 3 in order to move from maintenance user needs to maintenance functions through maintenance reference model.

  This REMAFEX way of working could be fully reusable in external companies

- **REMAFEX Distributed Maintenance System architecture** (section 4) expandable and open.

In section 5, **REMAFEX integration possibilities** are presented. It is very important that potential REMAFEX users analyse REMAFEX integration possibilities towards existing systems in the Control Area and the Technical Management Area.

At last to be consistent the **terminology used in the REMAFEX project** is described and commented in section 6 and is compared to the different European Standardisation work going on in the Maintenance area.

As proposed in the D8.2 **conclusion** (section 7), REMAFEX Consortium wants to promote and to exploit all the REMAFEX works performed during three years, and remains at the disposal of all maintenance actors to helps them to win the maintenance challenge.

This Deliverable D8.2 constitutes the first step to the REMAFEX world-wide use. This Deliverable will be used as such in the exploitation and dissemination strategy of the REMAFEX Consortium.

2. MAINTENANCE REFERENCE MODEL

A reference model is a (partial) model that can be used as a basis for particular model developments or for evaluation of particular models. Very often a reference model is used for comparing something to a reference. It can also be used as a reference to derive particular models from predefined models. For instance, a prefabricated or standard model accepted by all interested parties is a reference model.[1]

2.1. WHAT DO YOU MEAN BY A REFERENCE MODEL ?

In that way, one REMAFEX objective is to formalise a **Maintenance Reference** composed of different **reference models** (activities, information i.e.) and which can be used as a common basis to support all the phases and to ensure the consistency of the REMAFEX approach (**repository of the REMAFEX way of working**).

The Maintenance Reference, accepted by all the partners, consists in identifying the Maintenance as a part of the global Enterprise activity, and in integrating it with the other islands. Indeed in relation to the Enterprise architectures and more precisely the CIMOSA[2] one, the Maintenance activity has to be considered first as one Enterprise Domain having as objective or expected achievement to retain or to restore through time manufacturing resources, and has to be described second as a part of the Enterprise at the shop floor level integrated with the Control and Technical Management Domains : the CMMS concept.

This Maintenance Reference, upgraded all along the project by taking into account the return of experiences, is based on Maintenance current partial models. Such models may be Information Model for Maintenance Management[3], Integrated Maintenance Information System, Integrated Diagnostic System[4], specific database model[5] mainly focused on the maintenance management, and definitions proposed by standard[6] and academic people.

The main result through the Maintenance Reference is to offer to the external Maintenance World, a **generic validated Framework** of what the maintenance is in general in order to be used for the development of Plant Maintenance system (in general) or for the creation of particular models (turbine, generator, i.e.) basis for the development of specific Maintenance systems.

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[1] F.B. Vernadat, *Enterprise Modelling and Integration : Principles and Applications*, Ed. Chapman & Hall, ISBN0412605503, UK, 1996.
[2] Proceedings of the workshop on Process Modelling for Enterprise Integration with CIMOSA. CIM-OSA association. University of technology in Loughborough, UK, March 1996.
[3] Smit K. and W.H. Slaterus, *Information Model for Maintenance Management*, Ed. Cap Gemini Publishing BV, 1992.
[4] Wylie, R., R. Orchard, M. Halasz, and F. Dubé, *IDS: Improving aircraft fleet maintenance*. Proceedings of the 14th National Conference on Artificial Intelligence and Innovative Applications of Artificial Intelligence (IAAI-97), Providence, RI. July 27-31,1997
[5] Okogbaa G., J. Huang and R.L. Shell, *Database Design for Predictive Preventive Maintenance System of Automated Manufacturing System*, Computers and Industrial Engineering, volume 23, n° 1-4, pp. 7-10, 1992.
[6] IEC-50(191) International Electrotechnical Vocabulary - Chapter 191 “Dependability and quality of service”

2.2. SPECIFICATION IN THE MODEL: WHAT IS THE MAINTENANCE REFERENCE ?

The formalising of the Maintenance Domain in terms of activities given rise to the **Maintenance Focus Area**[7] (MFA, figure 2.2.a): a **Maintenance Activities Reference Model**, which is a **activity-based repository** allowing to assist the user and the vendor in the maintenance system specification, development and implementation.

The MFA is composed of Domain Processes[8], Business Processes, and Enterprise Activities of the Maintenance Domain. These Domain Processes are :

- The **Philosophy and Strategy** domain process aims at defining the philosophy and the strategies which are the basis for the global maintenance activities.
- The **Management** domain process aims at managing all the maintenance activities and information required for the maintenance system activity.
- The **Supervision/Monitoring** domain process aims at observing the state of an item, performed either manually or automatically.
- The **Fault and Degradation Diagnosis** domain process aims at recognising and at localising the faulty item, and at identifying the cause.
- The **Forecasting/Prognosis** domain process aims at forecasting the state, fault or degradation of the system.
- The **Fault and Degradation Correction** domain process aims at restoring the ability of the faulty system to perform a required function before or after a failure or a degradation.
- The **Fault and Degradation Compensation** domain process aims at forcing the system in a specific state or situation before or after a failure or a degradation, without restoring the ability of the faulty item.
- The **Analysis and Decision** domain process aims at analysing the present state of the system, and make decisions for future maintenance actions to be applied to the system.
- The **Field Execution** domain process aims at gathering and at validating the process data.
- The **Quality Assurance** domain process aims at evaluating all maintenance activities.
- The **Evaluation** domain process aims at evaluating results related to objectives, i.e. regarding performance, cost etc.

[7] J.B. Leger, B. Iung, A. Ferro de Beca, J. Pinoteau, *A new approach of Distributed Maintenance System : the REMAFEX way of Working*, Proceedings of ASI97 (ICIMS-NOE EP III-9251), pp 408-419, Budapest, Hungary, July 14-17, 1997

[8] *Each Domain is made of a non-empty set of Resources and Domain Processes processing real-world objects and a Domain Process is composed of a hierarchy of Business Processes and Enterprise Activities (Process/Activity/Operation) leading to a network of Enterprise Activities interconnected by Procedural Rules.*

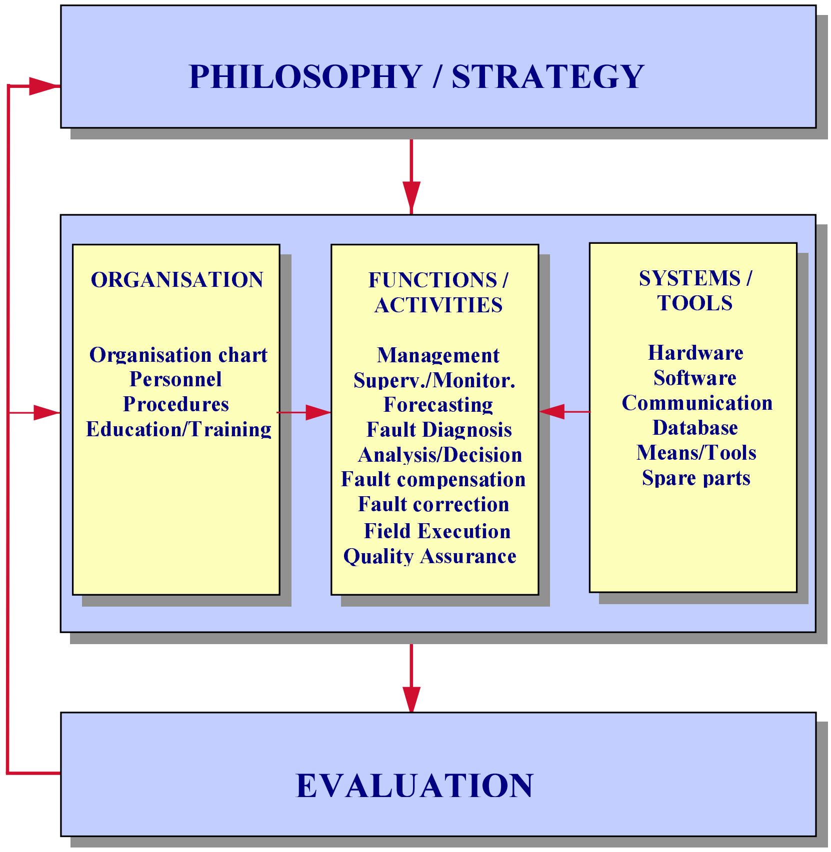

Fig. 2.2.a: Maintenance Focus Area

To complete the activity view, the objects of the Maintenance knowledge and processed by the activities, have to be captured inside an **information-based repository** (**Maintenance Information Reference Model**). Such a model is an improvement of the current models like VOICE[9] in order to take particularly into account the predictive maintenance objectives (Monitoring, Diagnosis, Prognosis) by introducing new entities and relationships such as failure modes, symptoms, alarms and causes (figure 2.2.b).

[9] Proceedings of the VOICE OPEN WORKSHOP, Berlin (Germany), 14 September 1993

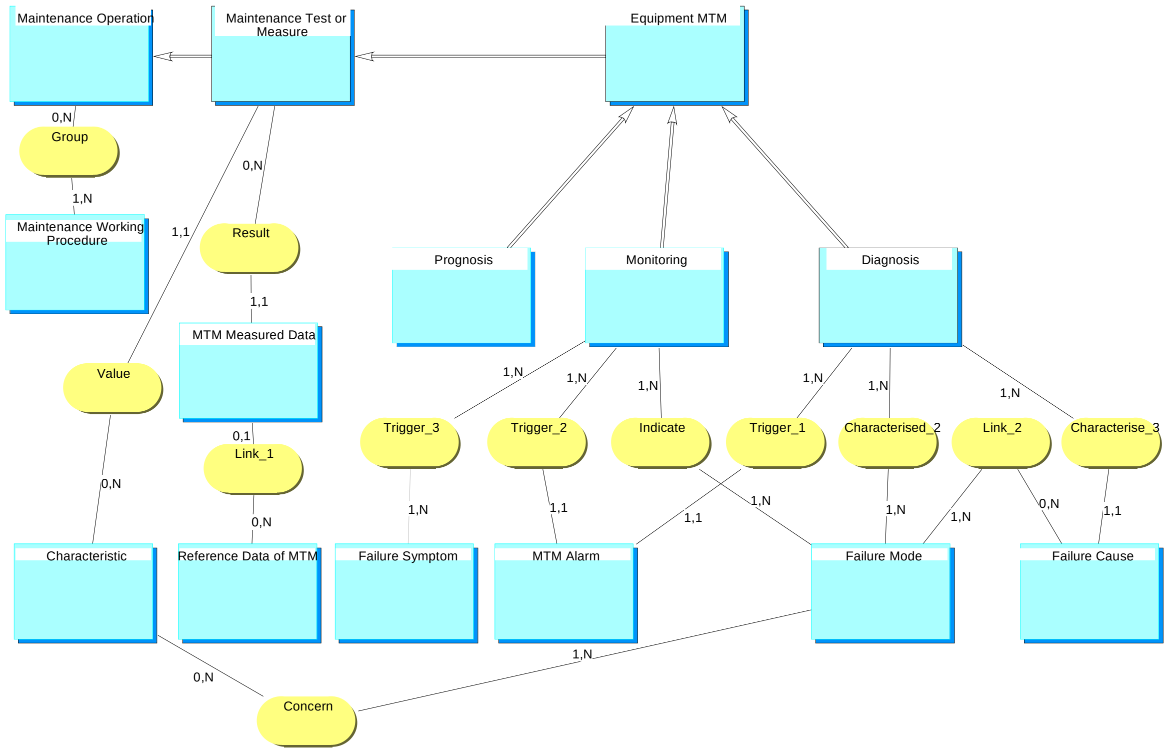

Fig. 2.2.b: Part of maintenance information reference model integrating predictive concept

These two previous information and activity reference models constitute the basis of the Maintenance Reference developed in REMAFEX.

So, by using the two Reference Models validated during the project (particularisation procedures), a collaboration with the ESPRIT IV PRIMA project (Process Industries Manufacturing Advantage) n° 20775 has also allowed, focusing more on **the Predictive Maintenance objective**, to formalise a particular reference model for "the equipment monitoring[10]" based on the first PRIMA work (see web-server http://www.prima-europa.com).

This reference model, based on the CIMOSA methodology, has to take into account the whole of the activities of the predictive maintenance sub-domain and the maintenance vocabulary and knowledge. These activities enabling, among other things, to process phases of the life cycle of the failure and degradation, are the **monitoring**, the **diagnostic**, the **behaviour forecasting** and the **effect forecasting**. The model, encapsulating the activities, the object views, the knowledge, ... related to "equipment monitoring", is able from a behaviour monitoring, to detect or to forecast change (normal, abnormal) and to decide maintenance actions in relation to this change (figure 2.2.c).
During this REMAFEX-PRIMA collaboration, the model has been validated by a particularisation procedure to the turbine equipment.

[10] Functional Requirements Definition, Maintenance Domain, Predictive Maintenance, WorkPackage4 Deliverable, PRIMA2 ESPRIT Project 20775, Draft, June 1997

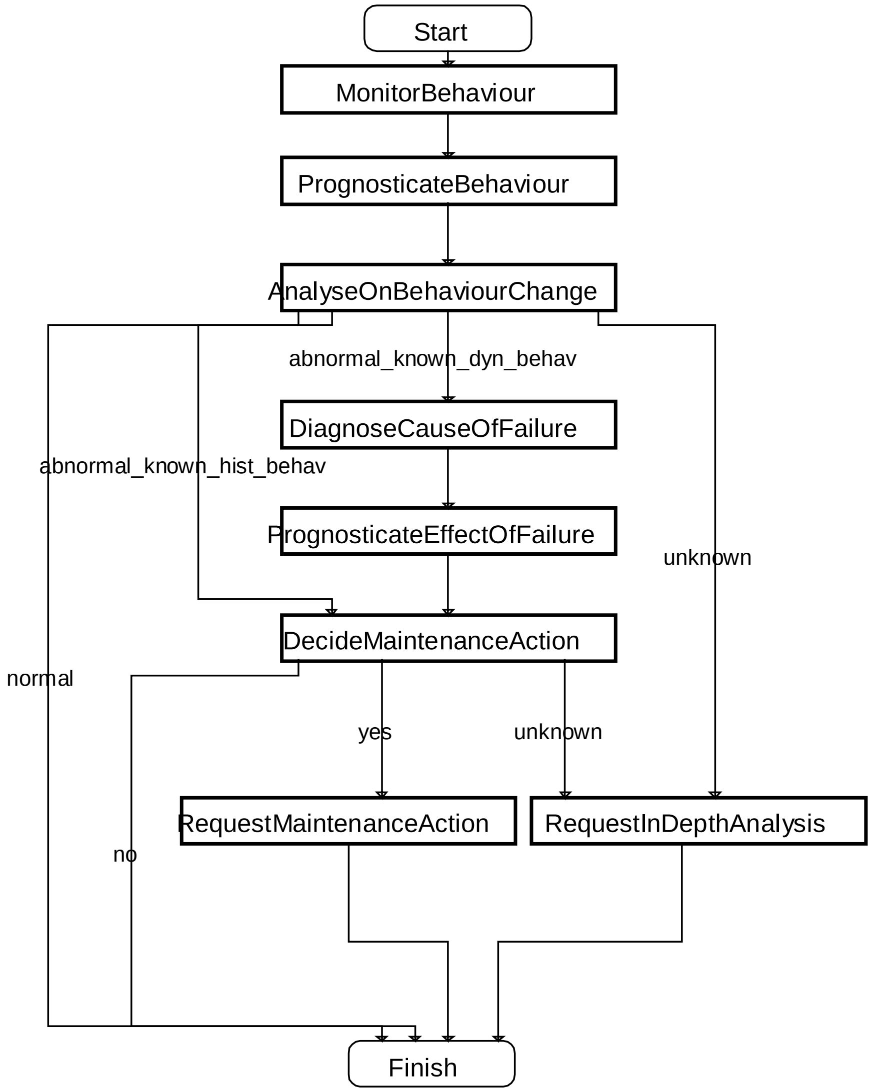

Fig. 2.2.c : PRIMA – REMAFEX predictive maintenance generic model (Activity view)

All these Reference Models have been used as repository to support the REMAFEX way of working.

3. REMAFEX: WAY OF WORKING

REMAFEX Consortium organised in a methodological way how to move from maintenance user needs to maintenance functions by using and through all activities defined in the maintenance reference model.

As reference model this REMAFEX way of working is fully reusable.

3.1. GENERIC METHODOLOGICAL APPROACH AND PRAGMATIC APPROACH

The definition and the implementation of a **Distributed Maintenance System** mainly based on **Information Availability and Integration,** cannot result from a technology assembling but really from a global approach requiring new ways of engineering. That means an **engineering process** allowing the definition of the **Maintenance user requirements** and the mapping **from the users requirements to the technological distributed system** by ensuring that the distributed system satisfies the required integrated user needs.

To meet this goal, one expected result of the REMAFEX project is to define, propose and finalise a **REMAFEX way of working** which has to be considered as a **Guide** (based on Maintenance Reference) for the users and the vendors in the maintenance system specification, development and implementation.

The elementary principles of this REMAFEX way of working, were made out in the beginning of the project. It was based on the consortium maintenance expertise, the current methodological state of the art and the current maintenance and integration work performed outside the REMAFEX project. It gave rise firstly to a **pragmatic approach** to concretely express the Hydraulic Distributed Maintenance System Requirements in terms of needs, functions and data. The limitation to the hydroelectric turbine-generator sets is according to the CEC project contract.

The final REMAFEX way of working analysed the pragmatic approach in order on the one hand to formalise it and to propose a **general methodological approach**: **a Maintenance framework** (based on Maintenance Reference), and the other hand to try to **generalise its results** (**reusable objects** composed of needs, functions, data). The aim was to offer a reusable basis to the expandability works of REMAFEX concept and to the external Maintenance world (other industrial sectors, other organisations).

Therefore the last modelling of the Maintenance Domain in a CMMS context has been referred to a **common model of understanding** (modelling process) based on the systemic principles considering[11](figure 3.1):

- the Maintenance integrated with the Control and the Technical Management because it is impossible to model separately the three islands (integration axis),
- the Maintenance system on the Functional (requirement), Organisational (design) and Operational (implementation) points of view (modelling axis),

[11] Mayer F., G. Morel, B. Iung and J.B. Leger, Integrated Manufacturing System meta-modelling at the shop-floor level, Proceedings of the Advanced Summer Institute - annual conference of the ESPRIT III ICIMS-NOE (n°9251), Toulouse (France), 6-9 June 1996.

- the Maintenance communication, storage and processing at each level of the abstraction axis (system axis).

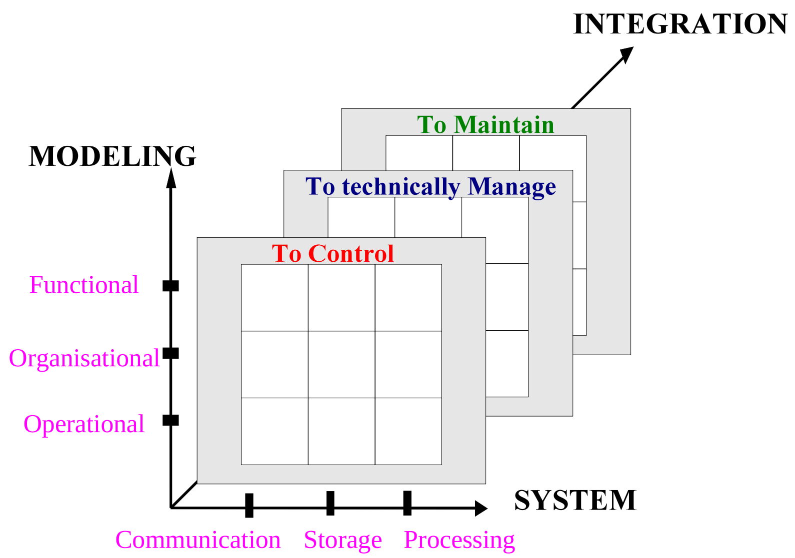

Fig. 3.1: CMMS in the systemic three axis referential

3.2. PHASES AND PRINCIPLES

3.2.1. Identification of the user needs

The REMAFEX way of working has to authorise and/or to implement several means (figure 3.2.1) allowing to identify the users needs from different starting points. This may be the system functional analysis, the system cost and risk analysis, the system structuring, the system documents, the system operation reports, the users background, the maintenance tools and systems state of the art.

From these starting points, the users can express **raw needs** (refer to Deliverable D2.1.) in terms of proprietary requests and reports (waited system services):

- request from the maintenance operator to process to perform its job (e.g. to request the dynamic behaviour of the hydroelectric set in terms of shaft vibration, to request start/stop sequences time, to request the condition of stator winding insulation, ...),

- report to the maintenance operator from the process to allow the maintenance actions or information(e.g. to report the causes of the cooling system degradation, to report the turbine performance, ...).

Then the raw user needs, more dedicated in REMAFEX to Predictive Maintenance, are necessary constrained by:

- the system structuring to define needs at each **component and sub-component** levels to ensure a degree of reusability and generic term to the needs,

- the MFA to obtain an **exhaustive definition** related to the different maintenance tasks and objectives. Moreover the MFA allows to implement a convergence between all the different starting points.

The raw user needs have to be characterised in relation to a list of attributes in order to obtain a consistent and common basis for the functions and data definitions. These attributes are typically: a title, a type, an Engineering Unit, a Finality, a Persistence, a Procedure Description, a Link, an Agent-Location, a connection, a Constraint, a Priority and a Label.

The users needs can be also formalised by fulfilling the Maintenance Information Reference Model (refer to chapter "reference model) because each request and report will create occurrences of entities and of relationships.

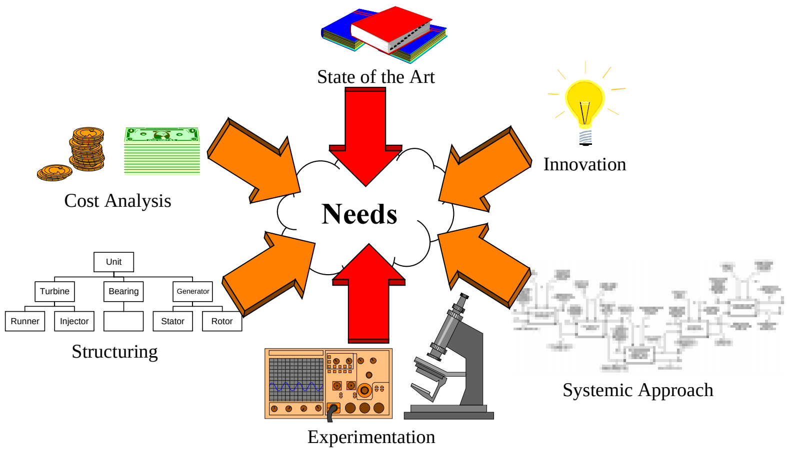

Fig. 3.2.1: A need in relation to what ?

Therefore, the starting points represent different models of the system knowledge that the way of working must **integrate** to obtain a consistent and pertinent identification of the needs. They can be classified as "a posteriori" knowledge (pragmatic approach) based on the system state of the art and return of experience. Alternately as "a priori" knowledge implying to analyse the system in relation to usual methodologies in order to lead to Maintenance needs (to solve or forecast the "dis-functioning") from the normal system functioning.

For example, an "a priori" knowledge has been extracted in REMAFEX on airport components by following the procedure: functional analysis (SADT method), study of the function flow variation (HAZOP method) then study of the failure modes linked to the function (FMEA method).

As the REMAFEX framework is totally open, the operator can use the approach most adapted to his problem and why not mix the different ones. Whatever the approach, the user needs definition has to be considered as necessary to move from the corrective Maintenance to the preventive one.

3.2.2. Identification and specification of functions

After the user needs identification, it is necessary to define functions (not existing), to find or to improve (existing), functions which will allow to satisfy these needs. This phase is a co-operation between the users and the vendors in order to go from a functioning point of view to a development one (different steps of functions: from user functions to vendor ones). In this way, Figure 3.2.2 shows the logical diagram for the analysis of identified REMAFEX functions ability to satisfy expressed user needs. According to the agreed definition, a REMAFEX function must totally or partially satisfy a user need (or needs). The new functions must be feasible and necessary input data must be available if the functions are expected to meet user needs.

The logical diagram consists of six main steps:

- Does an identified function already exist that satisfy the user need?
  1. If Yes, and necessary data is available, an existing function can be integrated into the REMAFEX platform.
  2. If No, the identified function must be analysed and specified in order to find out if the identified new function is feasible and can be integrated into the IT platform.

This function analysis and specification phase is essential in order to perform the next steps (feasibility and data availability).

- Is the new function feasible?
  3. If No, the new function can not be developed, and the expressed user need is not satisfied.
  4. If Yes, the data requirements of the new function must be analysed.

- Are data available (data necessary to fulfil the function) ?
  5. If No, the new function should not be developed and the expressed user need is not satisfied.
  6. If Yes, the new REMAFEX function can be developed and the expressed user need can be satisfied.

Identified functions :

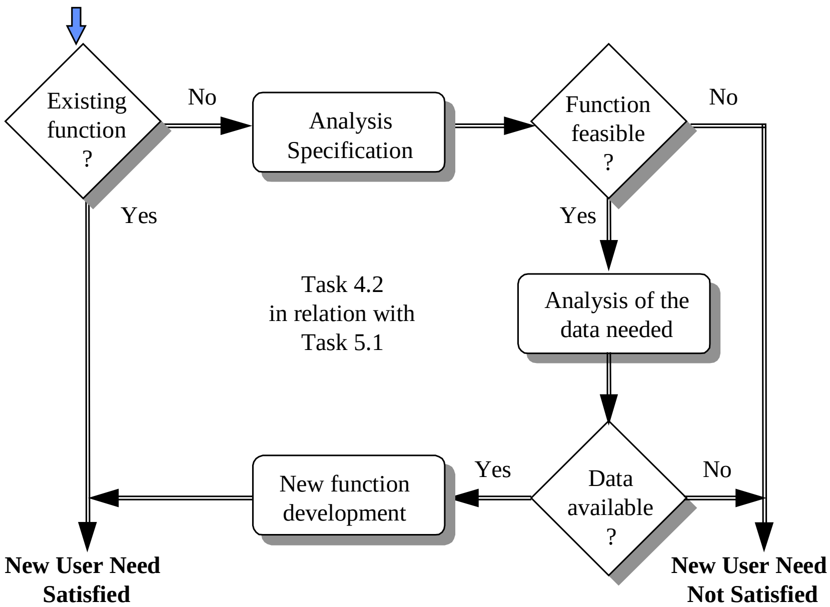

Fig. 3.2.2: Logical diagram of a new user need satisfaction.

Each function (and its behaviour based on formalisms such as Neural Networks, Fuzzy Logic, Petri Nets, i.e.) which has to be referred to the MFA Domain Processes and its structuring (Monitoring, Forecasting, Diagnosis, ...), has to defined with a list of attributes mainly identifying the link with the users needs :

- Item,
- Domain,
- User Need,
- Function,
- Aim,
- Task,
- Input data,
- Output,
- Trigging,
- Interface,
- Ability to meet user needs,
- Cost/Benefit,
- Implementation in REMAFEX,
- Work estimate,
- Constraints,
- Existing products and solutions,
- Remarks.

3.2.3. Identification of data

The identification of the functions is the starting point of the definition of the data necessary to fulfil the functions from an external or internal point of view.

This data can be already **available** (existing data in the CMM system), **new** (data captured through additional CMM devices) or **elaborated** (data composed from other CMM data).
The data is qualified according the function level (process, independent or not of the selected IT,...) but owns the same attributes:

- Title,
- State,
- Source,
- Type,
- Unit of measure,
- Range,
- Alarm value,
- Trip value,
- Logical address,
- User needs link,
- Functions link,
- Remark

3.2.4. Mapping from user requirements to implementation

To go from the Need to the Solution, the distribution of the data and functions on a Maintenance Distributed System (figure 3.2.4) is induced by the users and more precisely by the agents (equipment and operators) and their locations. It has to be guided by the interoperability principle to guarantee a large degree of opening, of re-use and of flexibility: **plug and play principle**.

The objective is to map the functions and data thanks to **distribution mechanisms** on a possible architecture of Maintenance in a CMMS context, by identifying the sites, the actors and by taking into account the existing tools and systems.

The Maintenance functions directly implemented into the field devices contributes to the increasing of the intelligence degree of the equipment, and to move to "autonomous" equipment such as the Holonic Manufacturing System[12].

Therefore the mapping consistency is ensured by the distribution of the Maintenance data which requires a communication support and implies to guarantee the data temporal and spatial performances, availability, status, directly from the Maintenance models up-graded all along the approach.

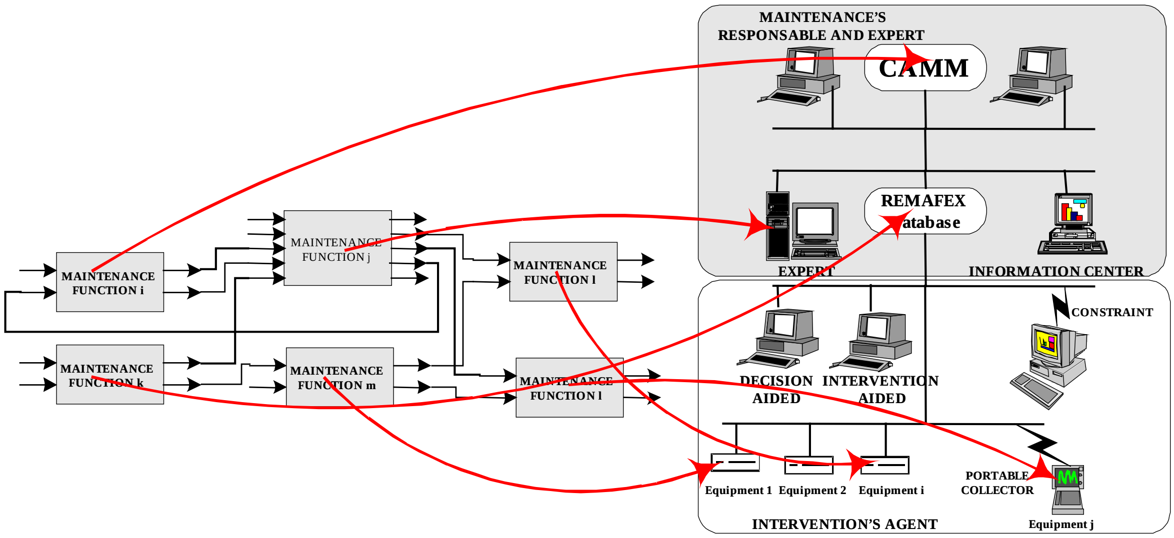

Fig. 3.2.4: Distribution of Maintenance functions

12 Valckenaers P., H. Van Brussel, F. Bonneville, L. Bonagaerts and J. Wyns, *IMS Test Case 5 : Holonic Manufacturing Systems*, Pre-prints IFAC workshop IMS'94,Vienna (Austria), 1994.

4. REMAFEX PLATFORM: AN EXPANDABLE AND OPEN ARCHITECTURE FOR A DISTRIBUTED MAINTENANCE SYSTEM (DMS).

In order to meet the main REMAFEX objective to take the right maintenance decision, at the right time, at the right place by the right people and in accordance with the REMAFEX way of working adopted (refer to section 3 here above), REMAFEX Consortium decided to design the future Distributed Maintenance System and IT platform in order to satisfy the strong and main requirements expressed at the beginning of the project by the REMAFEX user partners and coming from the REMAFEX market survey :

- REMAFEX maintenance system has to be integrated into the existing IT systems of the plant or the enterprise.
- REMAFEX maintenance system architecture has to be able to integrate all existing maintenance products and tools,
- new maintenance functions have to be plugged into the REMAFEX maintenance system,

To meet these requirements, it was clear that the future REMAFEX Maintenance System has to be integrated into the plant and /or enterprise but also distributed, open and expandable. REMAFEX Maintenance System will be a Distributed Maintenance System with an open and expandable architecture allowing to welcome:

- in an IT Technical platform the necessary hardware architecture to support maintenance, database and all IT functions which constitute the kernel maintenance set of functions.
- a set of specific maintenance functions implemented into the IT technical platform through a « plug and play » concept allowing to customize the distributed maintenance system in accordance with industrial facility constraints and requirements.

To perform this distributed maintenance System (DMS) REMAFEX Consortium decided:

- to integrate the REMAFEX DMS into the CMMS concept and model.
- to fully satisfy the generic requirements expressed here above by designing first a functional architecture.
- to fully adapt this functional architecture to the organisational and technological constraints to propose a REMAFEX DMS solution open and expandable.

4.1. REMAFEX OPEN AND EXPANDABLE ARCHITECTURE INTEGRATED INTO THE CMMS MODEL

Depending of the enterprise and of the plant organisation, the future REMAFEX maintenance IT solution and architecture have to acquire and exchange information with: the Process, the

Control System, Management systems and all other maintenance tools or functions currently available somewhere in the plant, in the enterprise.

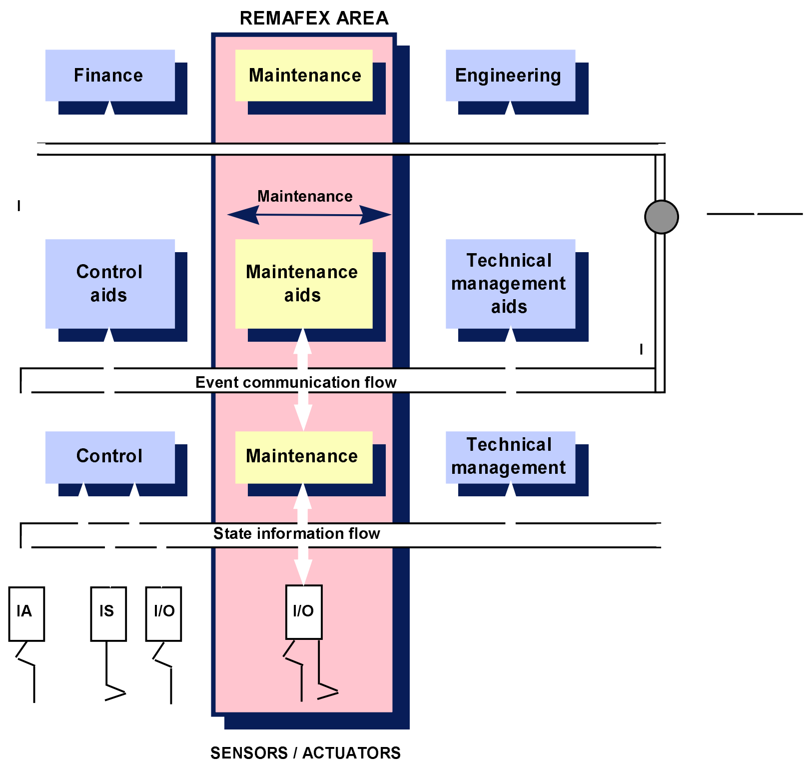

Fig 4.1: REMAFEX area in the CMMS model

Maintenance information already existing or scheduled in the next future, has to be shared between all systems.

But in addition **REMAFEX IT solutions and architecture have to be distributed** from the process to the corporate level. We have to act on the process, to monitor the maintenance information, to decide about maintenance actions and to help the maintenance operator to take the right decision, at the right time and in the right location. We also have to report to the corporate management taking into account in all the maintenance area about the information, systems, expertise locations as shown in fig. 4.1.

REMAFEX IT solutions and architecture have to be distributed in several areas:

- area where the process to maintain is
- area where the maintenance expertise is,
- area where the maintenance management is.

4.2 REMAFEX OPEN AND EXPANDABLE ARCHITECTURE MEETING THE USER REQUIREMENTS

To meet these strong requirements REMAFEX IT platform architecture integrated into the CMMS model is designed to satisfy the following generic technical needs:

- open software architecture able to integrate existing products and tools.
- generic equipment monitoring functions and maintenance data warehousing have to be included
- customised functions have to be plugged into the IT platform.

For that, **REMAFEX IT platform architecture was first designed at the functional level independently of organisation and technology.**

The critical equipment considered in REMAFEX (one hydroelectric turbine and generator) were fully defined, analysed and structured in order to link each part of these equipment to:

- the user function to satisfy
- fully detail the use case to satisfy that means to translate the user function in a set of use case of the IT system to perform user function.

A conceptual modelling was defined which proposes a consistent modelling from user requirements to IT solutions based on some known concepts « Maintenance domains » ; « Hydroelectric structuring » ; « user functions » ; « use case ».

These concepts are integrated, according to a systemic approach, in order to organise them into a complete business process view in relation with the external business processes, and to prepare the two next modelling stages. These steps validate the maintenance engineering framework, so called « REMAFEX way of working », and should improve it to obtain a consistent methodological approach of maintenance for the dissemination works.

The figure 4.2 summarises the whole of this conceptual modelling stage.

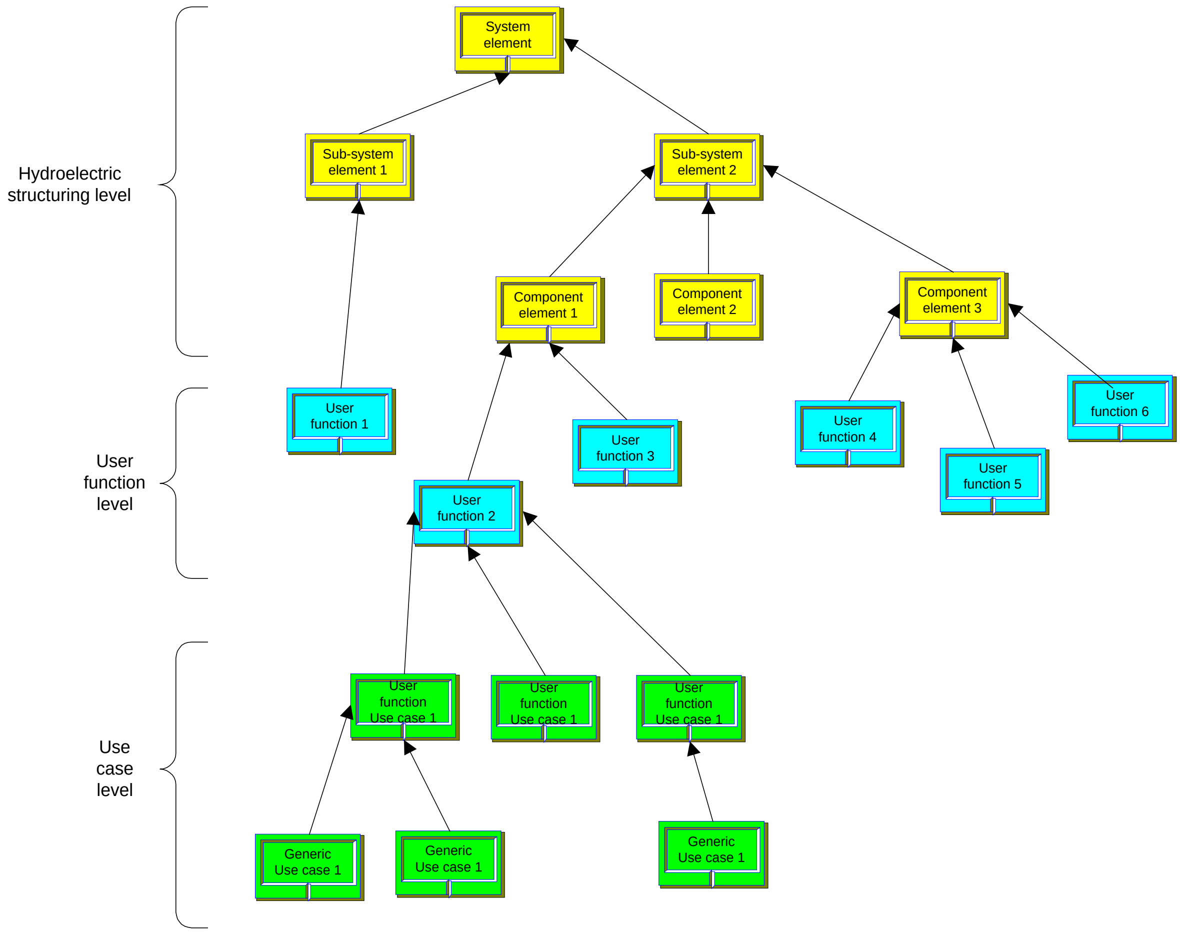

Figure 4.2: The conceptual model used

In addition, a second interest of this approach lies in identification of **generic and reusable functions** attached to each element of the structuring allowing to define Maintenance Functional Companion for expandability analysis (Airport or Oil Offshore Platform, for examples) and dissemination purposes. Generic ability and reusability can be seen at two different levels:

- **a functional one:** each user function attached to a structuring element can be considered as reusable regarding this element.
- **an IT one:** each generic use case prefigures a future generic IT function of the REMAFEX system..

In addition a third interest of this functional approach is the identification of the specific part of the user function and consequently to prepare to future interface to plug correctly this function into the IT platform.

4.3 REMAFEX OPEN AND EXPANDABLE ARCHITECTURE : TECHNICAL ORGANISATIONAL SOLUTIONS

4.3.1 Organisational solutions

At the organisational level REMAFEX IT Platform architecture is designed to define the possible mechanisms to **make the distribution steps** in order:

- to communicate with existing systems, products, tools,

- to use generic maintenance functions as a classical SCADA

- to host new and specific maintenance functions.

For that to distribute maintenance expertise, REMAFEX architecture is divided into two levels which can be used as the end user wants accordingly to its real plant organisation.

- local maintenance expertise dedicated to all local maintenance activities,

- central maintenance expertise dedicated to all central maintenance activities

The basic platform used for building the REMAFEX one is composed of two sub-systems satisfying the postulate for maintenance at two levels:

- a real time field level for elementary and immediate maintenance actions, called Local Maintenance Sub-system (LMS),
- a historical expert one for advanced maintenance operations and a posteriori analysis, called Central Maintenance Sub-system (CMS).

LMS is mainly dedicated to feed CMS with:

- real-time data retrieved from field equipment or external system,
- short term historic data computed from real-time acquisition,
- to propose elementary diagnosis through alarm management or real-time follow up.

LMS is managed by an operator called Local Maintenance Operator.

CMS is dedicated to exploit LMS information concerning the relevant industrial facilities. It provides functions:

- to monitor on-going processes and to keep tracks through long term historic data,
- to diagnose occurred events.
- to forecast some process behaviour for preventive maintenance purposes.

CMS is managed by an operator called Central Maintenance Operator.

CMS/LMS organisational structure is designed as a flexible hierarchy allowing for a CMS to manage information coming from different LMS and is freely located in plants to fit with user shop-floor organisation. The figure 4.3.1 gives examples of this flexible structure.

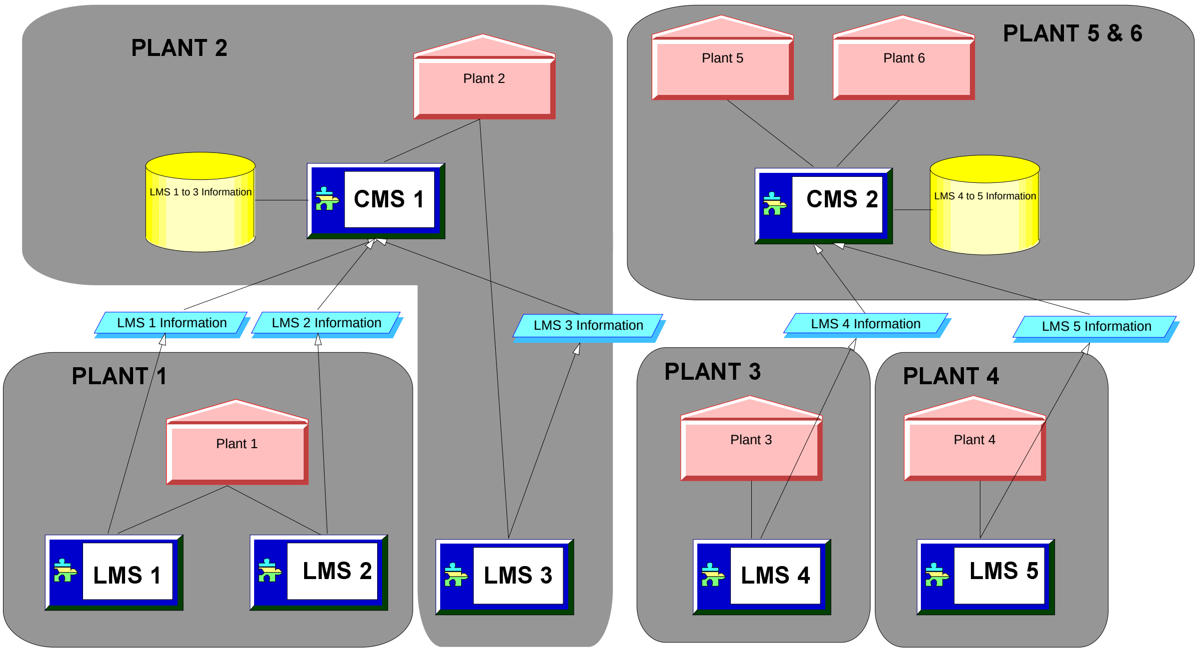

Figure 4.3.1: Organisational solutions

Within this REMAFEX solutions the maintenance management can be integrated in the CMS level with specific management applications and/or interface to Maintenance Management system (MMS) if necessary.

We can note that Maintenance Management functions were out of the REMAFEX scope but today the REMAFEX architecture allows already to take into account this kind of maintenance functions.

4.3.2 Technological solutions

To precise the basic platform objectives, each sub-system is decomposed in applications carrying out dedicated functions within it. Thus, LMS is composed of :

- A Data Acquisition Server (DAS) performing alarms acquisition and detection, variables acquisition and computation, short term historisation.
- A Local Man-Machine Interface (L-MMI) allowing operator to follow up the industrial process through alarms and variables display.
- A Field Communication Interface (FCI), connecting the DAS to the field process event flow by means of multiple protocols communication.

And CMS itself, is composed of:

- A Communication & Processing server (CPS) performing communication between different CMS or LMS applications and background jobs as long term historic data updating or real-time subscription.

- A Central Man-Machine Interface (C-MMI) allowing expert operator to monitor, diagnose and forecast the industrial process.

- A Network & Database Server (NDS), providing network and database administration.

- at the physical level : REMAFEX IT platform architecture was designed to allow all remote control about maintenance actions and to meet all technical requirements expressed here above.

Regarding REMAFEX technical objectives, the targeted system must be made of a distributed open and configurable structure, able to interface at low cost external functions developed with on-the-shelf standard products, and able to be customised with objects and configuration parameters.
To sum up, this architecture must be designed as a flexible system widely based on IT standards.

Concerning LMS, the technical aspects are the following:

1. To ensure a great level of openness by communicating with heterogeneous systems (PLC, SCADA, sensors, MMT i.e.) the FCI application is implemented on a **front-end** supporting multiple protocols communication (MODBUS, PROFIBUS, FIP, i.e.). This front-end use a MMS like presentation layer compliant with **TCP-IP** transport layer to forward data to DAS application.

2. DAS and L-MMI applications are implemented on a **single Windows NT workstation** connected with the front-end by an **Ethernet link**. Acquired data are stored in real time database.

Concerning CMS, the technical aspects are the following:

1. To ensure system reliability and availability each CMS application (C-MMI, CPS, NDS), are proposed to be implemented on a single PC machine, especially to protect connection between C-MMI and the permanent database (for example, if the CPS machine is shutdown). Thus, C-MMI and CPS can be implemented by a **Windows NT workstation** whereas NDS is necessary implemented as a **Windows NT server**. However, NDS and CPS can be gathered in the same server.

2. Any number of C-MMI machines can be connected to the CMS network. In addition, it is possible to connect remotely a C-MMI machine by using RAS facilities.

3. NDS administrates the permanent database through **Oracle DBMS**.

4. All communications between CMS machines are based on **Ethernet link with TCP-IP** transport protocol.

Finally, communication between CMS and any LMS is ensured by routers as standard LAN to LAN connection. By this way, all CMS and LMS machines can be considered as belonging to the same Ethernet network. This overall platform is illustrated in the figure 4.3.2.

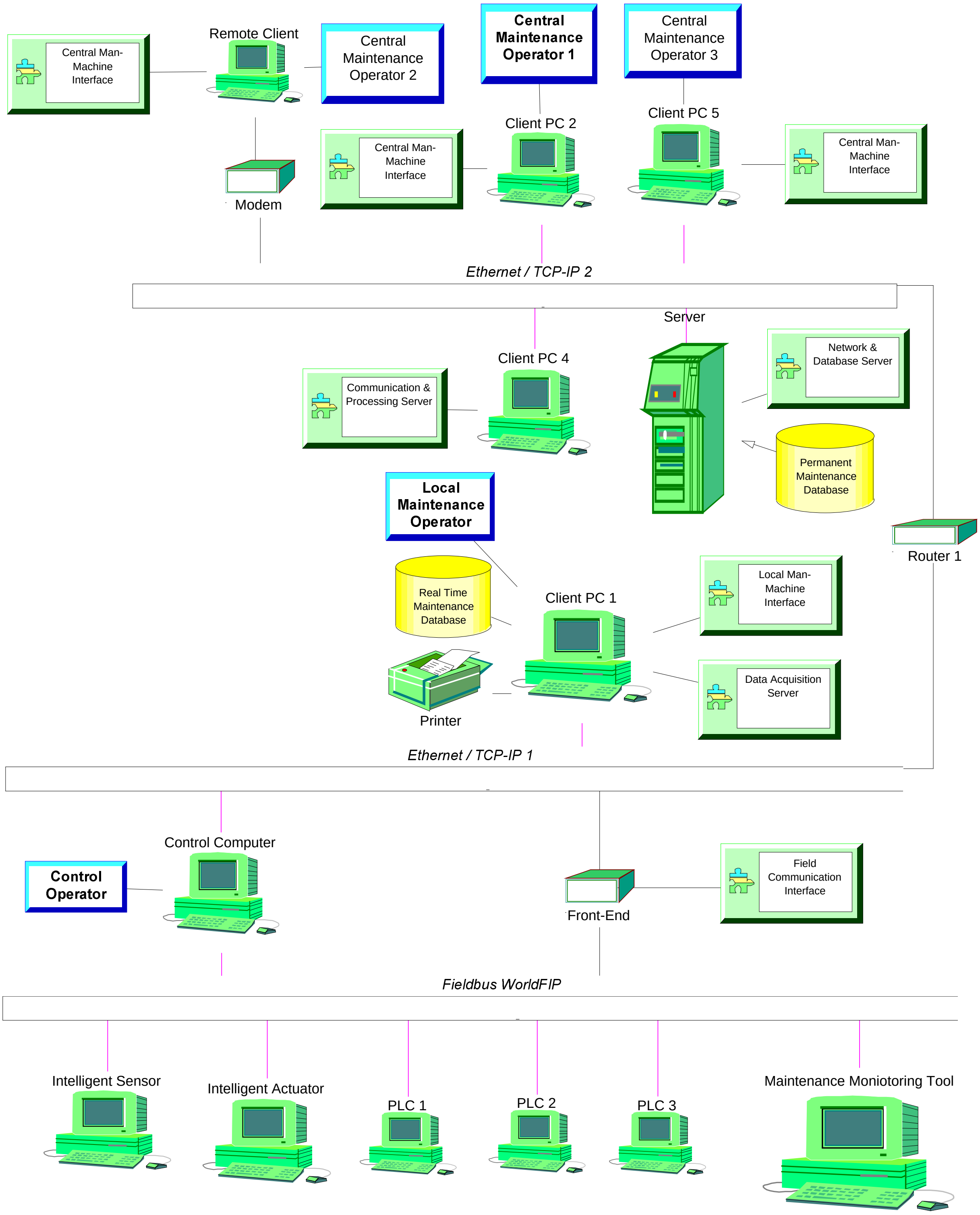

Figure 4.3.2: The REMAFEX overall platform

REMAFEX Platform was designed to be expandable, open and consequently this platform will evolve.

- REMAFEX experimentation on industrial site will provide REMAFEX Consortium with useful information to perform necessary evolution.

- REMAFEX current discussion with maintenance actors in several industrial sectors (airport, oil offshore platform, water management, chemistry ....) demonstrates that the REMAFEX platform is a new an useful tool:

  - to use the existing maintenance functions

  - to distribute the maintenance expertise in the enterprise.

It is too early to present some possible evolution, a REMAFEX system must meet the maintenance user needs (REMAFEX way of working is done for that), a REMAFEX system has to be more and fully integrated in the Enterprise Information System.

REMAFEX platform was designed for that and will be easily adaptable to these specific Enterprise System integration needs. We are already working on that (see section 5.1).

5. REMAFEX CONCEPT, ARCHITECTURE: INTEGRATION POSSIBILITIES

As already presented here above in order to meet the main requirements expressed at the beginning of the project, REMAFEX Consortium decided to integrate the future REMAFEX Maintenance system in the enterprise.

Consequently, REMAFEX maintenance system was and is designed to be fully integrated

- in the global maintenance activity of an enterprise which includes of course all maintenance management functions even if it was not directly in the REMAFEX scope.
- in the maintenance industrial process in order to address all real time maintenance aspects and activities.

REMAFEX integration possibilities were analysed and studied towards these two links in order to preserve the future REMAFEX Maintenance System exploitation into concrete plant and /or enterprise.

5.1 REMAFEX ENGINEERING INTEGRATION

5.1.1 Integration of enterprise information

Integration of the enterprise activities through information system answers to a basic need for increasing the enterprise competitiveness: sharing and providing the right information, at the right place, at the right time and to the right user.

As regard to information related to the production system, it means to provide a consistent and significant representation of the physical process. Intelligent Actuation and Measurement system (IAMS), based on the distribution of information processing down to the field-devices, are expected to be the supplier of this efficient information.

In other words, the closer is the data representation to the physical flow in the process, the better is the semantics of its informational representation for business flow. This information is made available through an "informational bus" for common use by the production agents responsible for the plant control, maintenance and technical management.

This efficient information from the production system could also been made available for use by the enterprise management activities such as for example production planning, resources planning, maintenance management, financial management, human resources management and so on.

This new organisation of the enterprise information system reduces the classical hierarchy promoted by CIM-OSA architecture. Indeed, IAMS and CMMS leads to an organisation of the enterprise information system that is limited to two levels[13]: the production level where the integrated CMM system using a distributed IAM architecture provides efficient information from the process that can be used by the enterprise management level (figure 5.1.1).

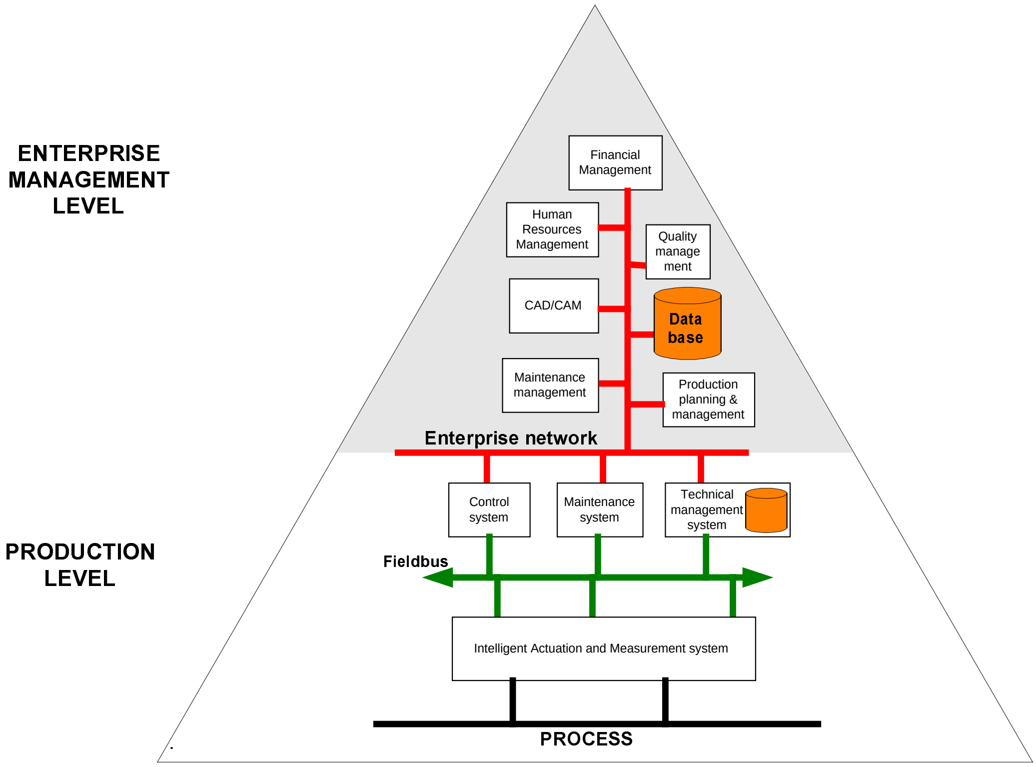

Fig. 5.1.1: Levels of enterprise integration

5.2 ENGINEERING OF ENTERPRISE INFORMATION SYSTEM

In this integration way, engineering of enterprise information system has to define what information needs to be processed, stored and communicated to different agents involved in enterprise business and production activities.

Two approaches can be used to satisfy these needs:

a) The first one is based on the use of **information modelling theory** in order to define models dedicated to a particular enterprise or class of application. This approach is usually based on a conceptual step required to define reference models for a class of application or even for a generic enterprise. Instantiation of the reference model leads to the development of a technical information system to be implemented for a specific enterprise (See chapter 2). As an example, we can notice the work done by PRIMA consortium to define reference models for the information system of a generic enterprise. Including maintenance information in this reference model has required to check conformance with the existing or future maintenance systems such as REMAFEX.

[13] J. Berge, Fieldbus advances diagnostics, International Journal for Measurement and Control, InTech, April 98.

b) The second approach is an **industrial pragmatic approach** which is based on ERP available tools (ERP tools: Enterprise Resource Planning tools) that support already defined reference models for the enterprise management activities and that provide mechanisms for implementing them. The engineering work to be done is then limited to the modelling of the user requirements in order to manage the parameterisation of the ERP modules that satisfy the enterprise needs.

ERP is the current evolution of manufacturing resources planning (MRP&MRPII) systems. ERP is being positioned as the foundation and integration of enterprise-wide information systems. Such systems will link together all of a company's operations including human resources, financials, manufacturing, and distribution as well as connect the organisation to its customers and suppliers.[14]

There are several vendors who have entered the ERP market with complete enterprise solutions[15]. Three vendors among the five companies dominating the ERP market are:

1. SAP AG[16]
   A German based company, SAP AG is by far the market leader in ERP software and it introduced its R/3 product in 1993. SAP R/3 system, on the basis of an extensive functionality and a high level of integration, meets the full range of business requirements, including financial accounting and controlling, sales and distribution, materials management, production planning, and human resources management. (See also D8.3, section 4.2).

2. Oracle Corp.[17]
   Oracle Corp. Grew out of being a database company. It introduced its first application modules approximately three years ago. Oracle Application has now more than 35 modules covering every facet of enterprise computing, from manufacturing and production control to human resources and sales force automation.

3. BaaN Co.[18]
   The BaaN Company's family of products is designed to help corporations maintain a competitive advantage in the management of critical business processes by having a product architecture that led itself to fast implementations and ease of change. BaaN IV is an integrated family of manufacturing distribution, finance, transportation, service, project and orgware modules. BaaN IV is specially designed to meet the needs of key vertical markets.

5.3 APPLICATION TO REMAFEX

In relation to the information modelling theory, an application of the engineering approach based on reference modelling to the REMAFEX proposal has been finalised. On the one hand, through the formalisation of the Maintenance Reference based on Maintenance reference models, and on the other hand, through the co-operative work done with PRIMA consortium to formalise a particular reference model for the "equipment monitoring" (refer to chapter 2).

[14] ERP Glossary of Terms – http://www.internec.com/erp/erp_glos.html
[15] Anne Robinson, *Enterprise Resource Planning*, December 1997 – http://mansci2.uwaterloo.ca/~msci604/summaries/erp.html
[16] http://www.sap.com
[17] http://www.oracle.com
[18] http://www.baan.com

In relation to a more industrial pragmatic approach, an application of the engineering approach based on the parameterisation of ERP tools requires integration of the REMAFEX tools dedicated to production level of the CMMS with the ERP modules devoted to enterprise management and more particularly to the maintenance management. This integration could be based:

- on sharing information with the help of a common database management system or ODBC (Open DataBase Connectivity) link between heterogeneous databases. This implies the availability of a model of the information processed by each tool to be integrated. This kind of integration could be experimented with integration of the REMAFEX tools to the ERP *Oracle Applications* through the *Oracle* database.

- on sharing information but also on providing interoperable information processing by using already defined communication objects such as O.L.E. (Object Linking and Embedding). In this case, interoperable information processing could be triggered to/from the different tools to be integrated by implementing Remote Functions Call (RFC). This approach could be experimented with integration of the REMAFEX tools to the ERP *SAP/R3* (figure 5.3).

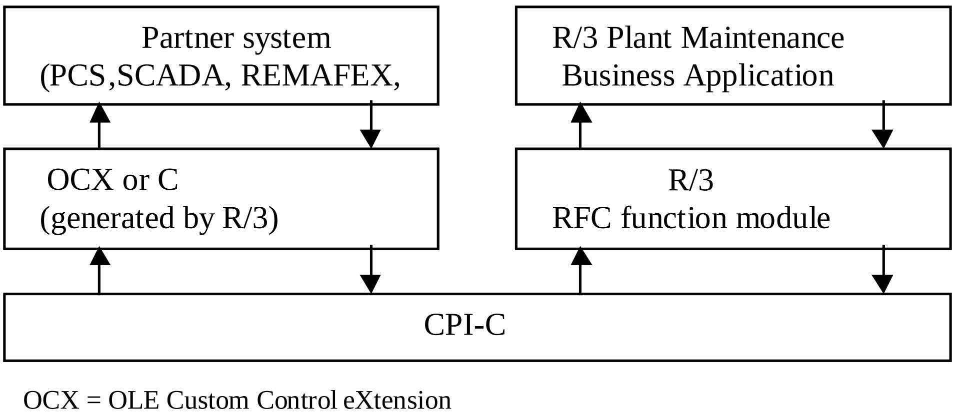

Fig 5.3: Communication between REMAFEX and SAP R/3

This will be a future improvement to perform to the current REMAFEX distributed Systems.

Today REMAFEX Distributed Maintenance system due to its architecture design is already able to integrate some management functions in the CMS's architecture level as specific management applications and/or interface all maintenance management system (MMS) using relational database facilities.

A more detailed example of integration between SAP and REMAFEX was analysed in oil offshore domain (please refer to D8.3, section 4.2).

5.4 REMAFEX PROCESS INTEGRATION

As already presented in chapter 4, REMAFEX architecture was designed to integrate the future system into the Control, Maintenance and Technical Management concepts and model.

By definition REMAFEX maintenance system is integrated into the process.

The technical architecture proposed allows to adapt this architecture to site, plant and enterprise constraints in order to:

- distribute the maintenance system
- open the maintenance system to all possible Maintenance Monitoring Tools (MMT) or not.
- gather all maintenance information already available everywhere in the plant.

For that, a front end supporting multiple protocols communication allows to ensure a great level of openness with heterogeneous process systems existing or not in the site, the plant or in the enterprise (PLC, SCADA, new sensors, MMT...). Distribution and expandability are ensured by using the main usable standards: windows NT operating system, relational database and its SQR standard, Ethernet using TCP-IP transport protocols.

6. MAINTENANCE TERMINOLOGY

6.1 TERMINOLOGY USED IN REMAFEX

In the REMAFEX project a specific deliverable (D 1.3: REMAFEX TERMINOLOGY) is dedicated to the terminology used within the project. The document consists of the following terminology sections:

- Hydroelectric installations terms and definitions
- Maintenance terms and definitions
- Maintenance REMAFEX terms

The terms used in the first section (hydroelectric installations) are identical with the correspondent definitions in IEC 50(191) or IEC 4/112/CDV. The second section (maintenance) are based on either IEC 50(191), EN 45543, NFX060-010 or IEC 545.

The section "Maintenance REMAFEX terms" in D 1.3 consists of terms that are more or less unique for the REMAFEX project/concept. (See section 6.2)

6.2 CEN/TC 319: PRELIMINARY STANDARD FOR MAINTENANCE TERMINOLOGY

The Technical Committee CEN/TC 319 "Maintenance", Working Group 4, has prepared a draft European Standard called "Maintenance Terminology", dated June 1998. The standard is harmonised with chapter 191 of the international electro-technical vocabulary issued by IEC in 1990. The purpose of the new standard is to define the basic terms used for all types of maintenance and maintenance management irrespective of item considered.

As pointed out earlier most REMAFEX definitions are harmonised with the correspondent terms used in various IEC or EN standards. There are, however, some terms that are more or less unique for REMAFEX. These terms are listed in a specific chapter in Deliverable 1.3 (Maintenance REMAFEX terms). The following differences between this CEN draft standard and the REMAFEX terminology should be noted:

Term	REMAFEX "definition"	CEN/TC 319 definition
C.M.M.	Control, Maintenance and Technical Management	(not included)
C.M.M.S.	Control, Maintenance and Management System; a distributed system composed of intelligent field devices, real-time computers and management computers which is used to operate industrial process, according to the CMM concept.	(not included)
Data needs	The data needs are the data	(not included)

Term	REMAFEX "definition"	CEN/TC 319 definition
	produced by the process and the other automation systems which are necessary to realise the functions (innovative or not) which satisfy the user needs.	
Distributed Maintenance System	The distributed maintenance system has to help maintenance operator to take the right decision at the right time in order to manage continuously all maintenance activities and to move in stepwise fashion from corrective to predictive maintenance.	(not included)
Innovative function	The innovative maintenance functions allow to customise the distributed maintenance system in accordance with industrial facility constraints and requirements. The innovative maintenance functions are new functions that are not available in the maintenance systems of today.	(not included)
Life cycle	Life-cycle concept encompasses all the phases of the life of a system as analyse, specification, designing, configuring, parameterising, tuning, commissioning, operating, maintaining.	Time interval that commences with the initiation of the concept and terminates with the disposal of the item.
Maintenance database	The maintenance database store all the maintenance information.	Maintenance documentation: Information in written or electronic form required to fulfil maintenance Maintenance record: Part of maintenance documentation which contains all failures, faults and maintenance information relating to an item. This record may also include maintenance costs, item availability or up time and any other date where relevant.
Maintenance domain, key	At a conceptual level, the	(not included)

Term	REMAFEX "definition"	CEN/TC 319 definition
domains and activities	maintenance domain is a manufacturing domain in the same way as the control or the marketing one. It is composed of key maintenance domains such as maintenance management, fault diagnosis, execution... A key maintenance domain is composed of a set of activities. For example the fault diagnosis key domain is composed of fault recognition, fault location and cause identification activities	
Maintenance focus area	The maintenance focus area is the all possible maintenance activities which define the global maintenance manufacturing domain.	(not included)
Maintenance technical platform architecture	The maintenance technical platform provides the hardware architecture necessary to support the maintenance database, and all IT functions constitute the kernel maintenance set of functions	(not included)
Maintenance user needs (or user requirements)	The user-needs relevant to maintenance system. They express the support the users need from the maintenance system. This support is defined in terms of: - The "requests" and "reports" exchanged between all the users of maintenance system and CMMS; - The functional support given by the "maintenance functions".	(not included)
Technical location	The technical location is the location of each equipment in the power plant architecture.	Item register: Record of the items individually identified in a given location.

7 . CONCLUSIONS

As already said in the Executive summary **this Deliverable D8.2 was designed by the REMAFEX consortium to be a guide to new external maintenance actors.**

- to fully understand what were performed in REMAFEX project
- to fully understand the REMAFEX result potentialities,
- to be able to understand the new possible added value of such REMAFEX results
- to be able to envisage to use in the next future these REMAFEX results.

But as such, this deliverable is really incomplete and has to be understood as an introduction to the REMAFEX training necessary to use the REMAFEX materials and results in an optimal way.

REMAFEX Project was a first step to set up a Distributed Maintenance System meeting really concrete and predictive maintenance user needs.

Experience obtained by all REMAFEX partners during the project was fruitful and will be maintained to all potential users through the REMAFEX WEB-page.

http//www.gsip.cran.u-nancy.fr/remafex/WP9_remafex/index.html

All results coming from the Project will be introduced, maintained and updated into this WEB-page by REMAFEX Consortium.

REMAFEX Consortium really wants to exploit this concept, the REMAFEX platform and maintenance functions and will continue at least for two more years to disseminate, to exploit and market REMAFEX results. An exploitation commercial agreement was signed by all REMAFEX partners to be able to perform this.

REMAFEX Consortium remains open through the exploitation commercial agreement to participate in the next future to any Maintenance User Group which will be able to be constituted in Europe.

A lot of contacts have already been taken with all maintenance actors to include REMAFEX Distributed Maintenance System as a full part of the new Technical Information System needed to continue and support the European growth. To avoid to waste time and money, **the new Technical Information System has to be distributed to allow all remote actions and diagnostics.**

This is the REMAFEX solution.