MELISSA

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Study of MELISSA Control System architecture and trade-off

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1 SCOPE

This document is the result of the study and trade-off of possible MELISSA Control System Architectures. Chapter 3 explains the process followed to specify a set of potential architectures. Chapter 4 provides some quantification of these MELISSA Control System characteristics to size architectural elements properly. Chapter 5, devoted to current trends in Control System Architecture implementations, identifies some attributes resulting from an overview of the current market trends and user requirements, used to perform the architectures evaluation. Chapter 6 presents a review of the current technologies (HW and SW) that can be applied in the implementation of a Control System. In order to obtain some industry assessment, several technology providers and MELISSA partners with expertise in this field have been consulted. Chapter 7, devoted to Space System Architectures, addresses some examples of Space Control Systems implemented and currently in use. Chapter 8 – Current Pilot Plant Control System implementation, reviews the Control System, which is going to be updated, stating the advantages and drawbacks of this implementation. Chapter 9 – Proposed MELISSA Control System Architecture, presents the recommended architecture concept and sets some assumptions for the evaluation process that follows in Chapter 10 – Architecture Trade-off. There, the various proposed architecture implementations are presented, hardware and software for the different levels are identified and finally an evaluation and trade-off of the proposed architectures is performed. Once the architecture is selected, different products that can implement it are evaluated in Chapter 11. Finally, the study conclusion, explaining the main characteristics of the selected system and including the schematics of the selected architecture, is presented in Chapter 12.

2 APPLICABLE AND REFERENCE DOCUMENTS

2.1 Applicable documents

[A1] **MELISSA. Adaptation for Space, Phase 1. Statement of Work**.TOS-MCT/2000/2977/ln/CL. Issue 5. April 2001.

[A2] **MELISSA. Adaptation for Space-Phase 1. Proposal issued by NTE**. MEL-0000-OF-001-NTE. Issue 2. October 2001.

2.2 Reference Documents

[R1] **Definition of the control requirements for the MELISSA Loop**. TN 72.2. Version 1. Issue 2. November 2002.

[R2] **Preparation of the Physical Realisation of the MELISSA Ecosystem.** ESA YCL/CHL 1609 November 1992

[R3] **Dependability Technical Analysis Specification.** TN 62.9. ADERSA, November 2001.

[R4] **Photoheterotrophic Compartment Set-up.** TN 37.6. UAB, February 1998.

[R5] **Nitrifying Compartment Studies.** TN 25.310. UAB, September 1996.

[R6] **Set-up of the Photosynthetic Pilot Reactor.** TN. 37.2. UAB, April 1998.

[R7] **MELISSA CONTROL SYSTEM: Software de control para la planta piloto del proyecto MELiSSA.** UAB**,** Javier Mengual Sánchez, Ramón Vilanova Arbós, February 2002.

[R8] **Preliminary Review of the MELISSA Pilot Plant Final Loop.** TN 47.3. UAB December 2000. Draft version, Issue 0.

[R9] **OMAC Baseline Architecture, Functional Requirements**. Version 1.0 25 Jan 2002.

[R10] **International Space Station Familiarization**. NASA - Mission Operations Directorate. Space Training Division. July 31, 1998.

[R11] **Life Sciences and Environmental Engineering and Management.** Research & Technology 1999. NASA – Kennedy Space Centre.

[R12] **MEL-3200-MN-013-NTE. MELISSA SPACIALISATION Phase 1.** MINUTES of MEETING at NTE. Control System Architectures Trade-off. October 9, 2002.

[R13] **Instrumentation et Systèmes.** December 2001. N. 214.

3 INTRODUCTION

In order to perform the evaluation of possible Control System Architectures for the MELISSA loop in a structured manner, some steps have been identified:

1. - From the MELISSA Control System Specifications gathered in [R1], and from MELISSA partners (ADERSA (F), UAB (E)) inputs, an attempt to properly dimension the system has been made and related characteristics have been quantified. Thus, sizing in performance, real-time data size, historical data size, data rate, number of sensors/actuators, number of variables, cycle time between levels, etc. have been investigated.

2. - MELISSA Control System should be a long-term facility therefore current trends have been studied in order to propose architectures in line with them. Thus, a review of current Control Systems common user requirements, hardware and software availability and experts' opinion has been considered. MELISSA Control System technologies need to be supported for several years (>5). Therefore, emerging technologies should be checked because some of them will be widely available in the near future. In addition, technology is continuously changing the risk exist that selected devices become not supported by vendors in the coming years.

3. - To find Space Systems synergies some implemented space control systems have been reviewed, analysing implementation from the engineering perspective, and placing special attention to communications, reliability, maintainability and modularity aspects.

4. - In order to understand, and also overcome, some limitations of the current MELISSA´s Control System in place at the UAB, it has been reviewed both "in situ" and through the existing documentation.

All these steps lead to a conceptual architecture definition and to a set of architecture implementations. This is followed firstly by a trade-off to select which is the most suitable implementation and secondly, by specific trade-offs to tailor the definitive hardware and software choices to deploy the selected architecture.

4 CHARACTERISATION OF THE MELISSA CONTROL SYSTEM

The MELISSA loop can be identified as an industrial continuous process where basic materials are transformed into an elaborated product. The goal of this process is the elaboration of a product whose quality and quantity can only be achieved according to specifications if the functional conditions are driven to well-determined values. Perturbations of different nature appear in the process and the use of a control system becomes mandatory. In addition, as MELISSA is essentially a Life Support System, human beings will be eventually depending of MELISSA's products. Therefore, the Control System must assure the continuity of the process, with good reliability, which will affect directly safety. The Control System must also be fault tolerant and easy to repair.

4.1 Control Levels

To assure good functional conditions in a complex system, it is convenient to break it down into several levels described hereafter.

Level 0: Local.
It is composed by the physical system, or process, under control equipped with sensors that provide measured data used to modify, based on a fixed strategy, the values of the commanding variables.
In the case of MELISSA, this level can be mapped to single variable, fast controls. Inside each compartment, many examples of level 0 regulation can be identified: reactor temperature regulation, regulation of incoming product quantity to a reactor, control of light power in a photo-reactor, etc.

Level 1: Process Control.
Regulation of significant processes output variables, which are provided by appropriated instrumentation and define the operation of the plant.

In MELISSA, this level can be identified to the multivariable regulations, whose time responses are in general higher than in level 0, as for example the control of biomass density in a reactor.

Level 2: Optimisation
This is a new functional system layered on the physical process. Its outputs correspond to the Level 1 set points and its inputs will be quality and quantity measurements. Sometimes, redundant variables are also available to allow the use of more advantageous combinations.
The plant is intended to deliver certain products whose quality and quantity will depend on the incoming products as well as on the commands provided by the control system. The objective in this level is to fix the plant's operation in such a way that the quantity and quality specifications are ensured while production costs are minimised.

At this time, in MELISSA, quality optimisation could be related to aspects like contamination control between compartments, or the control of the quality of the transmitted flux. From a Space System perspective, likely costs will be driven by Melissa's volume and weight. Therefore, Level 2 should contribute to the overall system optimisation. For instance, reducing recycling time, which in turn could result in a reduction of intermediate storage buffers, or even a reduction of the entire system volume.

Level 3: Production planning
In general terms, this planning responds to the conditioning of the plant's production attending to the market needs, existing stocks etc. This activity is well supported by the use of optimal commanding strategies and the consideration of dynamic aspects. Indeed, the success of the efforts carried out at this level is linked to meeting the objectives in lower levels.

In MELISSA, one example of Level 3 activity would correspond to the planning of the reactors' activity and the product quantities as function of the scheduled menus and crew activity. Weekly or longer term planning for the higher plants compartment, could also be another example.

4.2 Control System Performance

Each of the above levels has its performance requirements to guarantee an optimal control. Thus, fast calculations are required in the lowest levels, whilst highest levels' algorithms manage a large volume of data. Nevertheless, as shown in the following table, cycle time for the higher levels control algorithms is relatively high, and from the current estimations, the number of fast loops at every compartment is relatively low.

Level	**Description**	**Cycle time**	**Estimated Number**
0	Local control systems	<1s	20 per compartment
1	Dynamic control	1s to 5 hours	20
2	Optimisation	1 day	TBD
3	Planning	About a season	TBD

It is expected that the Supervision function will receive a high data rate, which implies the management of a large data volume. Data rate has been estimated taking as inputs the number of variables per compartment and refresh time from [R1].

Compartment	**Fast Variables (=1 sec.)**	**Slow Variables (>1 sec.)**
Compartment I	5	30
Compartment II	13	19
Compartment III	27	4
Compartment IVa	15	4
Compartment IVb	TBD	TBD
Crew Compartment	TBD	TBD
Compartment Connections	74	74
Total	**134**	**131**

Considering the worst case, but excluding streaming devices such image acquisition systems, which should be handled locally to avoid interference with the rest of the plant, a maximum of 4 KB/s has been estimated. Therefore, Supervision software and hardware shall be dimensioned to support updating variables at least at this rate.

4.3 Control System Data Management

Data Management will be archiving a large volume of data in real time and, in addition, it should allow access by the control algorithms and to historical data.

Two types of data can be defined:

- Analogue data: stored in periods of time (1s, 1min, 1hour, etc.)
- Digital data: stored at each change

The data size estimation that the system is going to manage with all compartments completed and interconnected taking into account the value of 4 KB/s is:

- ~ 345 MB of daily data
- ~ 1 GB per year (recycling data every day).
- ~ 60 GB per year (recycling data every 6 months)

This is a considerable amount of data and therefore, special attention should be given to Data Management. Possibilities for reducing the data volume are storing data max, min and average at fixed intervals over the sampling time, or classifying variables by its importance storing only full history when mandatory.

It is also advisable to differentiate between real time data and historical data and store them in different databases. Storing real time data is a virtually continuous process, while historical data storage is done at fixed intervals. Accessing the historical database, when needed, could impair the real time data storage process. Therefore, it is advised to locate both databases in different physical supports. Real time database and Supervision SW should be placed in the same server to simplify the data transfer operations. Historical database should be stored in a separate server. This partition would also allow maintaining a restricted access to the real time database while access to the historical database could be less restrictive.

5 CURRENT TRENDS IN CONTROL SYSTEMS IMPLEMENTATION

Control System technology is a very conservative domain, which implies that technology changes are slowly incorporated. Two trends can be identified:

- Those in favour of the Open option, supporting more flexible and inexpensive implementations, as the OMAC Users Group [R9],
- Those in favour of specific hardware (mostly automation technology manufacturers), that lead to proprietary systems and force customers to follow manufacturer evolution.

Nowadays, these two opposite trends coincide in some aspects. For example, Switched Ethernet is being introduced widely whereas in the recent past was strictly forbidden. In fact, it is becoming the driving factor of commercial campaigns of some vendors, as for example Schneider’s Transparent Factory architecture specification. Another standard that is becoming widely available from the Automation manufacturers is the IEC-6-1131-3 languages collection standard, which allows preserving the investment in learning PLC programming.

The OMAC Users Group promoted a set of requirements for control systems in order to achieve an optimal Return of Investment (ROI).

- Open: Allows integration of Commercial of the Shelf (COTS) Hardware and Software components into a “de facto” standard environment.
- Modular: Functions are implemented modularly which permits “plug & play” of hardware and software platforms.
- Scaleable: Enables easy and efficient reconfiguration to meet specific application needs across a broad spectrum of different size implementations.
- Economical: Achieves a low life – cycle cost
- Reliable & maintainable: Support robust plant floor operation (maximum uptime), expeditious repair (minimal downtime), and easy of maintainability.

Automation technology manufacturers are researching factors that differentiate them from the available options and the movement to more flexible architectures is a factor gaining consideration. The determinant aspect is reliability. Hardware and Software provided by these manufacturers has been formally tested in real, rough industrial environments and all them can deliver key reliability figures such as Mean-Time Between Failures (MTBF), Mean-Time Between Repair (MTBR), etc.

In conclusion, as reliability is a driving characteristic for the MELISSA Control System implementation, the technology choice must look for hardware and software where these attributes are available and provide enough confidence degree.

6 AVAILABLE INDUSTRIAL HARDWARE & SOFTWARE

Several commercial hardware and software could be selected to implement a Control System and the choice directly impacts on the architecture selection. In this chapter a list of generic types of hardware and software are proposed without specifying particular products or vendors.

Controllers

- **Programmable Logic Controllers (PLC)**: robust and reliable systems that use industrial control buses to communicate, with high performance in process control algorithms. Software Development tools are vendor specific, some of them supporting IEC's standard languages collection.
- **Distributed I/O**: Modular systems that allow distribution of computing power and acquisition modules through the plant. Software Development tools are vendor specific, some of them can use general-purpose development languages.
- **Embedded PC**: Small, packed size PC-based computers. Board design is specified in the standard PC/104, allowing many manufacturers to implement solutions for this standard. Software consists normally in a Windows Embedded OS, and some general-purpose development environment. Use of standard TCP/IP over Ethernet communications.
- **Industrial PC**: PC boards mounted in a passive bus in racks designed for industrial environments, with redundancy in power supplies and fans. Generally, they feature MS Windows operating system, with a general-purpose development environment (C, C++, Java, etc.). Use of standard TCP/IP over Ethernet communications.
- **Server PC**: High performance PCs with possibility of redundant power supplies, fans and hard disks. Need to be located in conditioned rooms. OS is normally an MS Windows environment with a general-purpose development environment (C, C++, Java, etc.). Use of standard TCP/IP over Ethernet communications.

Network

- **Industrial control buses** (Modbus, FieldBus, CanBus, etc.): Vendor specific implementations, normally configured as bus topology. Specially designed to cover long distances and to be real-time which results in slow data transfer velocities (~1Mbit/s).
- **Industrial Ethernet** (twisted pair, F.O. ring): Ethernet over fibber or shielded twisted pair cabling systems. Connection is normally done through switches. Data Transfer is 100 MBits/s, with expectations of reaching 1 GBit/s in the near future.

Supervision & Data Management

Server PC: High performance PCs with possibility of redundant power supplies, fans and hard disks. Need to be located in conditioned rooms. OS is normally Windows NT Server with a Supervisory Control and Data Acquisition (SCADA) package and a Relational Database Management System (RDBMS).

7 SPACE SYSTEM CONTROL ARCHITECTURES

Two examples of Control Systems developed for Space have been studied; the U.S. Segment Command and Data Handling System and the BIOPLEX Plant Growth Chambers Control System.

ISS Command & Data Handling U.S. Segment

The first example is the control architecture of the U.S. Segment of the International Space Station, currently in use. Information is taken from [R10] Section 2 (Command and Data Handling Overview), showing the tiered architecture of the Command and Data Handling (CDH). There are three tiers:

Tier 1: Redundancy in three identical computers. Two fault tolerant. Implements user interface, vehicle level software and other computer interfaces.
Tier 2: Redundancy in two identical computers. Single fault tolerant. Implements system specific software.
Tier 3: Redundancy by duplicating tasks among several computers. Redundancy in sensors. Implements Sensors/Actuators handling.

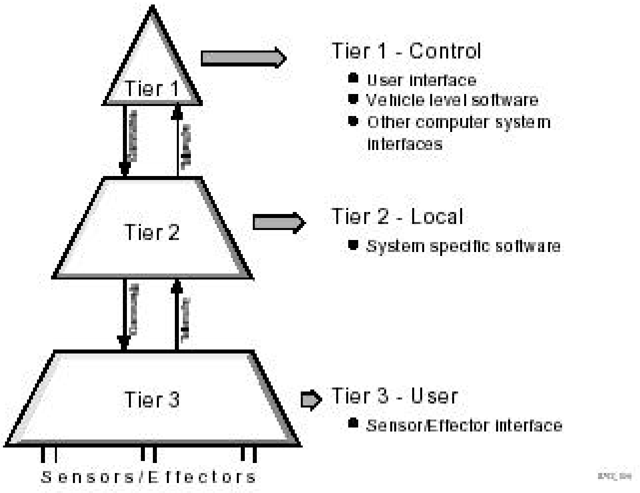


Figure 2-7. Conceptual view of CDH architecture

Processing units are formed as boards connected to a back plane in a box, similar to commercial computers thus permitting easy components replacement.

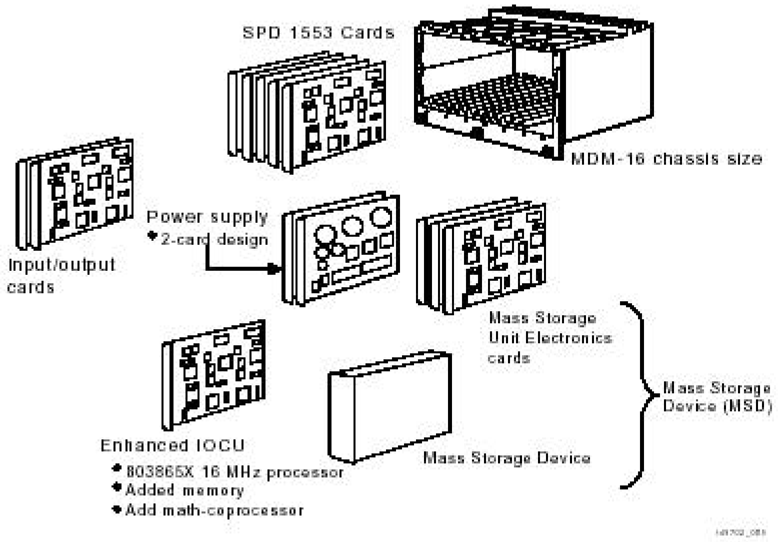


Figure 2-9. Typical CDH MDM

These boxes are based in Intel 386 CPUs, with cards for communications, Input / Output and power supply. It can be equipped with a Mass Storage Device (Hard disk).
At the network level, the standard MIL-1553B is used. This bus is doubled and therefore redundant, having only one bus active at a time. The two buses are placed in separated conductions. In addition, Ethernet is used to communicate with Payload systems.

BIOPLEX Plant Growth Chambers

The other example reviewed is the control of the BIOPLEX plant growth chambers, in NASA-JSC [R11]. There, the Control System is implemented with hardware manufactured by OPTO22. It is built up using Distributed I/O, with some devices called “Brains” acting as controller devices. These devices communicate through a standard TCP/IP network, and programming tools are vendor specific. System is interfaced with common PCs, from where devices are monitored and programmed.

8 CURRENT MELISSA PILOT PLANT CONTROL SYSTEM

The existing control system at the UAB´s Pilot Plant has been analysed and discussed with its users. Experience has confirmed that distributing the control functions into tiers was a right decision. Basic control functions are placed close to the compartment, which results in an effective form of performing small changes directly into the controller algorithms, using the controller displays and having direct visual inspection of the changes. More complex control functions, such as Dynamic Control, are placed in the Control/Command stations connected to the PLCs. The use of dedicated PCs allows the use of complex tools to develop and supervise these algorithms. Optimisation is placed in the GPS in communication with the Control/Command stations, which presents the same advantages than placing these functions in a PC. In addition, the breakdown of functions into levels improves reliability, allowing a failure in the upper level, whilst the local controllers continue with the programmed setting points.

Difficulty to communicate with the system using the present technology is one of the major problems of the current implementation. Control/Command stations are using mono-task OS and modern software and hardware have changed the interfaces in such a way that they are not compatible with this system. In addition, several control buses and protocols are used (RS-485, JBUS, ARCNET) at the same level, which adds complexity to the system architecture and reduces scalability.

9 PROPOSED MELISSA CONTROL SYSTEM ARCHITECTURE

After the studies, analysis, comparisons etc. described in the precedent chapters, a new architecture for MELISSA's Control System can already be proposed.

Based on the conclusions drawn from the above mentioned studies two elements within this new architecture are already set forth, first the distributed architecture and second the use of Ethernet in control networks. The next stage is to define the conceptual architecture that meets the MELISSA needs and to provide few possible conceptual implementations.

9.1 Distributed Architecture

The current implementation of the control system at the UAB's Pilot Plant [R7] has confirmed that the distributed (versus centralised) architecture is a good choice, as it provides the following characteristics:

- Reliability: failure in upper levels does not affect lower levels.
- Scalability: dividing the functions into different separated devices allows scaling precisely where necessary.
- Performance: again separating functions into different devices allows the use of specific hardware that will better satisfy performance requirements at each level.

Distributed architecture is therefore selected for the new Control System.

9.2 Control Network

It has been observed that a current trend in Control Systems implementation is the increasing use of Ethernet in control networks. At present, almost all manufacturers offer products for Industrial Ethernet, configuring a backbone to communicate all control devices of the plant. Switched Ethernet has become deterministic, fault tolerant and covers large distances.

Additionally, Ethernet offers the possibility of interconnecting heterogeneous devices using wide available interfaces, reducing costs and allowing the selection of products from a large number of vendors.

For these reasons, it is proposed to implement Ethernet in the new MELISSA's Control Network.

Redundancy is necessary to implement a reliable network, since a failure in a network device or a broken network segment, will prevent to communicate with some or even all controllers. Therefore, network devices, network interfaces and cabling need to be redundant.

Ethernet networks can be implemented using several technologies and topologies. For control systems, fibre optics (FO), which allows a ring configuration with inherent redundancy (FDDI ring over Ethernet) and Shielded Twisted Pair (STP), configured in start topology are the most commonly used.

A trade-off, presented hereafter, between these two options has been performed to select the most appropriate option for MELISSA.

Fibre Optic Redundant Ring

Advantages	Disadvantages
- Intrinsically Safe for hazardous environments (inflammable, gas, etc.) - Electrical isolation between points. - Electromagnetic, RF or lighting isolation. - Long distances (>100 meters) - Tolerant to segment breaks	- Not appropriate for short distances (<5m) - Ring requires one switch for every local point (and total number of switches doubles in a redundant configuration). - FO is difficult to manipulate

STP Redundant Star

Advantages	Disadvantages
- Reduced number of network switches (only two switches of increased capacity) - Easy to manipulate - Suitable for short distances	- It is not intrinsically Safe - Does not allow Electrical isolation between points. - Segment breaks need to be detected by software.

Considering that for MELISSA Plant (current and future location):

- Distances between compartments are short (all located in the same room with distances around 5 meters between compartments, and segments over 100m are not envisaged),
- Electrical isolation between compartments is not needed (grounding is common),
- It is not located in a noisy environment,

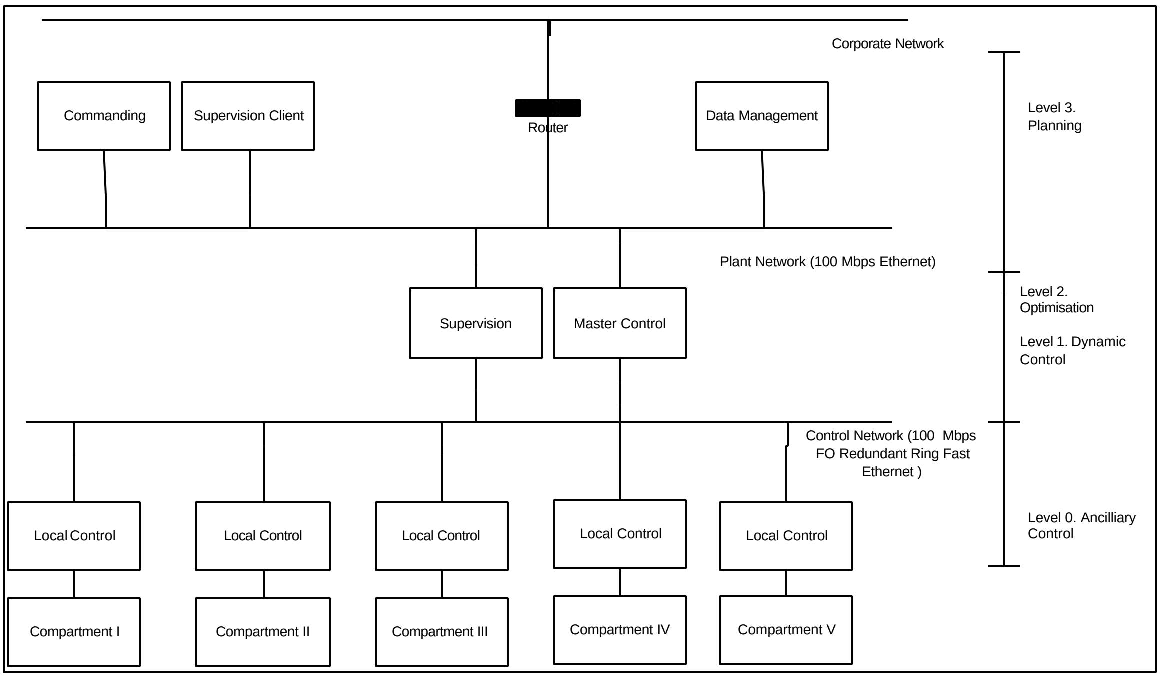
it is concluded that an STP redundant star configuration is well suited to implement the physical transport for the Control Network.

9.3 Conceptual Architecture

The proposed conceptual architecture is presented in the next figure. Each box in the diagram corresponds to a defined function in [R1]. Controller functionality is separated into Master Control and Local Control. A brief description follows:

- **Commanding**: Development, modification and debugging of control algorithms, Supervision displays and administration of the Control System.
- **Supervision Client**: Visualisation of Supervision displays, on-line modification of variables. Execution of Planning (Level 3) algorithms to modify lower level settings. It interacts with the Supervision Server.
- **Data Management**: Storage of historical data into the Historical Database by means of a Relational Database Management System (RDBMS). It allows access to extract data for analysis, reporting, diagnostics, etc.

- **Supervision Server**: Performs supervision tasks, storing acquired data to a Real Time Database by means of a RDBMS.
- **Master Control**: Dynamic and Optimisation Control algorithms (Levels 1,2).
- **Local Control**: local controllers (Level 0).



9.4 Architecture Implementation Proposals

The presented conceptual architecture can be implemented in several ways, since different kinds of software and hardware exist that are able to meet the functionality required at each level. Three implementations of this architecture are proposed and detailed below:

- Full PLC based architecture,
- Mix PLC/PC based architecture,
- Embedded PC based architecture.

These implementations are from the less open (which allows less integration of heterogeneous devices) to the most open. Openness provides the possibility of system evolution due to factors like modularity and scalability, allowing interconnection of different interfaces, easy replacement of parts, and adapt performance and reliability requirements specifically to each part. Unfortunately, we will see that openness is opposite to proven reliability. Therefore, the above classification also corresponds to the most reliable implementation to the less reliable one. In this case, “less reliable” means that manufacturers do not have available reliability measurements such as Mean Time Between Failures (MTBF), Mean Time Between Repair (MTBR), etc.

Notwithstanding that, a path to a Fault Tolerant configuration is possible for each proposed implementation. It is technically possible to implement fault tolerant systems, by means of redundancy and hardware failure detection, in many cases solutions are already available. However, it has to be taken into account that one of the major causes of problems in open systems is the easiness of changing the initial verified configuration. The same characteristic that allows flexibility increases the risk of a failure. Therefore, it is clear that in open systems a strict configuration control is mandatory to guarantee reliability.

We can approximate a definition for a Fault Tolerant configuration, taking into account that a detailed Dependability Analysis needs to be performed to obtain detailed specifications, and therefore this can only be a superficial approach. We will understand as a Fault Tolerant configuration the one that is transparent to one failure (First Failure Transparency). That is, all single-point failure elements are identified and there, redundancy can be technically implemented. It is understood that redundancy must be implemented from the sensors/actuators level to the mandatory control functions at the highest levels. Other kind of tolerated failures should be logic/data errors and leaks in performance. Logic/Data errors can only be prevented by duplicating and comparing data acquisition and calculations. Leaks in performance are detected by watchdogs programmed in each CPU. In addition, diagnostic algorithms can be used to detect malfunctions in system devices, running it at fixed periods.

Crash-down Failures: Crash down failures are prevented by implementing redundancy at all levels. CPU can be configured redundantly and the important factor will be the down time i.e. the time that the system is unattended while is switching from the failing CPU to the redundant one. Other elements, such as network switches can be configured redundantly and the network itself is also redundant as it is implemented by means of a double STP star.

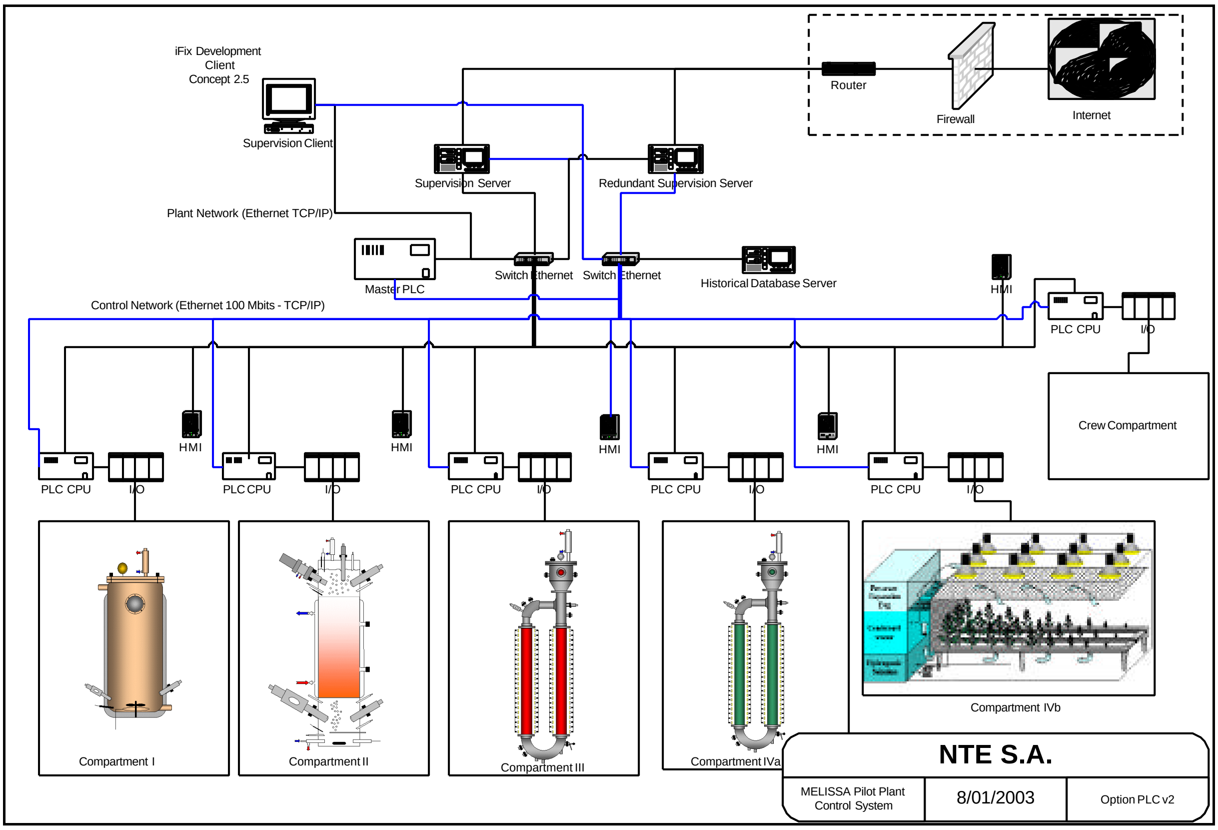
Logic/Data Errors: Logic/Data errors can be prevented by programming adequately the control algorithms. Indeed, data acquisition needs to be duplicated and at least two different sources for measuring need to be provided to allow this error detection. At the beginning of the algorithm, the two measurements are compared and in case of differences, an alarm or counter-measure can be initiated. In addition, calculations can be done separately and results synchronised by two or more CPUs, and again in case of differences, problem can be notified or counter-measures started.

Performance Leaks: Input/output operations, bad program operation (end-less loop) or hardware malfunctions that may cause the system to slow-down can be overcome by means of a watchdog. This counter needs to be rearmed at fixed time intervals when reaching zero value. Therefore, it provides the means for detecting an anomalous situation and trigger the appropriate recovery action (switching control to backup, restart it, notify an alarm, etc.).

Because reliability is a key issue in MELISSA Control System, once the Dependability Analysis [R3] would be mature enough, a detailed study as to how to implement a complete Fault Tolerant Control System needs to be performed.

Figures shown in the following sections depict three proposed implementations to the above explained conceptual architecture (PLC, PLC/PC and Embedded PC options). Note that all figures display the nominal as well as the redundant system.

9.4.1 Full PLC based architecture

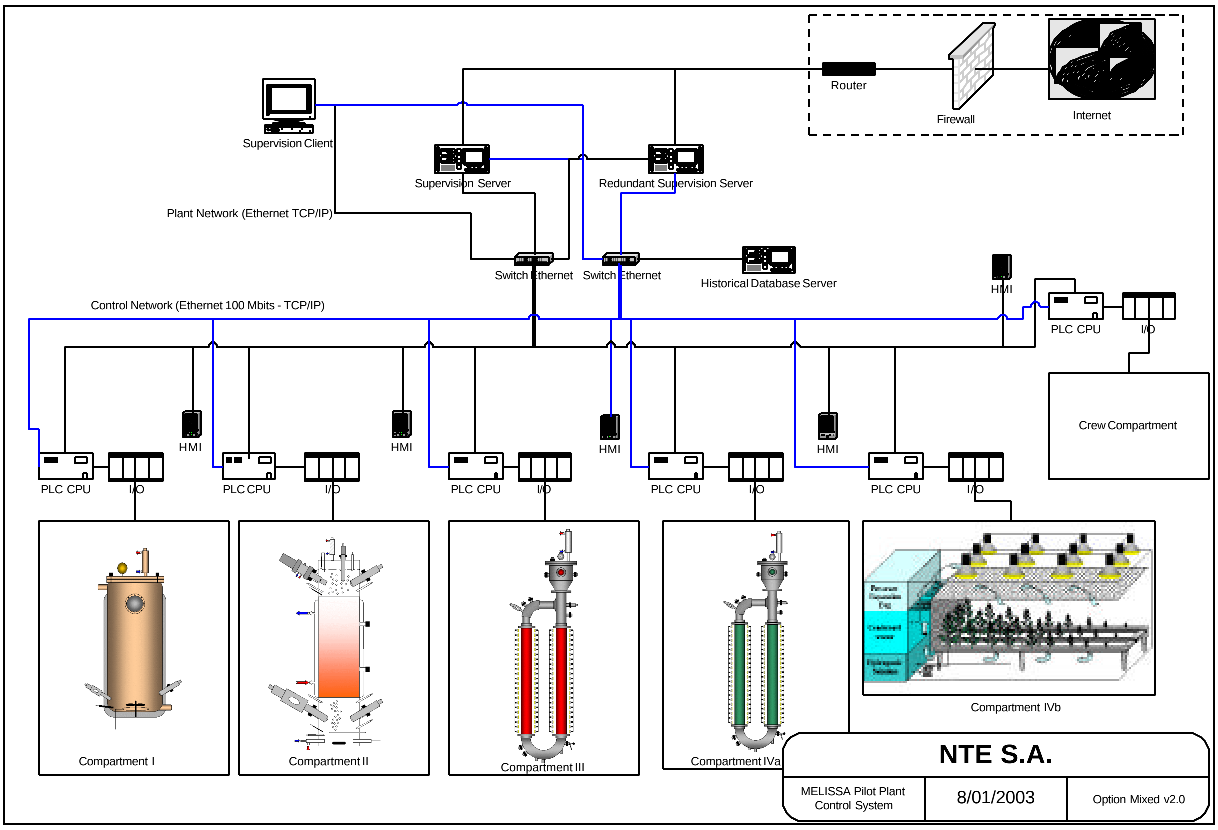


Level 0	Local controllers are implemented by means of a Programmable Logic Controllers (PLC) connected through Ethernet to the Control Network.
Level 1,2	Dynamic control & optimisation is implemented in a Master PLC. This PLC is communicating with the lowest levels PLC through the Control Network.
Level 3	Planning & scheduling is implemented in a Client Computer. This Client Computer is communicating with the Plant through the Plant Network.

The use of PLC increases reliability because they are devices designed specifically for system control, and reliability is an essential issue in these devices. The majority of vendors offer mounting kits that guarantee a “hot-standby” configuration, so when the master CPU stops, the backup takes over and starts controlling. The switching is completed in milliseconds, and therefore the effect is minimised. In addition, reliability attributes such as MTBF and MTBR, among others, are available.

On the other hand, PLC are very restricted to the inter-operation of different vendor devices. Normally PLC can only handle devices from the same manufacturer or at least using the same control protocol. This can be a limiting factor in the Master PLC, since only devices from the same vendor can be directly controlled using this configuration and other devices such as image acquisition devices could not be easily integrated.

9.4.2 Mix PLC/PC based architecture

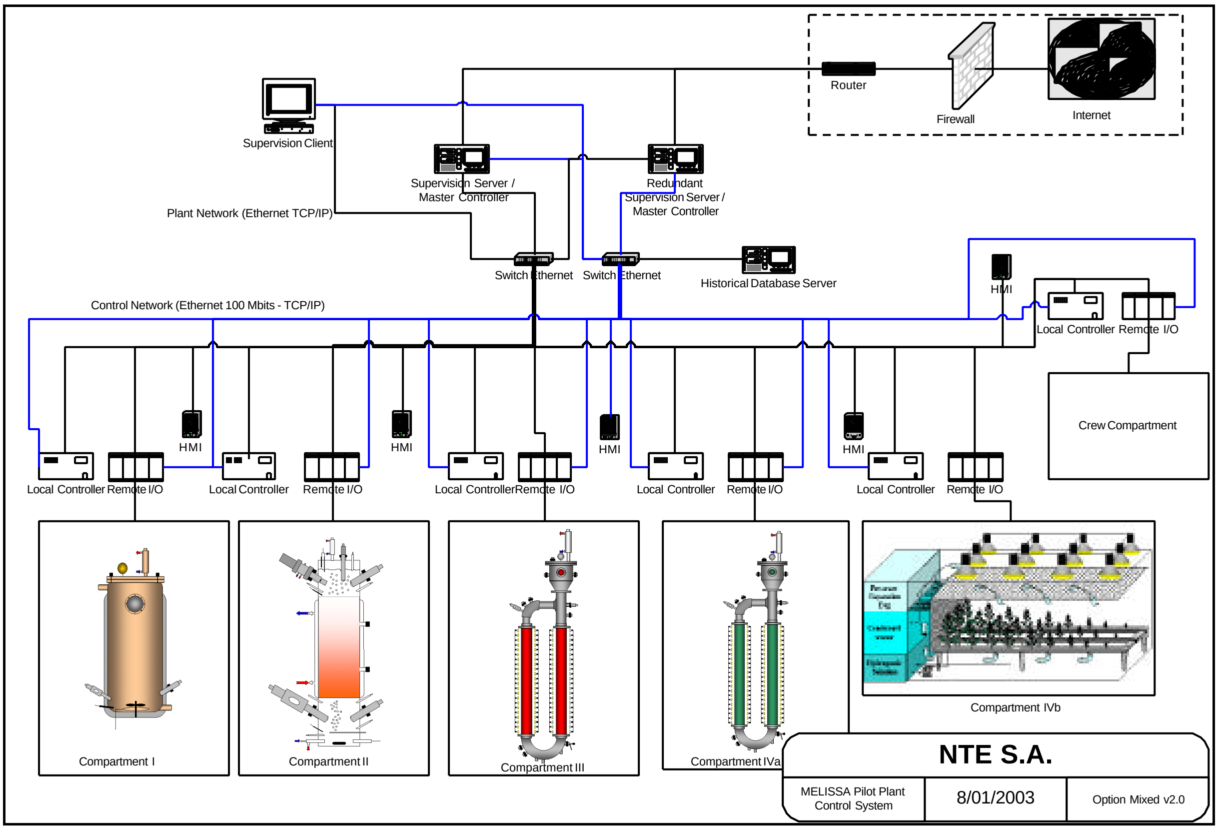


Level 0	Local controllers are implemented by means of a Programmable Logic Controllers (PLC) connected through Ethernet to the Control Network.
Level 1,2	Dynamic control & optimisation is implemented in a Server Computer. This Computer is communicating with the lowest levels PLC through the Control Network.
Level 3	Planning & scheduling is implemented in a Client Computer. This Client Computer is communicating with the Plant through the Plant Network.

Control of heterogeneous devices connected to the network is allowed by this configuration because several communication interfaces can be used in the Server. In addition, the control algorithms at Levels 1,2 can be implemented using general-purpose languages integrated to the Supervision Software.

Although Server is based in a PC architecture, reliability can be assured in several ways: implementation of redundant parts in the Server, that is, power supplies, fans, and hard-drives, and the installation of two servers in “hot-standby”. The most advanced commercial Supervision software allow the connection of two servers to the same network. In case of failure of one of the servers, the second takes over the control in a transparent manner for the lower level controllers and the Supervision Clients.

9.4.3 Embedded PC based architecture



Level 0	Local controllers are implemented by means of Embedded PC connected through Ethernet to the Control Network.
Level 1,2	Dynamic control & optimisation is implemented in a Server Computer. This Computer is communicating with the lowest levels PLC through the Control Network.
Level 3	Planning & scheduling is implemented in a Client Computer. This Client Computer is communicating with the Plant through the Plant Network.

In this configuration the local controllers are implemented by means of Embedded PC, adding more flexibility to the architecture:

- Providing large local storage capacity,
- Possibility of interconnection of heterogeneous devices
- Use of general-purpose development tools to implement the control algorithms.

The drawback is that custom implementations need to be developed to guarantee reliability in the same manner than offered by a PLC. In addition, diagnostic functions are not widely available.

10 ARCHITECTURES TRADE-OFF

In order to evaluate the proposed architectures the following selection of attributes has been performed:

Open: Incorporation of “de facto” standards and availability of several options in commercial hardware and software components. Not only at hardware interfaces level (ISA, PCI, etc.) but also at application programming interfaces (API), and network protocols.

Modular: Enables easy plug and play of system components without the need for significant reengineering. Changes in the system requirements can be implemented without dramatic changes in the architecture.

Scalable: Allow control modules to be configured, added, and/or removed from the control system in order to provide the control capability required by each application.

Maintainable: Architecture enforces maintainability reducing required skills and repairing time and enforcing maximum uptime and minimum downtime.

Performance: Process capacity of processing units and overhead caused by network protocols.

Reliable: Capability of being fault tolerant. Availability of dependability measurements such as MTBF, MTBR, etc.

Economical: Total costs associated to a control system, both acquisition costs and estimated life cycle costs, taking into account that open modular systems allow incremental upgrades and easy component integration.

Deployment: Effort to deploy system. Learning curves, different environment needs, estimated time to set-up systems.

Spacialisation: Synergies with space control systems.

Following the conclusions of the MELISSA Trade-off Meeting held at NTE’s premises in October ‘02 [R12], a weight has been given to these attributes. Reliability is the most important one, with a mark of 3, as it is directly related with safety and in the near future experiments with living beings will be performed. Maintainability and Performance are the following attributes, with a mark of 2. Finally, the remaining ones are marked 1.

Relative Weight	Attribute
3	Reliability
2	Maintainability, Performance
1	Open, Modular, Scalable, Economical, Deployment, Spacialisation

Attributes evaluation for each option are summarised in the following table:

	Open	Modular	Scalable	Maintainable	Performance
PLC Based	Less Open then is not possible to control directly heterogeneous devices. (*)	Replacement of modules is subjected to vendor possibilities. (*)	Options of scalability are vendor dependant.(*)	Easy maintenance due to unification of technologies.(***)	High performance due to proprietary protocols and specific design.(***)
Mix PLC/PC	Open only at high level, connection of heterogeneous devices implies the use of additional devices. (**)	Replacement of modules is restricted to vendor possibilities at local controllers. (**)	Options of scalability are vendor dependent at local controllers. (**)	Medium difficulty due to the use of several technologies .(**)	High Performance at local control. Medium performance at higher level due to the use of standard protocols.(**)
Embedded PC	Open allows the connection and control of heterogeneous devices. (***)	Replacement of modules is possible at any level. (***)	Options of scalability are open in all levels. (***)	More difficult due to the use of many different technologies.(*)	Less Performance due to the use of standard protocols at all levels.(*)

	Reliable	Economical	Deployment	Specialisation
PLC Based	High reliability due to hardware redundancy. (Hot stand-by configuration) (***)	Expensive to restricted vendor options. (*)	Easy due to unified vendor technology. (***)	PLC cannot be space qualified.(*)
Mix PLC/PC	Reliability is Hot Stand-by at local controllers level and High-availability configuration is possible at higher level.(**)	Medium, local control is restricted to vendor options. (**)	Medium, due to the use of several technologies. (**)	Architecture more similar to flight system.(**)
Embedded PC	Reliability at controllers level must be provided by software. High availability configuration is possible at Master Controller level.(*)	Low cost due to high availability of choices at all levels. (***)	Medium due to the use of several technologies. (**)	Architecture Similar to a flight system. Components can be substituted almost by one by one by qualified ones. (***)

Taking into account the attributes evaluation for each architecture and the associated weight, the **best-balanced solution is the Mix PLC/PC**. It delivers high reliability and is flexible enough to support the current heterogeneous devices and future demands.

11 PRODUCTS EVALUATION

In order to implement the selected architecture with actual HW and SW elements a products evaluation has been carried out.

One problem to overcome when performing such products evaluation is the knowledge that can be obtained to compare them. On one side, the use of the products is very restricted to the area where they are intended. For example, the experience from an automotive sector is not relevant to MELISSA. However, comparable architectures, especially from the reliability and safety standpoint, have been studied. For example, the oil and chemical sector is using highly advanced control systems, implemented using commercial hardware, where efficiency and reliability are essential factors. For example, the proposed local control "hot-standby" configuration presented later is based on an already implemented solution by a petro-chemical company (Repsol-YPF). In addition, vendors offer only limited information about the reliability and performance features of their products, and detailed information is difficult to obtain. Finally, it is noted that leader manufacturers of Control Systems hardware and software offer more and more, products with similar features.

Ideally, the best approach to perform the products assessment would be to implement several different choices and evaluate them on MELISSA in order to select the most suitable one. However, this approach is not possible due to time and budgetary constraints. Therefore, the evaluation that follows is based on the information obtained from vendors and other sources. The final selection has been performed taking into account:

- MELISSA Control System Requirements specification from [R1],
- MELISSA partners recommendations (ADERSA (F), EPAS (B), UAB(E)),
- Specialised press (http://www.controlengineering.com) and
- Market share [R13].

Products are selected attending to the following groups:

- Supervision Software
- PLC Controllers
- MMI

11.1 Supervision Software

In MELISSA, the Supervision system hosts the control system's user interface and control algorithms of levels 1, 2 and 3. Therefore, reliability must be assured in order to maintain the Plant in its optimal conditions and to avoid catastrophic deviations. At this level, downtime is not as critical as for the Local Control, since cycle time is approximately between 1 second and 5 hours, which should fix the maximum downtime for the system (1s).

At present, commercial Supervision Software products run on Server computers using Windows (only few over Unix) platforms. Most of them allow "hot-standby" configurations, where two identical computers are running, one as a master and the second as a backup, being continuously synchronised. The hardware should be configured to provide maximum uptime and existing options for increasing availability are redundant hard disks (raid configuration), power supplies and fans. In addition, performance needs to be checked to allow the data management at the given rates and disk space needs to be dimensioned according to data storage estimations (see Chapter 4).

A number of Supervision Software products have been screened (data obtained from *Instrumentation et Systèmes* – December 2001), attending to technical features and market share. Full results are documented in Annex A and the following table presents the SW brands with larger market share:

Product / Manufacturer	**Market Share (units sold in France)**
1. InTouch /Wonderware	20000
2. PcVue 32 7.1 /ARC Informatique	13000
3. Panorama /Coda Europe	6500
4. RS View 32 / Rockwell	6000
5. Factory Link / US DATA	4500

In addition, from CONTROL Magazine 2002 product awards (January 30, 2002), the following products have been selected by the magazine readers (500 responses) in the Supervisory, Control and Data Acquisition (SCADA) software category:

Product / Manufacturer	**Selected as the best product**
1. iFix / Intellution	23%
2. InTouch / Wonderware	14%
3. RS View 32 / Rockwell	9%
4. Honeywell	8%
5. OSI Software	6%

Taking into account these two rankings, the following four Supervision SW products are selected for an in-depth evaluation. Factory Link is included in the shortlist in spite of its low ranking because Schneider (one of the PLC suppliers best candidate) strongly recommends this SW for their products.

- **iFix**
- **Intouch**
- **RS View 32**
- **Factory Link**

The following attributes have been evaluated in detail for each of these SW and presented in the next table:

- **Supported Platforms**: Windows, Unix, others.
- **Reliability**: is redundancy/replication in at least two servers in “hot-swap” configuration allowed?
- **Client/Server**: is connection from any client allowed?
- **PLC integration**: Specific protocol support for the evaluated PLC.
- **Cost**: Compared cost (* Low, ** Medium, *** High).
- **Support**: are hot line, technical support, courses, etc available? (*None, **Some, ***All)
- **Maintenance**: are on-line changes in displays and attached algorithms, on-line debugging, simulation without connection to PLC allowed? (*None, **Some, ***All)

Product	Platforms	Redundant Servers	Client/Server	PLC Integration	Cost	Maintenance	Support
IFix	Windows	Yes	Yes	Full	***	***	***
InTouch	Windows	Yes	Yes	Full	**	**	**
RS View 32	Windows	No	Yes	Full (OPC)	**	***	**
Factory Link	Windows	Yes	Yes (TS)	Full	*	**	**

Compliance of selected products with requirements specified in [R1] has been checked.
(See Annex B for the results of the survey to the local distributors)

iFix

- Allows client/server through MS Windows Terminal Services, allowing connection from any client with Windows TS installed.
- Allow update application without shutdown.
- Operator actions are recorded according to FDA rules.
- Integrated report generation.
- “hot-standby” redundant server in a transparent way is allowed.

InTouch

- Allows on-line update of views.
- FDA rules compliant.
- DBMS is not included in the product
- Working in simulation mode without connection to the PLC is not allowed.

RSLogix

- Does not include transparent switch between “hot standby” PLC configurations.
- Does not allow a redundant Supervision Server.

FactoryLink

- Does not allow changes in external programs (DLLs) without shutdown.
- Client license is not floating and therefore access to the Supervision Server from any client is not allowed.

In conclusion the product **iFix SCADA Software** by Intellution (featuring iFix SCADA Server Only + iFix iClient Developer) has been selected since:

- It is the most functionally complete SW
- It presents a well-balanced cost/functionality,
- It offers a good customer service, and
- It is the best evaluated by the users (best product in the category by the Control Magazine 2002 product awards).

In addition, another important reason in support for the iFix choice is the fact that EPAS (B), a MELISSA partner company, is already using it successfully in several projects.

11.2 PLC Controllers

The PLC Controllers will run the Level 0 control algorithms. They should provide maximum reliability and performance, since the cycle time at this level can be lower than 1 second, support the number and types of estimated input/outputs and provide Ethernet connectivity. Reliability shall be assured by means of "hot-standby" configurations, with redundant CPU, and by allowing input/output redundancy.

The following products have been screened (data from *Instrumentation et Systèmes* – December 2001) attending to technical features and market share. Full results are documented in Annex C and the following table presents the most selected PLC brands:

Brand / Product	**Agencies /Distributors in France**	**Memory**	**Execution Time**	**Programming Languages**	**IO Capacity Digital /Analog**
Schneider / Quantum	**27/600**	**up to 2.5MB**	**0.8 µs**	**5 IEC**	**8192/2048**
Siemmens / S7 400	**15**	**up to 4MB**	**0.1 µs**	**4 of 5 IEC**	**131072 / 81935**
ALSTOM / Alspa C80	**10/17**	**up to 6MB**	**0.2 µs**	**4 of 5 IEC**	**32 / 12000**
Rockwell / ControlLogix	**9/50**	**up to 750MB**	**0.08 µs**	**3 of 5 IEC**	**128000 / 4000**

In addition, from CONTROL Magazine 2002 product awards (January 30, 2002), the following products have been selected by the magazine readers (500 responses) in the Logic Controller, Programmable category:

Category: Logic Controller, Programmable

Manufacturer	**Selected as the best product**
1. Rockwell – Allen Bradley	68%
2. Schneider Electric	10%
3. Siemens	5%
4. GE Fanuc	5%

Taking into account the above rankings, interviews with domain experts, key features as redundancy availability and high capacity performance and finally local, fast support availability for the products, the following PLC manufacturers and devices have been selected for a detailed evaluation:

- **Rockwell Automation - ControlLogix**
- **Schneider - Quantum**
- **Siemens Step7**

The following attributes have been assessed in detail, and the results reported in the next table:

- **Redundancy**: is "hot-standby" configuration possible?
- **Ethernet**: is Ethernet Network connectivity possible?
- **Cost**: Compared cost (* Low, ** Medium, *** High).
- **Support**: are hot-line, technical support, courses etc available? (*Low, **Medium, ***High)
- **Maintenance**: are on-line algorithms changes, "hot" replacement of damaged modules allowed? (* No, ** Partially, ***All).
- **Performance**: Compared performance (*Low, **Medium, ***High).

- **Development tools**: Support of IEC languages.

Product / Manufacturer	Redundancy	Ethernet	Cost	Support	Maintenance	Performance	Development tools
ControlLogix 5555 / Rockwell – Allen Bradley	Yes	Yes	*	**	**	***	IEC
Quantum 140CPU43412A / Schneider	Yes	Yes	**	***	***	***	IEC
S7 400 H / Siemens	Yes	Yes	***	**	***	***	Not IEC

Rockwell-Allen Bradley ControlLogix

- Platform allows redundancy in CPU by mounting in different racks two CPU configurations and I/O modules need to be mounted separately using Control Net Bus.
- Configuration allows up to 7.5 MB of user memory (evaluated device with 1.5 MB).
- It is programmable through IEC languages (only 4 of 5 supported) collection, using RSLogix software.
- Up to 128.000 I/O (up to 4000 analogue).
- Allows communications by Industrial Ethernet, but switches are third party.
- Switch over in 100 ms.
- Execution time is 0.08 ms per 1000 instructions.
- MMI interfaces are connected locally to one PLC.

Schneider Quantum

- Allows redundancy in CPU by mounting in different racks two CPU configurations and I/O modules need to be mounted separately using RIO (Remote Input Output) bus.
- CPU is an Intel 80486 at 66Mhz, integrates 2 MB of user memory, 896KB for programs and co-processor is installed.
- It is programmable through IEC languages collection (5 of 5 supported) using Concept 2.5 software.
- Around 6000 analogue I/O per CPU.
- Allows communication through Industrial Ethernet by means of a specific Ethernet module.
- CPU switchover time ranges from 13 to 48 ms after fault detection.
- Execution time ranges from 0.1 to 0.5 milliseconds per 1000 instructions.
- MMI terminals can interact with any PLC connected to the network.

Siemens STEP7

- User memory is up to 64 MB (evaluated system with 1MB), 768KB Program memory (384KB for programs and 384KB for data).
- Allows redundancy connecting I/O through Profibus-DP, and mounting CPUs in separated racks.
- Execution time ranges from 0.1 to 0.6 microseconds per instruction.
- Programming languages are not IEC.
- It supports up to 4096 analogue channels.
- MMI interfaces are connected locally to one PLC.

Because it has a well-balanced cost/functionality, and taking into account ADERSA´s experience with the manufacturer (good relations, known implementations, good reactivity to problems and good service) **Schneider Quantum PLC** has been selected.

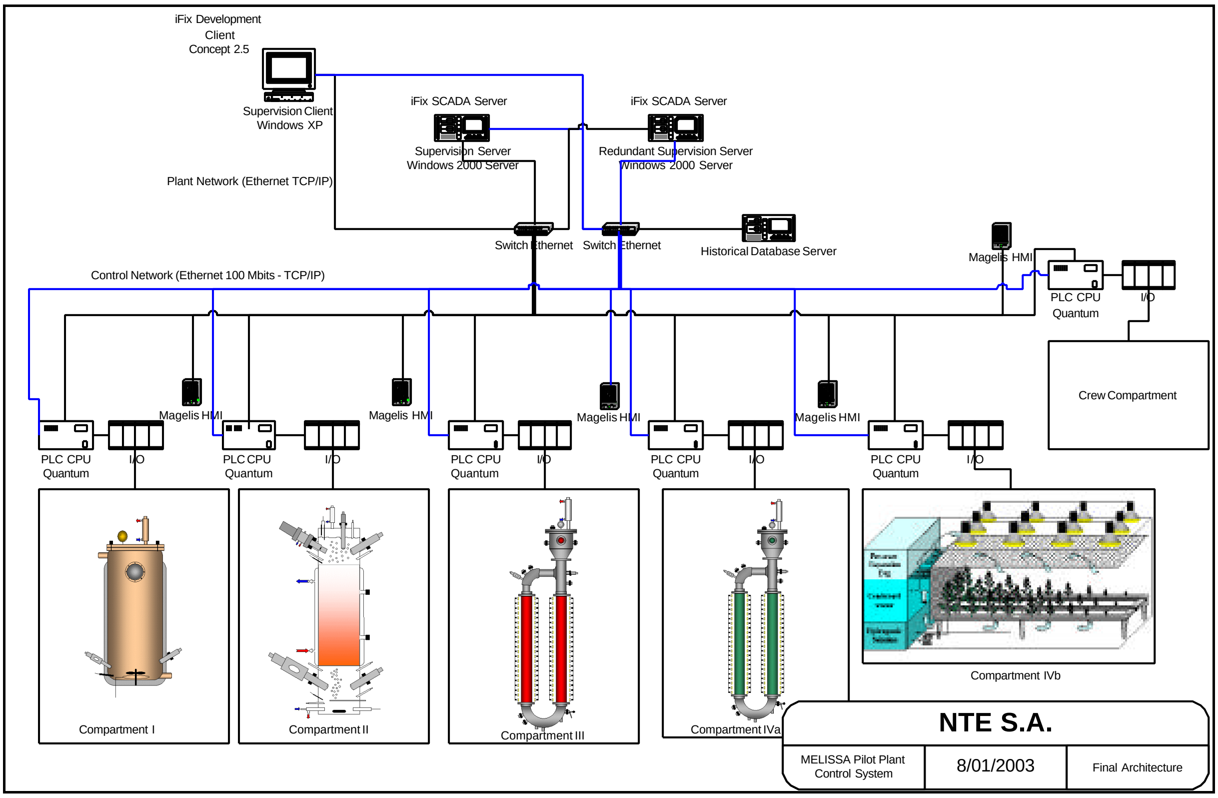
11.3 MMI

To allow closer user interaction with the system, MMI interfaces need to be installed. It has been detected as an important feature that the MMI device could be used to monitor any compartment variables. These devices are dependent of the selected controller technology therefore, based on the PLC choice, the **Schneider Magelis** MMI device has been selected. From this family of devices, the mixed touch/key pad device is selected to allow programming most common tasks in the keypad, since touch screens are very user friendly but become damaged with the continuous use.

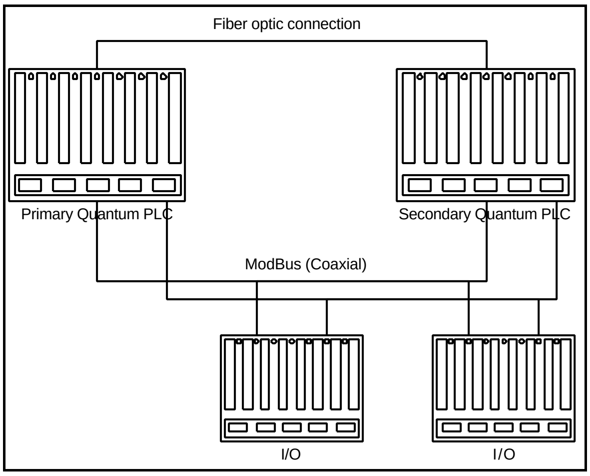
12 CONCLUSION

As a conclusion, the proposed MELISSA Control System Architecture implementation with the actual HW and SW elements selected through this study's trade-off is summarised in the following diagram. The complete and detailed identification of the different selected products to implement such architecture is listed afterwards.

12.1 Selected Architecture



The actual hot-standby configuration for the Local Control level is detailed hereafter:



12.2 Selected products

Reference	Description
Master Controller	
	PC Server
	iFix SCADA Server Software (Control laws can be integrated by means of ActiveX or DLL.)
	O.S. Microsoft Windows 2000 Server
	Microsoft SQL Server 2000 (included in iFix)
Supervision Client / Commanding	
	PC Workstation
	O.S. Microsoft Windows XP Professional
	iFix SCADA Development Client
372SPU47101V25	Schneider Concept 2.5 (Quantum PLC programming tool)
Historical Database Server	
	PC Server
	O.S. Microsoft Windows 2000 Server
	Microsoft SQL Server 2000 (additional for Historical DBMS)
Network	
	3Com Ethernet Switch 3300 16 ports
	STP Cabling
MMI	
XBTF034610	Schneider Mixed touch-screen / keypad Schneider Magelis
XBTL1003S	Schneider Kit Software for Magelis
Programmable Logic Controller (Local Control)	
140CPU43412A	Schneider Quantum CPU
140NOE77101	Schneider Ethernet Module
140CPS11420	Schneider Power Supply
	Schneider Backplane (depending on the number of slots)
	Additional Power Supply for I/O
	Schneider Input/Output cards
Auxiliary Devices	
	Laser printer
	Backup device (CD RW, Tape)
	Router + Firewall for Internet connection to allow remote supervision and troubleshooting.
	Alarm panel (wall display, lights panel)
	Alarm notification system (telephony card for digital messages transmission, e-mail configuration)
	Cupboards (Rittal is the current standard for the Pilot Plant)
	Connection Panel (Phoenix is the current standard for the Pilot Plant)

13 GLOSSARY

CPU	Central Process Unit
FDA	Food and Drugs Administration (USA)
GPS	General Purpose Station
Kb	1024 bits
KB	1024 Bytes
Mb	1024 Kb
MB	1024 KB
MMI	Man Machine Interface
MTBF	Mean-Time Between Failures
MTBR	Mean-Time Between Repair
OMAC	Open Modular Architecture Controls
OS	Operating System
PLC	Programmable Logic Controller
SCADA	Supervisory Control And Data Acquisition
STP	Shielded Twisted Pair
TCP/IP	Transfer Control Protocol/Internet Protocol
UAB	*Universitat Autònoma de Barcelona (E)*
RDBMS	Relational Database Management System

14 ANNEX A: SUPERVISION SW BRANDS SCREENING

Product	Market Share in France	OS	Configuration On-Line	Redundancy	N. Variables	N.Alarm Levels
TOPKAPI Vision Aréal	1500	Windows 95, 98, NT, 2000, XP	yes	yes	Unlimited	9
ALSPA P1200NT Alstom	600	WinNT4 – Win95	yes	yes	Unlimited	16
CITECT CI Technologies	2500	Win95/98,NT	yes	yes	450000	1024
T3500 Intellution	150	WinNT	yes	yes	65000	16
Intouch Wonderware	20000	WinNT,2000	yes	native	60000	999
Apigraf Apilogic		Windows / DOS	yes		Unlimited	unlimited
Genesis 32 Iconics		Win95, 98, NT, 2000, CE	yes	yes + Dataworx	Unlimited	unlimited
PANORAMA Codra/Europe Supervis.	6500	WinNT, 2000, XP, .net	yes	yes	Unlimited	unlimited
InfiniLink KEP	1000	Windows, 32 bits	no	no	Unlimited	unlimited
CPI/CFA MCII	800	HP Unix, Solaris, Aix, DEC Unix, Linux, WinNT	yes	yes	30x65535	unlimited
WIZCON EMation	4000 World > 30000	Win95, 98, NT, 2000, XP Clients: Windows, Unix, Mac	yes	yes	65000	65000
Web@aGlance EMation		Windows, Unix, VMS, Linux	yes	yes	Unlimited	unlimited
Factory Link US DATA	4500	Win NT, 2000	yes	yes	2^32	750
Induscreen Genad Concept Ordinal Technologies	4000	Win NT, 2000	no	yes	32000	5000
Induscreen Operator Ordinal Technologies	new product	Windows	no	no	256	1000
GlobalSCREEN Intra Ordinal Technologies		WinNT, Unix, Linux, Solaris	yes	yes	Unlimited	unlimited
LabView DSC National Instruments		WinNT, 2000, Me, 9x	no	no	Unlimited	unlimited
Lookout National Instruments		WinNT, 2000, Me, 9x	yes	yes	Unlimited	unlimited
CAESAR ACC La Jonchère	650		no	yes	16384	65536
CIMPLICITY HMI GE Fanuc Automation	2000-2500	Win95, 98. NT, 2000	no	yes	Unlimited	unlimited
OPERATE ABB	300	WinNT, 2000	yes	yes	50000	16

Product	Market Share in France	OS	Configuration On-Line	Redundancy	N. Variables	N.Alarm Levels
IC2000 AFE Technologies	1000	Win 3.1, 11, Win95, 98	yes	yes	8000	2+2x2
WinCC Siements	> 2000	WinNT, 2000	yes	yes	64000	16
I/A SERIES Foxbore	> 320	WinNT, Solaris		yes, software batch redundant	Unlimited	5
RS View 32 Rockwell Software	6000	Win95, NT, 2000, CE	yes	yes	100000	8
InfoPlus.21 AspenTech	> 100 World > 2000	WinNT, 2000	yes	yes	65000	variable dependant
Esuite/EOperate Eurotherm / Wonderware	10, new product	WinNT 4.0	yes	yes	60000	5000
PCIM AFCON	< 100	DOS, Win 3.21	“aide”	yes	2000	unlimited
PcVue 32 7.1 ARC Informatique	13000	WinNT, 2000, Me, XP	yes	yes	Unlimited	32000
PlantVue ARC Informatique		Win Me, 2000, NT	no		Depending on config.	unlimited
Exaquantum/ Explorer Yokogawa Marex	1	WinNT	yes	no	2000 or unlimited	
Monitor Pro Schneider Automation	3000	WinNT, 2000	no	yes	2^11	15000
Video Look Schneider Automation		WinNT, 2000, Me	yes	no	2^32	

Note: Market Share is given in units sold

15 ANNEX B: SCADA SW SURVEY

15.1SCADA Survey Content

Survey sent to SCADA software distributors (in Spanish):

1.- Plataformas: Windows __ Unix/Linux __ otras:

2.-Servidores Redundantes: Si __ No __
2.1.- Cambio es transparente al cliente: Si__ No__
2.2.- Cambio es transparente para el automata: Si __ No__
2.3.- Tiempo aproximado de conmutación: __

3.- Hardware recomendado (5 Usuarios 500 tags)
3.1.- CPU: __
3.2.- RAM: __
3.3.- HD: __

4.- Cliente/Servidor:
4.1.- Permite acceder desde Browser sin instalación: Si __ No__
4.2.- Premite acceder con Windows Terminal Services: Si__ No__
4.3.- Licencia Cliente Flotante: Si __ No__

5.- Soporta drivers nativos para:
5.1.-Modicon – Quantum __
5.2.-Siemmens S7 __
5.3.-Allen Bradley ControlLogix 5555 __

6.- Base de datos: ______________
6.1.- Incluida en el producto: Si __ No__

7.- Depuración y modificaciones
7.1.- Permite modificar pantallas sin parar la aplicación: Si __ No__
7.2.- Permite modificar programas externos (DLL, ActiveX, …) sin parar la aplicación: Si __ No__
7.3.- Permite depuración on-line: Si __ No__
7.4.- Permite simulación sin PLC: Si __ No __

8.- Tiempo mínimo de refresco para una variable (5 Usuarios 500 tags, HW recomendado): __

9.- Permite agrupar alarmas para su desactivación en modo mantenimiento: Si __ No__

10.- Soporte técnico:
10.1.- Hot-line 0-24h: Si __ No__
10.2.- Tiempo de respuesta soporte técnico: horas __ Días __
10.3.- Soporte técnico en instalación: Si __ No__

10.4.- Base de datos de problemas (knowledge base) en web: Si __ No__

10.5.- Actualizaciones por año: 1 __ 2 __ más: __

11.- Cursos de formación: Si __ No__

12.- Media de Tiempo entre Fallos (MTBF): __

13.- Número de desarrolladores del producto: __ < 10 < __ < 50 < __ < 100 < __ más

14.- Departamento de Calidad del Software: Si __ No __

15.2 SCADA Survey Results

	Intellution iFix	**Wonderware InTouch**	**USData Factory Link**	**Allen-Bradley RS-Logix**
1.- Plataformas:	*Windows*	*Windows*	*Windows*	*Windows*
2.-Servidores Redundantes:	*Si*	*Si*	*Si*	*No*
2.1.- Cambio es transparente al cliente:	*Si*	*Si*	*Si*	
2.2.- Cambio es transparente para el automata:	*Si*		*Si*	
2.3.- Tiempo aproximado de conmutación: __				
3.- Hardware recomendado (5 Usuarios 500 tags)				
3.1.- CPU: __	*Pentium 4 a 1Ghz*	*Pentium III*	*Pentium 4 a 1,5 Ghz*	*Pentium II 400 Mhz*
3.2.- RAM: __	*128 MB*	*384 MB*	*256 MB*	*128 MB*
3.3.- HD: __	*120 MB*	*30 GB*	*20 GB*	
4.- Cliente/Servidor:				
4.1.- Permite acceder desde Browser sin instalación:	*Si*	*Si*	*Si (Gráficos antiguos)*	*Si*
4.2.- Premite acceder con Windows Terminal Services:	*Si*	*Si*	*Si*	*Si*
4.3.- Licencia Cliente Flotante:	*Si*	*Si*	*No*	*Si*
5.- Soporta drivers nativos para:				
5.1.-Modicon – Quantum	*Si*	*Si*	*Si*	*OPC*
5.2.-Siemmens S7	*Si*	*Si*	*Si*	*OPC*
5.3.-Allen Bradley ControlLogix 5555	*Si*	*Si*		*OPC*
6.- Base de datos:	*Propietaria + ODBC*			*Propietaria*
6.1.- Incluida en el producto:	*Si*	*No*	*Si*	*Si*
7.- Depuración y modificaciones				
7.1.- Permite modificar pantallas sin parar la aplicación:	*Si*	*Si*	*Si*	*Si*
7.2.- Permite modificar programas externos (DLL, ActiveX, …) sin parar la aplicación:	*Si*	*Si*	*No*	*Si*
7.3.- Permite depuración on-line:	*Si*	*Si*	*Si*	*Si*
7.4.- Permite simulación sin PLC:	*Si*	*No*	*Si*	*Si*
8.- Tiempo mínimo de refresco para una variable (5 Usuarios 500 tags, HW recomendado):	*50 ms*			*500 ms*
9.- Permite agrupar alarmas para su desactivación en modo mantenimiento:	*Si*	*Si*	*Si*	*Si*
10.- Soporte técnico:				

	Intellution iFix	**Wonderware InTouch**	**USData Factory Link**	**Allen-Bradley RS-Logix**
10.1.- Hot-line 0-24h:	*Si*	*No*	*No*	*No*
10.2.- Tiempo de respuesta soporte técnico:	*12 h*	*24 h*	*Si*	
10.3.- Soporte técnico en instalación:	*Si*	*Si*	*Si*	*Si*
10.4.- Base de datos de problemas (knowledge base) en web:	*Si*	*Si*	*No*	*Si*
10.5.- Actualizaciones por año:	*2*	*1*	*1*	*1*
11.- Cursos de formación:	*Si*	*Si*	*Si*	*Si*
12.- Media de Tiempo entre Fallos (MTBF): __				
13.- Número de desarrolladores del producto:	*50-100*	*más de 100*	*más de 100*	*más de 100*
14.- Departamento de Calidad del Software:	*Si*	*Si*	*Si*	

16 ANNEX C: PLC BRANDS SCREENING

Product	Agencies/Distributors in France	Memory	Execution Time	Programming Languages	IO Capacity Digital /Analog
Momentum M1 Schneider	27/600	64 to 512 KB	1 to 3 ms/K	IEC-61131-3	64 mod. E/S
April 5000/7000 Schneider	27/600	64 KB program 160 KB data	5µs/K	Grafcet, Ladder, FB IEC-61131-3	9600
Atrium Schneider	27/600	256 KB	0.25µs/inst. base	IL, LD, SFC IEC-61131-3	1024/128
Micro Schneider	27/600	40 Kinstruc.	0.15µs/inst. base	IL, LD, SFC IEC-61131-3	248
Zelio Schneider	27/600			Ladder	20
Premium Schneider	27/600	64 to 512 KB	0.2 ms/instruc.	IEC-61131-3	2048 / 256
Nano Schneider	27/600	1 Kinstructions	0.8 to 2.5 ms/K	IL or Ladder	24
Quantum Schneider	27/600	109 to 2.5 MB	0.8 to 2.5 ms/K	IEC-61131-3	8192 / 2048
TSX/PMX Schneider	27/600	352 KB	0.32ms/inst. base	PL7, Ladder Grafcet	2048
FP0 Matsushita Electric Works	6/16	5-10 KB	1.6 µs/inst. base	IL, Ladder, FB, SFC, ST	192/20
FPM Matsushita Electric Works	6/16	5-10 KB	0.9 µs/inst. base	IL, Ladder, FB, SFC, ST	128/6
FP1 Matsushita Electric Works	6/16	2-5 KB	1.6 µs/inst. base	IL, Ladder, FB, SFC, ST	152/4
FP2 Matsushita Electric Works	6/16	16 to 32 KB	< 1ms.	ST, Ladder, FB, SFC, mnemonic	0/2048
Melsec FX1S Mitsubishi Electric	1/5	2K – 8K lines	10ms	Ladder, IL, SFC, FB, ST	128/16
Melsec Alpha Mitsubishi Electric	1/5	15KB	10ms	FB	20
Melsec F Mitsubishi Electric	1/5	4-16KB	5ms	SFC, Ladder, mnemonic	256
MicroBox PPC860 Mii	2	16 MB	<1ms local io	IEC-61131-3	1000/10000
VISIO 230 Unitronics	8	16 KB	0.5 µs/bit oper.	Ladder	128
M90 Unitronics	8	2 KB	12 µs/bit oper.	Ladder	64
Simatic S7 200 Siemens AG	15	4K-16 KB	0.37 ms/K	IL, CL	248/35
Simatic S7 300 Siemens AG	15	6KB-512KB	1.2 µs/K	IL, CL, SFC, FB	65536/4096
Simatic S7 400 Siemens AG	15	96KB – 4MB	0.1 µs/K	IL, CL, SFC, FB	131072/81935
GE Serie 9030 GE Fanuc Automation	1	4 MB flash, 1 MB RAM, 240 KB logic	0.11µs/K binary instructions	Ladder, IL, C	12000/3240
GE Serie 9070 GE Fanuc Automation	1	6 MB	0.4 µs/K binary instructions	Ladder, IL, C	12000/8000

Product	Agencies/Distributors in France	Memory	Execution Time	Programming Languages	IO Capacity Digital /Analog
IsaGRAF PRO AlterSys	1			IEC-61131-3	4^9
System 100 V VIPA Gmbh	1	8-16 KB	0.25 µs/ binary instruction	Step7	16-56
System 200 V VIPA Gmbh	1	8-512 KB	0.18 µs/ binary instruction	Step5-7, IEC-61131-3, C,C++, Pascal	1024/256
ZEN OMRON Elec. SARL	5/31	384 Kw	2 ms	Contacts layout	10/34
CPM 2A/2C OMRON Elec. SARL	5/31	4 KB	0.64 ms/KB	Ladder, mnemonic	192/10
CQM1H OMRON Elec. SARL	5/31	3-16 KB	0,35 ms/KB	Ladder, mnemonic	256/512
CPM1A OMRON Elec. SARL	5/31	2 KB	0.6 ms	Ladder, mnemonic	100
CPM2CS OMRON Elec. SARL	5/31	4 KB	0.6 ms/KB	Ladder, mnemonic	256
Gamme CL Bosch Techniques d'Automation	4/2	64-256 KB		IEC-61131-3	8 K
MILLENIUM Crouzet Automatismes	200	64 blocs		Graphic	6-20
RPX Crouzet Automatismes	200	2800 lines/ 8KB	µs/ instruction	IL, Ladder, Graphcet	
MIDU Crouzet Automatismes	200	2700 lines/ 8KB	µs/ instruction	IL, Ladder, Graphcet	8 modules
ALSPA C80-35 Alstom	10/17	32-240 KB	0.2 ms /KB	LD, SFC, FBD, C	16/2048
ALSPA C80-75 Alstom	10/17	512 – 6MB	0.2 ms /KB	LD, SFC, FBD, C	32/12000
Super H Risc 32 Hitachi	1/1	3-182 KB	0.05 µs	Graphcet, IL, FB, Ladder	4000
Module A32 AIM	½	256K-8MB	0.5 µs	C, Grafcet, Ladder, IEC-61131-3	8-4000
FEC FC 640 FST FESTO	5	512 KB	5 ms/K		256/256
FEC FC 34 FESTO	5	512 KB	5 ms/K		8/12
SERVER A ABB Control France	7/760	34 KB	0.4 ms /KB	LD, FBD	130
AC31 ABB Control France	7/760	240 KB	0.4 ms /KB	SFC, LD, FBD, IL, IEC-61131-3	14-1000
MAS CPU Selectron		512KB-1MB	1.2 µs/ instruction	SFC, FBD, LD, IL, ST and C	64
WIZPLC EMation	3/2			Grafcet, LD, Logic, IL, ST, Row chart	80-65000
APIGRAPH-IP Apilogic			0.5 µs/ cycle time	IEC-61131-3	unlimited
Alto Leroy	3/3	512 KB	20 ms	IEC-61131-3	128/48
LI-160 Leroy	3/3	512 KB	10-100 ms	IEC-61131-3	960/160
PS4-341 Moeller		512 KB	5 ms /K bin. instructions	IEC-61131-3	15/2
PS4-271 Moeller		Program 24 KB, Data 64 Mb	5 ms /K bin. instructions	IEC-61131-3	12/2
PS-416 Moeller		2-4 Mb	0.5 ms /K bin. instructions	IEC-61131-3	unlimited
PS4 141/151 Moeller		Program 24 KB, Data 64 Mb	5 ms /K bin. instructions	IEC-61131-3	14/3
PS4 201 Moeller		Program 24 KB, Data 64 Mb	5 ms /K bin. instructions	IEC-61131-3	14/3

Product	Agencies/Distributors in France	Memory	Execution Time	Programming Languages	IO Capacity Digital /Analog
ControlLogix Rockwell Automation	9/50	750 KB – 750 MB	0.08 ms / K instructions	Ladder., FBD, SFC	128000/4000
FlexLogix Rockwell Automation	9/50	64 – 512 KB	0.08 ms / K instructions	Ladder., FBD, SFC	512/128
SLC 500 Rockwell Automation	9/50	8 – 64 KB	0.09 ms / K instructions	Ladder.	4096/1024