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DYNAMITE
Dynamic Decisions in Maintenance

# Publishable Final Activity Report 8

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# DYNAMITE
# Publishable Final Activity Report 8

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# DynaWeb e-maintenance solution for dynamic decisions in maintenance

## 1 Introduction

Maintenance is the field of technology that consists of technical skills, techniques, methods and theories which all aim at technical and organisational solutions for large assets like factories, power plants, transportation vehicles and constructions, as well as for smaller assets such as household machines, hobby devices and consumer products, to function properly, in a cost effective way, with low energy consumption, without polluting the environment and in a safe, controlled and predictable way. The costs and risks related to improper maintenance are huge. Poorly functioning production machines and unreliable products are negative for a company's business. Effective maintenance is crucial for the competitiveness and the future of a company.

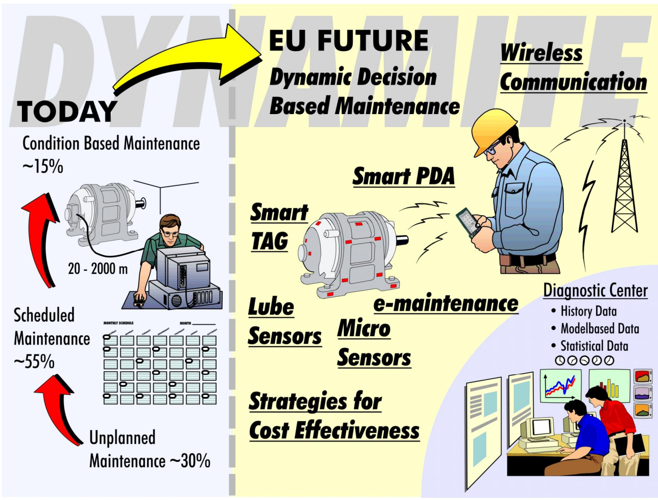


Figure 1.1 The DYNAMITE vision for future IT-based maintenance.

The optimal solution would be to know continuously the condition of the asset and its components and take repair and service actions only when really needed. Today there is an improved understanding of the phenomena initiating and triggering disturbances and failures and new effective sensor as well as information and communication techniques that makes it possible to analyse and deal accurately with large amount of data and information on global level (fig. 1.1). The concept of ***e-maintenance*** that takes advantage of this development is defined as "The network that integrates and synchronizes the various maintenance and reliability applications to gather and deliver asset information *where it is needed*" (Baldwin, 2001).

We report here a flavor of advanced techniques and methods that form the basis for a novel DynaWeb e-maintenance approach and solutions including advanced micro sensors, smart tags (RFID, radio frequency identification), on-line oil sensors, PDA maintenance applications, ontology based diagnostic and prognostic methods, wireless communication, semantic web service for distributed intelligence, dynamic cost effectiveness based decision making tools and a holistic e-maintenance concept. Experiences both from laboratory testing and use in industrial environments is presented. The reported cases are demonstrations on global level, with milling machine, machine tool, foundry hydraulics, maritime lubrication system and automatic stamping machine.

## 2 DYNAMITE project objectives and contractors

The DYNAMITE project aimed at delivering a blend of leading-edge communications and sensor technology, combined with state-of-the-art diagnostic and prognostic techniques, which will advance the capabilities of European industry in maintenance. The objective was to deliver a prototype system with a clear exploitation route to take the technology into the European market.
The monitoring of machines and processes for predictive maintenance and control is crucial for sustainable and competitive industry in Europe. Distributed, autonomous monitoring is fundamental to the penetration of e-maintenance to the cutting edge of high capital and highly productive plant. DYNAMITE aimed at creating an infrastructure for mobile monitoring technology and creating new devices which will make major advances in capability for decision systems incorporating sensors and algorithms. The key features were planned to include wireless telemetry, intelligent local history in smart tags, and on-line instrumentation.

**Objectives**

1. A flexible infrastructure to host technologies for global e-maintenance
2. A hardware and software demonstrator of smart tag technology incorporating identity, health history and communications
3. A mobile device for access to and reporting from the e-maintenance infrastructure
4. A low cost wireless sensor demonstrator – a self-powered, multi-sensor, smart device with wireless communications
5. An online oil sensor incorporating particle counting, distribution and composition in one instrument
6. Tools and methods for cost-effective applications of the maintenance technologies for continuous enhancement of company's profitability and competitiveness.

**Contractors**

The DYNAMITE contractors are listed below.

| No. | Code | Name | Country |
|---|---|---|---|
| 1 | VTT | VTT Industrial Systems | Finland |
| 2 | TEK | Fundación Tekniker | Spain |
| 3 | SUN | University of Sunderland | UK |
| 4 | MAN | University of Manchester | UK |
| 5 | UHP | Université Henri Poincaré | France |
| 6 | VXU | Växjö University | Sweden |
| 7 | ZEN | Zenon S.A. Robotics & Informatics | Greece |
| 8 | CRF | FIAT Research Center | Italy |
| 9 | VOL | Volvo Technology AB | Sweden |
| 10 | GOR | Goratu Maquinas Herramienta S.A. | Spain |
| 11 | WYS | Wyselec Oy | Finland |
| 12 | MAR | Martechnic GmbH | Germany |
| 13 | ESS | Engineering Statistical Solutions Ltd | UK |
| 14 | DIA | Diagnostic Solutions Ltd | UK |
| 15 | PRI | Prisma Electronics | Greece |
| 16 | IBK | IB Krates OÜ | Estonia |
| 17 | HYD | Hydrox Pipeline Oy, 1.9.2005-28.2.2007 | Finland |

# 3 E-maintenance scenario analysis

The design of a flexible structure for DYNAMITE (Dynamic decisions in maintenance) is supported on the assumption of the existence numerous companies that can benefit from a subset of the technologies addressed in the project, providing customised plug and play to the desired upgrades with respect to each company's existing maintenance activities. It is also understood that there is not a single 'upgrade' solution that fits for all concerning the maintenance needs.

Given this, one of the first activities performed in the project, apart of a conventional study of requirements for ICT and sensor technologies, has been the study of the use cases involved in the project, with the aim to identify clear separate scenarios for demonstration of new technologies, which should also facilitate the implementation of cost-effective maintenance solutions. Scenarios are extracted out of initial use cases, as likely representative examples of a wider group of companies having similar objectives in the maintenance process, sharing similar technology status, or sharing a need with respect to maintenance technologies needed. As a result, different have been separated, including large companies with de-centralised production, OEM suppliers, small companies with few dozens of machining systems and third party consultants.

Table 1, which was compiled from end user analysis during the first stages of DYNAMITE, clearly shows that our initial assumption is true, and it is not possible to find a single system for a global upgrade of existing maintenance systems. The existing strategies, legacy systems and other issues differ very much, as well as perceived technical problems and economical motivations. However, if we take this table as reference, it allows generalizing scenarios that can go beyond a particular use case, and thus provide an entry point to the technologies for companies that share similarities with one of the scenarios (Roles, operational contexts, applications, components, preferred upgrades etc).

Table 1: Summary of end-user scenarios in DYNAMITE project

| Providers | Plant operators | OEM manufacturers | Consulting | Trasport (OEM + consulting.) |
|---|---|---|---|---|
| Context | Single location (Manufacturing plant). Multiple machines | Technical Assistance Services. Guarantees Multiple locations | Specialised services (e.g. lube analysis) for multiple locations | Specific machinery on movement |
| Application (Components) | Milling, drilling and high speed machine tools (Hydraulic systems, gearbox, spindle) | | | Motors (Marine, Automotive) |
| Current strategy | New PM ( 10- 20 % CBM) | BDM | PM | - |
| Current economic motivations | Overall economic impact to the company for different maintenance strategies not always known | Uneven workload Enforce/surveil remote maintenance procedures on guaranteed machinery | Decrease downtime, repair and maintenance costs | Plan new cost – effective e-Maintenance for new equipment |
| Current technical problem(s) | Evaluation of machine condition depending on expert knowledge (subjective) | Improve diagnosis Communication sensors to OEM (bypass CNC) | Lack of experienced diagnosis and decisions over existing parameters | Lack of proper knowledge |
| Interesting technologies | Include advanced sensors Wireless communication Smart PDAs Include cost-effectiveness | Upgrade to CBM Use remote monitoring e-Maintenance. Wireless gateways Cost effectiveness | Use e-Maintenance to remotely assess expert and communicate to operators. Training systems. | Initiate predictive maintenance |
| Likely CBM/PM parameters (sensors) | Temperature, Voltage, Current, Oil level, Oil quality, vibration, pressure, Wear debris | | | |

# 4 Intelligent sensors

The development of intelligent sensor is fundamentals to support different diagnostic, prognostic and maintenance activities. In Dynamite project, three categories of intelligent sensors are focused including smart tags, micro sensors and lube sensors.

Three categories of intelligent sensors contain different purpose. The investigation of smart tags is concentrating on utilising existing radio-frequency identification (RFID) technology to improve the assets maintenance and management. Different to the smart tags, the role of investigating micro sensors is to develop a more powerful and self-powered wireless micro-electro-mechanical systems (MEMS) sensor for advanced condition monitoring. And finally, the investigation of lube sensors is targeting on various sensor techniques for analyzing and detecting different lubrication features.

For smart tags, both passive RFID and active RFID technology are considered. The passive RFID is suggested to be used for the replacement of barcode system and it is recommended specific for asset identification and inventory purpose including machines, spare parts and tools. Moreover, passive RFID and PDA can be used together as a perfect maintenance tools. It can effectively reduce the improper asset identification in order to prevent a series of inappropriate maintenance activities.

Alternatively, the active RFID is perfect for real-time location tracking (RTLS) of mobile assets. It can be applied for security and mobile assets tracking purpose to detect any unauthorized people getting into a protected area, and also search and reserve any shared mobile resources like vehicles.

For micro sensors, a powerful wireless micro-electro-mechanical systems (MEMS) sensor for advanced condition monitoring has been developed. It combines and integrates three sensors including vibration, temperature and pressure together and a Zigbee wireless communication module to a single MEMS sensor. By using this, multiple sensor values can be collected and transmitted directly to the wireless sensor network for processing at the same time.

Also, in order to support the idea of wireless senor technology continuously working for a long time, a self-powered electronic power management module has been developed to bridge the wireless sensor and the harvesting devices including solar-based devices and vibration-based devices for recharging batteries.

In the Dynamite project, four types of lube sensors are focused in the lubrication system: fibre optic laser and SLED absorption and scatter sensors for solid contaminants, particle senor, oxidation sensor and water sensor. Various sensor techniques described here are important in analyzing and detecting different lubrication features

Firstly, a low cost fibre optic laser and super light emitting diode (SLED) absorption and scatter sensors for solid contaminants sensor uses optical fibres as data and energy channels to give well a cleanliness index for solid particle content in the measured lubrication.

Secondly, a particle sensor is developed to measure particle content of lubricating oil. Through using a CCD camera together with an illumination system, particles even smaller than 1 micron size can also be detected.

Thirdly, an oxidation sensor is used to measure oxidation level of lubricating oil. Through measuring the transmittance of the light in the visible range (380-780 nm) of the light spectra, the degradation status of the lubricating oil can be calculated by the correlation of absorption of light and the oxidation level of lubricating oil.

Fourthly, a water sensor can measure water content of lubricating oil. Similar to oxidation sensor, the transmittance of light in the NIR range (about 1400 nm) of the light spectra can be measured and check with the correlation the absorption of light and the water content of lubricating oil.

The following figure illustrates a complete information flow of a lubrication system. Various lube sensors are connected to the target system for data collection. Then a PC or a PDA can be used as a basic data collector to extract features and critical information and send the results to the Mimosa database for storage and further processing.

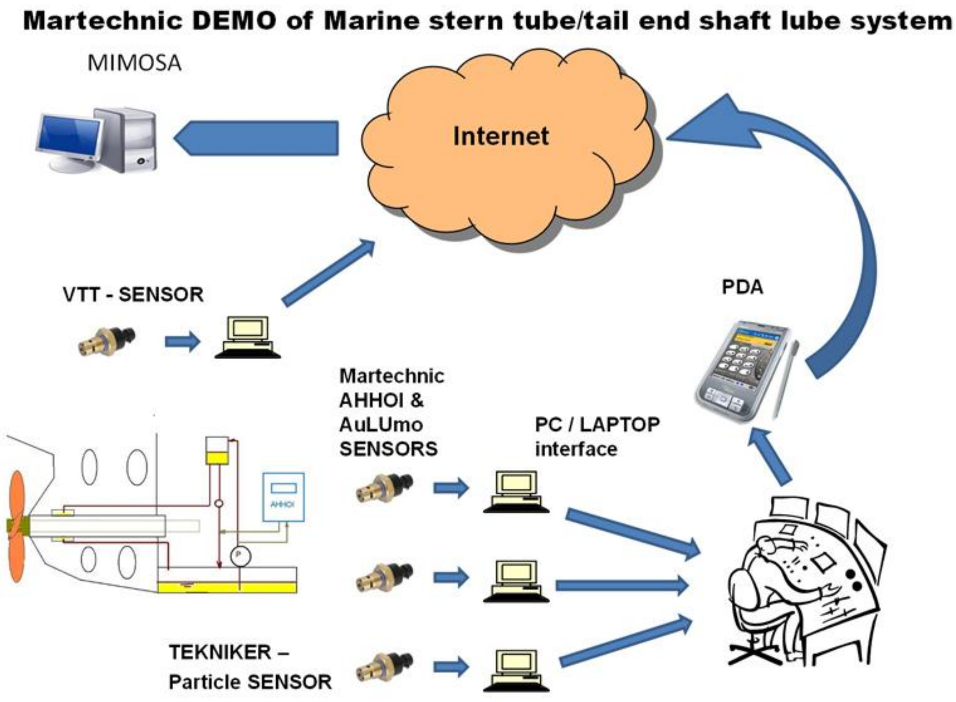


Figure 1. The complete information flow from lube sensors to Mimosa database

In order to support the manipulate of sensor data in the Mimosa database, a complete set of web-services are designed and developed to support asset information querying, monitoring, diagnostics and prognostics. Those web-based services and sensor techniques are detailed as different DYNAWeb components.

Finally, it is necessary to notice that all works described in this section including smart tags, wireless MEMS sensors and lube sensor systems are successfully tested in laboratory and demonstration. And they are fully support the connection to the Mimosa database for storage and retrieve of information. Based on that, engineers can call different web services provided to read the up-to-date data anywhere by using their PC, PDA and mobile phone via accessing WiFi and mobile internet.

# 5 Information and communication infrastructure

Actual industrial maintenance activities are mainly driven by traditional strategies where events are normally time-based. Tough it has been pointed out that more advanced, condition-based strategies can provide clear savings in many maintenance activities, their application is normally prevented by different causes, such as the need to manage, both physically and logically, an increasing volume of data and information. At DYNAMITE, one of the main developments has been related to the development of a flexible architecture concept to provide flexible data and information management.

On the one hand, a platform of web services to provide intelligent processing capabilities has been designed. This platform is logically structured according to OSA-CBM decision layers, from Condition Monitoring to Decision Support, but also to the existing operators (Sensors, PDA, CMMS etc). The result is a three level framework (machine, plant, company) that provides a flexible configuration that allows the system to be used 'on-demand' and to grow according to the needs (new sensors and functionality), together with a flexible communications infrastructure, where a generic wireless 'gateway' device is being developed, in order to complement existing communications options (wired or wireless) between sensors and company decision areas when other communication options are not available (such as SCADA, PDAs, etc). The different components developed, together with additional issues related to a global approach were firstly envisaged as a global system that was nicknamed DynaWeb. The structure is highlighted in the following figure.

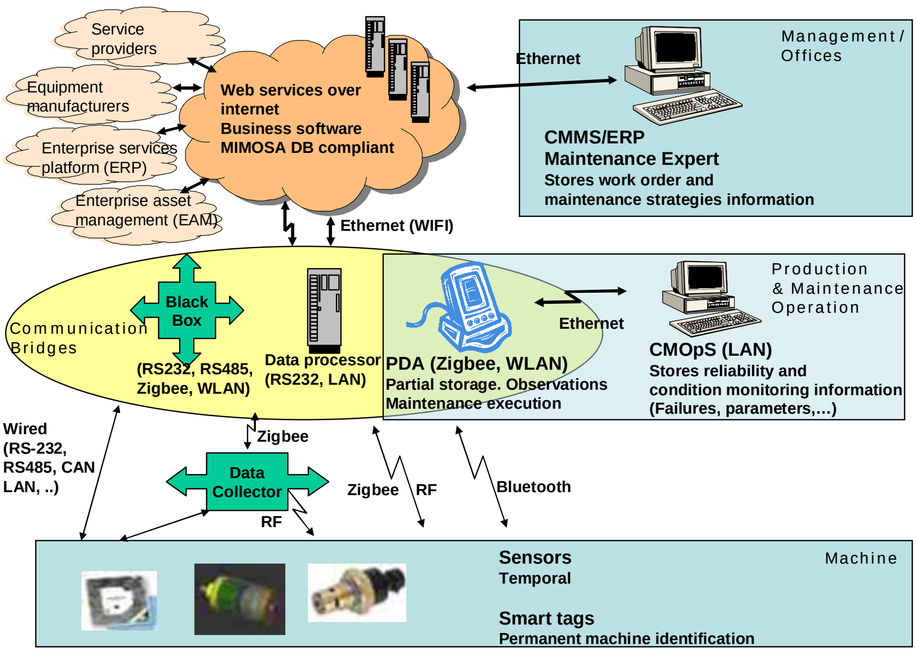


*Figure 2: DynaWeb platform*

On the other hand, this platform has been populated with different ICT components to facilitate an this web distributed e-maintenance solution

A mobile handheld device has been developed, and includes wireless access to smart tags and sensors and centralized databases within the e-maintenance infrastructure, including application software for performing analysis of monitoring data and early stage diagnose of faulty conditions. Specific developed modules that can be pointed out include the interfaces for managing the information and communicating with operators, the infrastructure and agents for interoperation with remote web services, and the inclusion of specialized models to retrieve information from smart tags and optimise the maintenance scheduling

A dual system for wireless communication across different operators has been developed. This system is composed of a physical gateway for communication between machine and plant, plus a data collector to facilitate communication between wired systems and wireless gateways. The protocols used are Zigbee and Wifi. This physical system is complemented by a translator developed to assist the interpretation of SQL Queries into MIMOSA database structure.

A complete set of web services have been designed and developed, covering the complete OSA-CBM information process layered structure. These services can operate from any type of location (sensors, PDAs, PCs) and provide an standardized means to access to information located in any machine, without the need to change existing legacy systems, with a minimum need of adaptation.

Last, it can also be stated that MIMOSA arquitecture was decided to be a central part of our development process. This has allowed different positive outcomes:

- Interoperability between all developed components have been secured not just along the across the entire project
- Many components developed can now be used in two different ways: Straight to MIMOSA databases, or via XML message passing to non-MMOSA databases, using also MIMOSA architecture in the protocols. In this way, the web services can also be standardized, no matter where is the information stored.
- The use of MIMOSA standard, even tough not much extended yet at the beginning of the project, seems to become aware in many different areas, which now turns into a positive selling argument, as the compliance of any system with MIMOSA is allowing interoperability among an increasing number of maintenance software systems.

All the results achieved have been detailed in a list of DYNAWeb components. Concerning ICT communications the available components resulting from DYNAMITE are shown below

For direct operation of the PDA

| | |
|---|---|
| 2. Active smart tag, asset tracking | Zenon |
| 9. Mobile maintenance PDA user interface | VTT |
| 10. Smart tag PDA support | Sunderland University |
| 11. Active smart tag PDA support | Zenon |
| 12. Hand held PDA vibration data collector | Diagnostics Solutions Ltd. |
| 13. PDA scheduling support | Zenon |
| 14. Smart PDA maintenance user interface | Prisma technologies |

For communications across different operators (sensors, PDA, PC), MIMOSA database and web services

| | |
|---|---|
| 15. Communication SW module | Prisma technologies |
| 16. Mimosa translator | University Henri Poincaré |
| 17. Collector (=Gateway) | Prisma technologies |
| 18. Wireless communication system for e-maintenance | Prisma technologies |

Concerning web services development

| | |
|---|---|
| 19. Condition monitoring web service | TEK |
| 20. Diagnosis web service | TEK |
| 21. Prognosis web service | University Henri Poincaré |
| 22. DynaWeb e-maintenance platform (TESSNet) | Fundación Tekniker |
| 23. Scheduling web service | Zenon |
| 27. MEMS SW support module | Diagnostics Solutions Ltd |
| 28. Vibration measurement system | Wyselec |

Concerning structures for MIMOSA

| | |
|---|---|
| 25. DynaWeb platform | IBK |
| 26. Mimosa database | IBK |

## *6 Cost effectiveness based decision support*

In general, decisions of when and why to stop a producing machine and whether it is cost-effective or not are crucial for production profitability especially in companies of intensive capital investments, e.g. process industry, shipping and engineering manufacturing, where stoppage time is very expensive. It is vital to have a system providing reliable data required to achieve cost-effective and dynamic maintenance decisions for maintaining and improving company profitability and competitiveness.

A novel Maintenance Decision Support System (MDSS) was developed that offers three different strategies for cost-effectiveness that can be applied integrated or separately, Fig.6.1. MDSS can help companies to reduce economic losses through mapping the situation of production and maintenance processes and enhance maintenance performance. It allows following up maintenance performance measures more frequently, thereby be able to react quicker on disturbances and avoid unnecessary costs. It will also be easier to trace the causes behind deviations.

MDSS consists of three toolsets, where every toolset consists of one to three tools with different functions, see the Table 1. MDSS provides services that existing systems cannot do. It helps to identify the most beneficial areas for future investments in maintenance. MDSS applicability and usefulness have been tested successfully by personnel from FIAT/CRF (Italy) and Goratu (Spain) and it has been installed at Fiat/CRF, Italy for test since 16$^{th}$ of Jan. 2009. The final conclusion of the test and demonstration of MDSS is that MDSS is user friendly and can be used successfully for analysis of data and achievement of maintenance dynamic and cost-effective decisions.

Table1. Functions of the toolset and tools included by MDSS

| **Toolsets** | **Tools** | **Features & Function** |
|---|---|---|
| **MDSS:**<br>**Toolset 1**<br>**Toolset 2**<br>**Toolset 3** | | Easy to use, effective and low cost |

| | | |
|---|---|---|
| **Toolset 1** to enhance the accuracy of maintenance decisions | **A.** PreVib (Prediction of Vibration level) | To predict the vibration level of a component/equipment in the next planned maintenance action or measuring moment. It is important to avoid sudden and dramatic changes in the vibration level and catastrophic failures. Prediction is done using specially developed Mechanistic model that re-assess its parameters and constants after each vibration measurement using non-linear regression |
| | **B.** ProFail (Probability of Failure) | To assess the probability of failure of a component (using machine past data) at need or when its vibration level is significantly high. |
| | **C.** ResLife (Residual Lifetime) | To assess the residual life of a component. To avoid failures and delivery delays, ResLife can be used to control whether it is possible for the production process to proceed according to the production schedule or not. The probability of failure and residual life are assessed using a modified form of Total Time on Test (TTT-plots) |
| | | |
| **Toolset 2** simulate and select the most cost-effective maintenance solution | **A.** AltSim (Alternative Simulation) | To simulate technically applicable alternative solutions suggested for a particular problem, and to select the most cost-effective maintenance solution using an intelligent motor. This tool is important to improve the cost-effectiveness of maintenance investments and planned actions. We use here the same sets of formulas used for MainSave for converting technical impact of maintenance on the company business to economic measures. The selection is done using well-defined criteria, such as the proportion of maintenance savings to the invested capital, total maintenance profit. |
| | | |
| **Toolset 3** to identify & prioritise problem areas | **A.** MMME (Man-Machine-Maintenance-Economy) | To identify and prioritise problem areas and to assess the losses in the production time. It is beneficial to plan maintenance actions according to a prioritising list justifying maintenance actions. A special model for analysing production process with respect to production time losses and the causes behind is used in this tool. |
| to map, follow up, analysis and assess the cost-effectiveness of maintenance | **B.** MainSave (Maintenance Savings) | To monitor, map, analyse, follow up and assess maintenance cost-effectiveness, i.e. maintenance contribution in company profit (maintenance savings & profit). It is a reliable tool for securing cost-effective maintenance actions. A set of formulas for converting technical impact of maintenance to economic impact on the company business are used for Main Save. |

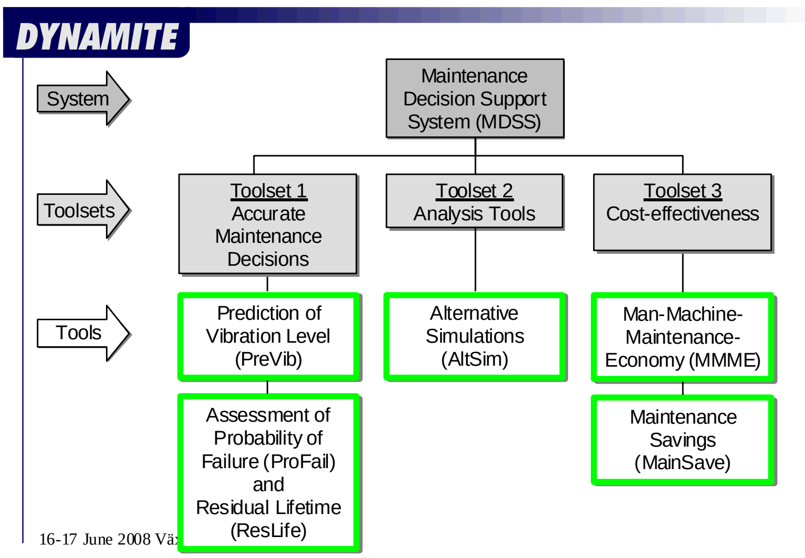


Fig.6.1. The MDSS Maintenace Decision Support System of strategies for cost-effectiveness.

# 7 DynaWeb integrated solution

In order to solve software related technical issues and to integrate the work in Dynamite project a Software Team was nominated. The software team discussed issues related to the programming tools and techniques used in the project and tried to unify the programming work and support the communication between various modules developed by various partners in Dynamite.

The Software Team members created a document/deliverable that describes the programming techniques used in programming the software modules of Dynamite project “D7.6 A Short Tutorial on How to Build Web Services, Agents and PDA Software”. Even though the title suggests that the document is not big in size it in the end became a 130 pages long document containing the most important aspects and guidelines for programming Dynamite modules. During this process of definition of the basic rules for programming it was realised that the challenge on how to organise the communication between various modules of Dynamite had not been solved in the Description of Work (DoW) i.e. the project plan. After long discussions in a separate meeting the decision was made to rely on a common database when integrating the various software modules. The decision was not easy to make especially because many of the partners already had some maintenance related software together with various database formats. However, it was realised that here lay the key to success of Dynamite i.e. it could only succeed if all the modules could communicate together and therefore a common ground was needed. In fact the whole idea in e-Maintenance is to be able to pass information to where ever it is needed so the correct maintenance action can be taken at the right time using effective methodology.

When the decision had been made to rely on a common database for data exchange between the Dynamite software modules it was a logical decision that the database should be Mimosa. Why to choose Mimosa? Mimosa organisation gives the following definition “MIMOSA is a not-for-profit trade association dedicated to developing and encouraging the adoption of open information standards for Operations and Maintenance in manufacturing, fleet, and facility environments. MIMOSA's open standards enable collaborative asset lifecycle management in both commercial and military applications.” Clearly this is the optimal strategy for an international project aiming for collaborative work and integration of results.

As such Mimosa is relatively big containing hundreds of tables. Mimosa definition covers issues related to measurements, condition monitoring, diagnosis, prognosis and management of maintenance work orders etc. Rather soon after the adaption of Mimosa it became clear that it was not an easy step for such partners that were not used to working with relational databases. Even though Mimosa is well documented and it is easy to download and install to run e.g. under SQL Server it is not an easy step to start using a database in a logical way. In fact quite a lot of effort was spent in discussing how Mimosa should be used in order it to be an effective tool.

The common Mimosa database was installed in the project server at IB Krates located in Tallinn. IB Krates also built a clever user interface to help the use of Mimosa and especially the manual input of data into Mimosa. After using Mimosa for data exchange all partners by the end of the project agreed that the decision to go for Mimosa was the right decision to make and that in fact no other solution is seen to have had a similar effect in supporting the integration within Dynamite. Figure 7.1

shows the communication within DynaWeb in simplified flowchart format. As can be seen in Figure 7.1 Mimosa database is the central point where most of the data goes and where it can be read from. As can be seen there is also communication between various modules on module to module basis following the same common data format.

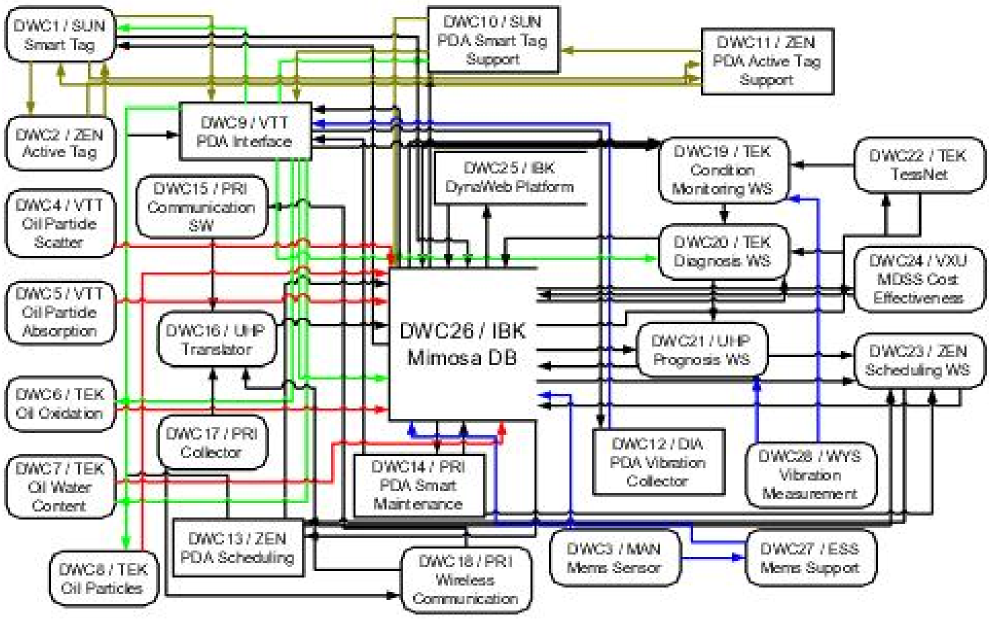


Figure 7.1 Simplified flowchart of the communication within DynaWeb through Mimosa database.

## *8 DynaWeb demonstrations*

DynaWeb demonstrations were carried out in industrial environment on global level, with milling machine, machine tool, foundry hydraulics and a maritime lubrication system.
The functionality of the DynaWeb and its components were tested and demonstrated in the following way:

- demonstrations were performed in 4 different test sites at Fiat, Volvo, Goratu and Martechnic,
- technical and economical evaluations of these demonstrators were carried out and
- recommendations for further implementation, development and industrialisation were done.

The following results were achieved on the four demonstration sites:

1) Fiat tested and demonstrated the integration between 25 DynaWeb hardware, software components and services. The demonstration was done in an industrial machining centre similar to what is used in car production. Detailed results are available in the technical reports. As a summary of the demonstration:

- The overall results are extremely positive, with technical and economical feasibility proven.

- The level of quality of components and adequacy to requirements was high, with people extremely dedicated to enhancing their components and testing them onto the demonstrator.
- As expected, integration was not straightforward and required a major effort from all involved partners.
- Unfortunately some components were not delivered on-time and thus not integrated.

2) Volvo tested the oil sensor system from Tekniker designed to measure the level of oxidation of the lubricant by spectroscopy of visible light. The demonstration was done in a hydraulic system in real industrial environment, production line in the foundry. In conclusion:

- The oxidation sensor hardware and software worked fine in the foundry installation.
- The environment in the foundry at Volvo was extremely dirty which was a good test for the sensor but made it impossible to have the computer at the same location. The sensor required a continuous low speed oil flow without air bubbles and at a low oil pressure. The sensor signal was jumping up and down depending on e.g. irregular oil flow, air bubbles etc. and made the interpretation more difficult and not straight forward.
- Volvo IT policy made it almost impossible to demonstrate communication with the Mimosa database at external server but a one-way web service communication to store data in the Mimosa database was created by Tekniker and included in the software and tested finally.

3) Goratu tested several DynaWeb components and their communication to the Mimosa Database.

- The VTT Particle Scatter lube sensor for hydraulic system, the TEK water content lube sensor for cooling system and the Wyselec vibration measurement system for spindle vibration were implemented at a Goratu machine, and the data collected where sent to the Mimosa Database located at IBK server. All the data collected provided great information for Goratu, who did not have any kind of information related to these issues. Apart from this, the web services provided an important tool for machine reliability. Web services allow Goratu to implement the online diagnosis and condition monitoring, which was impossible until now.

- The hand held vibration unit and the PDA maintenance user interface were tested too. These allow inserting new assets on the database and doing measurements using a PDA, which due to its size is very comfortable for the user.

- This demonstration gave new feedback to Goratu, who will use this information for machine improvements and new utilities for the customers. The innovation is very important, but some improvements are needed for a full implementation in an industrial environment, higher flows and pressure for sensors and better filters for vibration system.

4) Martechnic, the demonstration consisted of a simulated application of a stern tube bearing/tail end shaft assembly from an 8000TEU container ship. For logistical and security reasons this demonstration could not take place on board the ship. Specially designed test rig conditions on board a ship were replicated and the cycled lube oil was progressively contaminated with water and particulate matter.

- The demonstration which ran for nine days evaluated four sensors (one from Tekniker was not enabled for DynaWeb communication). The other three (two from Martechnic and one from VTT) performed satisfactorily communicating their results via two separate routes to the MIMOSA database.
- The demonstration was deemed a success and the economic scenario surrounding this application clearly demonstrated considerable benefits from applying the DYNAMITE concepts.

# 9 Standardisation issues

At the beginning of the DYNAMITE project some standards already existed that could influenced on the investigations and developments to be done. The main standards were EN13306 Maintenance Terminology, ISO/DIS18436-2 & ISO13374 (condition monitoring purpose); IEEE 802.11x and IEEE 802.15 (communication purpose); EN457:1992- ISO7731:1986, EN418:1992, EN60204-1:1997/IEC60204-1 (Safety of machinery); IEC6224; MIMOSA OSA/CBM, IEEE 1232 (interoperability purpose).
Among these standards, MIMOSA (Machinery Information Management Open Systems Alliance) was used to support the integration issues in DYNAMITE as the key pillar. The interest for the DYNAMITE components to be MIMOSA compliant is to ensure that information can be freely exchanged with all other MIMOSA compliant applications without the necessity of any customized interpreter or wrapper.
The results issued from this compliance and detailed in most of the deliverables of DYNAMITE, represent potential material for current standardisation initiatives in two main aspects:

- MIMOSA-based initiatives to develop standard in Maintenance area to support integration issues. Indeed MIMOSA is not really today a standard approved by all but initiatives advocated by International Organisation are referenced to MIMOSA for normalising “interoperability profiles” between all maintenance processes. Some modifications on MIMOSA issued from DYNAMITE, could impact, for example, the proposal ISO TC 18435-1 – Industrial automation systems and integration – Diagnostics, capability assessment, and maintenance applications integration – Part 1 to 5.
- Wireless-based initiatives to focus on wireless monitoring and alerting needs for the industries. Such initiatives such as ISA 100 Wireless Networking Committee which is progressing toward its first standard ISA100.11a, are intended to provide reliable and secure operation for non-critical monitoring, alerting, supervisory control, open loop control and "soft" closed loop control applications. Taking into account results of tests done on PRISMA Gateway and Web-Services, DYNAMITE could impact the first thinking on ISA100.11a.

Thus it can be expected that a future challenge after DYNAMITE could be to develop suggestions to launch work at several national levels within the national standard organisations (e.g. AFNOR in France) to push DYNAMITE results (Interoperability-Integration aspects; Wireless aspect) as a contribution to these new standards for improving the initial version (CD or DIS format) to lead to last one (IS format).

## 10 Conclusions

1) A pioneering e-maintenance solution named DynaWeb was developed. It is based on scenario analysis of future industrial needs and trends for plant operators, OEM manufacturers, transportation and consulting companies.
2) DynaWeb is a flexible web distributed ICT structure capable of multilevel condition monitoring and maintenance data treatment with common MINOSA structure, internet web services, training services and decision support based on technical and economical considerations.
3) DynaWeb consist of 28 integrated hardware and software components. They include smart MEMS sensors with energy harvesting, on-line lubrication sensors, smart tags for identification and location of components, maintenance actions supporting handheld mobile computers (PDA), wireless communication and a strategic and economical decision support system.
4) A condition monitoring data and statistically based decision support system MDSS was developed. It includes toolsets for accurate maintenance decisions, maintenance analysis and cost effectiveness.
5) DynaWeb components and the integrated structure was successfully tested and demonstrated on global level, with milling machine, machine tool, foundry hydraulics, maritime lubrication system and automatic stamping machine industrial installations.

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**http://osiris.sunderland.ac.uk/~cs0aad/DYNAMITE/Index.htm**

**NEW web site** **http://dynamite.vtt.fi/**