EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN - SL DIVISION

CERN-SL-95-42 CO

SL 9525

INTERFACING INDUSTRIAL EQUIPMENT

TO CERN's

ACCELERATORS AND SERVICES CONTROL SYSTEM

P. Anderssen, P. Charrue, R. Lauckner, P. Liénard,
R. Rausch, M. Tyrrell, M. Vanden Eynden.

Abstract

Increasingly industrial equipment is being interfaced to the existing SPS, LEP Accelerators and Services to rejuvenate old obsolete systems and new projects for LHC will take shape.

The scope of this Document is purposely limited to the connection of industrial equipment to the Accelerators and Services control network, to the use of an homogeneous software equipment access and to an alarm retrieval method compatible with the existing Accelerators and Services control system. It concentrates on various interfacing methods that the SL Controls Group can support today in its existing infrastructure, this does not preclude future evolution depending on the results of on-going technical evaluations of new software products and the emergence of new open industrial systems to be proposed by the manufacturers in the future.

The objective of this document is to provide a few clear guidelines, for those who have to write a Technical Specification for an industrial contract, and to propose technical alternatives for their discussions with manufacturers or potential suppliers.

Geneva, Switzerland
April, 1995.

TABLE OF CONTENTS

INTERFACING INDUSTRIAL EQUIPMENT

TO CERN's

ACCELERATORS AND SERVICES CONTROL SYSTEM

P. Anderssen, P. Charrue, R. Lauckner, P. Liénard,
R. Rausch, M. Tyrrell, M. Vanden Eynden.

1. - Introduction

Following requests for advice from SL/CO users and recent CCIP meetings it seems desirable that SL Controls Group provides a few guidelines on how industrial equipment can be smoothly interfaced to the Accelerators and Services control system. CERN Accelerators and Services have an existing large investment in control networks, fieldbuses, workstations, front-end process computers, system software and application programs. The SL Controls Group supports and maintains all this environment around SPS, LEP and also for the Services on the Meyrin Site.

Increasingly industrial equipment is being installed to rejuvenate old and obsolete systems and new projects for LHC will take shape. Various Equipment Groups need to know how new industrial equipment can be integrated into the Accelerators and Services control system, how this equipment will be supervised centrally and how it can be operated locally for its commissioning and maintenance. It is important for Equipment Groups to know what support they can expect today from SL/CO: i.e. contribution to the technical specification, system integration effort or supervision of this integration by the contractor, maintenance, upgrades and what are the boundaries of responsibility between CERN and the manufacturers who provide, install and have to maintain on site their proprietary equipment.

In addition to the people in the SL Controls Group there are "Active Controls Experts" in most Equipment Groups. As the number of experts in the SL Controls Group is shrinking the support for the various industrial systems is the responsibility of these equipment control experts who have maintenance contracts negotiated with the suppliers for their industrial equipment.

2. - Scope of this Document

This document does not cover all aspects of interfacing industrial equipment; in particular new ideas, like centralized Data Servers and/or Event Driven communication (TDS Project ST/MC, ADAMO, RTWorks,...), are being debated amongst experts and are not covered here. The conclusions and recommendations of these experts will be published later.

The scope of this document is purposely limited to the connection of industrial equipment to the Accelerators and Services control network, to the use of an homogeneous software equipment access and to an alarm retrieval method compatible with the existing Accelerators and Services control system.

This document concentrates on various interfacing methods that the SL Controls Group can support today in its existing infrastructure, this does not preclude future evolution depending on the results of on-going technical evaluations of new software products and the emergence of new open industrial systems to be proposed by the manufacturers in the future.

The objective of this document is to provide a few clear guidelines, for those who have to write a Technical Specification for an industrial contract, and to propose technical alternatives for their discussions with manufacturers or potential suppliers. This Document can also be annexed to CERN Technical Specifications to inform tenderers and manufacturers about the architecture of the existing Accelerators and Services control system. There is no restriction on the type of industrial equipment to be interfaced to CERN's Accelerators and Services networks provided the manufacturer's responsibility and his technical support are clearly specified and respected. The limit of responsibility and the support which can be expected from the SL Controls Group are also defined in this document.

3. - Accelerators and Services Control Architecture (Fig.1)

The architecture of the Accelerators and Services control system is modeled on three layers: the Control Room Layer, the Front End Computing Layer and the Equipment Control Layer.

The Control Room Layer provides operators with a high performance and user-friendly interface to the Accelerators and Services, using modern UNIX workstations, servers and X-Terminals. This layer is completed by other UNIX servers for file storage, for public displays, for management of alarms and for an ORACLE on-line relational database.

The Front End Computing Layer is centered on Front End process computers or controllers (FEs) based on PCs and/or VMEbus crates. The FEs are responsible for supervising clusters of equipment and the task assignment between FEs is done on geographical and/or functional criteria. The chosen operating system for the front end computing layer is LynxOS. Alternatively, industrial Supervisory Stations and Master PLCs can be connected directly to CERN's control network provided their communication protocol can coexist with TCP/IP and can cross network bridges and routers conforming to International Network Standards.

The Equipment Control Layer consists of Equipment Control Assemblies (ECAs) and industrial Programmable Logic Controllers (PLCs) which are connected to the FEs via various equipment fieldbuses (MIL-1553, GPIB, BITBUS, FIP, PROFIBUS, JBus, etc...) or via RS-232/422 links. Control equipment is distributed around the Accelerators and the Meyrin Site, in underground halls and in surface buildings.

The structure of the control network is made of local Ethernet segments bridged to large Token-Rings and 100 Mbit FDDI backbones to cover the entire CERN Site. The TCP/IP protocol suite is used for general communication and the control network management uses SNMP.

4. - Industrial Equipment Interfacing

The method of interfacing industrial systems depends on several parameters such as: the type of equipment and its openness to International Standards, the size of the process to interface, the need for local and/or global communication, the required real-time response, and so on. In the Accelerators and Services control architecture one can identify four levels; at each level industrial equipment or systems can be interfaced:

4.1 - Interfacing at the Control Room Level (Fig. 2)

In the case of a complete industrial turn-key system, all the hardware and the software is provided by the contractor according to a CERN Functional Specification. Even if CERN may express a certain technical preference the contract may be adjudicated to a qualified manufacturer using his private products not conforming to any International Communication Standard; it may be the cheapest, suitable for big systems with well defined functionality and life-times of 10-15 years, and it may be the most technically satisfactory solution to fulfill the requirements.

In this case, the manufacturer's supervisory station will be located in the Central Control Room and CERN operators will have to learn how to operate this proprietary system and become acquainted with its particular man-machine interaction and behavior. Private connections from any local equipment to the central control room via dedicated cables, fieldbuses, private networks have to be supplied, installed, operated and maintained by the contractor. Alternatively, dedicated TDM channels may be allocated to link local PLCs to the manufacturer's Central Supervisory Station.

From the controls point of view, a "gateway" between this supervisory station and the CERN control network has to be provided and programmed in such a way as to allow a limited high level remote access for integration into the CERN Central Alarm Server (CAS) and into the logging system. Remote control of such a system from any other Control Room must be achievable by X Protocols and TCP/IP. This approach is currently being achieved for the new SPS Personnel Access System where the gateway is a Hewlett-Packard workstation running FactoryLink and to which the SL-EQUIP Package and the SL-ALARM Package have been ported (see Sect. 6 & 7).

The advantage of such a complete industrial turn-key system is that the manufacturer writes software, he has the full responsibility of the project and brings to CERN his "expertise" in his domain of activity. The drawback is the duplication of the whole control network by a private one and this duplication will be repeated with every new industrial system of this type. This approach is unsuitable for systems to be integrated into accelerator operation as it gives a restricted network visibility and equipment access, there is only one single interface point between the industrial system and the control network, and CERN relies entirely on the manufacturer's intervention under the rules of its maintenance contract.

4.2. - Interfacing at the Network Level (Fig. 3)

Complete industrial turn-key systems can be connected to the Accelerators and Services control network provided they have an Ethernet interface, use TCP/IP for remote communication, work in the UNIX environment, support MOTIF and X11 as their graphical interface and allow SNMP to supervise their network connection. An ever increasing number of manufacturers offer today, or will offer in the near future, this openness to International Standards.

If the manufacturers use proprietary communication protocols these must be able to cohabit with others and with TCP/IP on the control network. For the CERN infrastructure it means that multiprotocol bridges and routers have to be installed, (see Sect. 5).

If the manufacturer's protocol conforms to an International Standard and can cohabit with other private protocols and TCP/IP on the CERN control network then interfacing at the network level is a derivative of the case described in 4.1. in the sense that multiple connections to the control network can be made all over the CERN site. In this case, the existing network infrastructure is used and no network duplication is required. Logical integration remains at the top of the communication layers and diagnostic procedures to distinguish network faults have to be defined.

When an industrial equipment is tendered for, CERN's Technical Specification must clearly request the Tenderer to deliver his equipment with these compatible communication protocols, diagnostics and presentation tools. At this level the manufacturer's master PLCs are directly connected to CERN's control network on one side and to his own equipment on the other side, either directly or via private fieldbuses.

From the global control point of view this approach can be integrated into CERN's existing environment provided the manufacturer's protocol conforms rigorously to International Standards and that the existing TCP/IP Bridges and Routers of CERN accelerators and services network are replaced by new multi-protocol routers. X-Terminals exist now in all central and local control rooms and industrial equipment can in this case be accessed from any place at CERN. This implies that each Proprietary Supervisory Station, from a different manufacturer, will present its own man-machine interface to the accelerators and services operators; unless the various industrial applications are adapted to conform to an homogeneous presentation approach.

This scheme requires an Accelerator or a Services network available at the various locations from where this type of industrial equipment has to be controlled and supervised.

For the maintenance of his equipment the contractor may connect a proprietary Supervisory Station to the control network at any suitable place at CERN or even at his factory or service plant communicating via modem and telephone lines.

To allow CERN operators high level supervision and control of industrial systems, the homogeneous equipment access and alarm reporting methods must also be provided for industrial equipment by porting the SL-EQUIP and SL-ALARM Software Packages to the various Supervisory Stations connected to the control network. By doing so, manufacturer's supervisory control of any industrial equipment can be achieved by CERN operators, a subset of the functionality of these systems can be exploited from an external application and high level alarms can be transmitted to the CAS. (see Sect. 6 and 7).

4.3. - Interfacing at the Process Level (Fig. 4)

At the process level, industrial equipment can be controlled and supervised by the CERN FEs running the real-time LynxOS operating system. The connection of industrial controllers is made via the manufacturer's preferred fieldbus. At present the SL Controls Group has LynxOS drivers available for GPIB/IEEE-488, BITBUS RS-232/422 and MIL-1553. In addition, a driver for the JBus is available under OS9 from ST/IE; this driver could be ported to LynxOS with little effort.

Additional LynxOS drivers for other popular fieldbuses (PROFIBUS, SINEC-L2, WorldFIP, FIPIO, mini-MAP, etc...) could be made available on request for new industrial applications. The SL Controls Group can interface to and support other fieldbuses on the FEs provided a standard VMEbus driver module is available from the manufacturer for his proprietary fieldbus.

In this approach the manufacturer has the responsibility for the supply, the installation and the maintenance of the industrial PLCs, the fieldbus equipment, the VMEbus module, the software driver for his private protocol and the local test and control station connected to his fieldbus. The advantage of interfacing at the process level is that CERN can accept a wide variety of industrial equipment fully integrated and presenting an homogeneous man-machine interface to the operators: all communications relying on TCP/IP and the CERN SL-EQUIP and SL-ALARM packages.

This method has the big advantage to provide a CERN wide and homogeneous supervision of both: equipment made at CERN and equipment of any type supplied by industry. The counter-part is that CERN has to write some software to interface various industrial equipment at the LynxOS FE level with the SL-EQUIP server and the SL-ALARM server. Moreover a considerable effort is required to write and support the associated software needed in the Control Room. If necessary, this additional software can be provided by industry under a distinct software contract.

4.4. - Interfacing at the Equipment Level (Fig. 5).

This is the lowest level where industrial equipment can be interfaced to the Accelerators and Services control system, either by direct connection to a PC or a VMEbus crate or else via one of the SL/CO supported fieldbuses. Most industrial PLCs provide at least one RS-232/422 connection in addition to their private network.

Interfacing via RS-232/422 links to the FEs is supported both on the FE directly and on the MIL-1553 fieldbus via an RS-232/MIL-1553 interface named "Pizza Box". The connection to the fieldbus can only be justified for isolated equipment geographically dispersed over the CERN site or inside an accelerator building.

5. - Accelerators and Services Network Transparency.

5.1. - General concept

The accelerator controls and services networks are presently based on a routed network structure. In its original concept, the LEP and SPS control network was adapted for the transport of the TCP/IP suite of protocols and for the Apollo Domain.

Today, despite the removal of the Apollo workstations with their specialized network protocol, there is a demand for the transport of industrial protocols. The implications are various, but could be overcome by the selection of appropriate technologies and suitable network topologies. The problems are :

1) The crossing of IP/Routers where software should be made to allow the configuration in BROUTER. Encouraging tests have been made which show the possibility of transporting OSI protocols.

2) If we would like to be protocol transparent, the choice of the VLAN (Virtual LAN) concept is the most suitable. In this mode, we can establish groups of devices and groups of systems which are bridged together at the lowest transport level. This would solve our transport problem for any kind of protocol.

5.2. - Network Management

At the present time, our network management platform (H.P. Open-View) uses SNMP (Simple Network Monitoring Protocol) for the discovery of the network topology and its monitoring, but generally, PLCs do not support this type of agent.

Some discussions with other network managers and with Hewlett-Packard are already under way to find appropriate solutions to this management aspect. Unfortunately, at least one or two years will be needed to find a suitable commercial product.

5.3. - Warning

To be able to interconnect PLCs or industrial products on the accelerator network, the following critical aspects have to be considered :

- Possibility for PLCs or industrial products from different manufacturers to coexist on a common network. Tests are currently in progress to check this.

- Capability for PLCs to share resources with other devices on a common network.

- Special care has to be taken concerning broadcast, multicast, etc ....

6. - Homogeneous Equipment Access: the SL-EQUIP Package (Fig. 6)

The control of an accelerator is based on data exchange with remote devices located all around the accelerator. A set of equipment access routines called the "SL-EQUIP Package" to be used from application programs has been developed. They offer a flexible and generic interface to heterogeneous equipment such as MIL-1553, GPIB/IEEE-488, BITBUS, RS-232/422 as well as to specific user software such as industrial PLC control or SPS data modules.

Its main purpose is to simplify and to unify every equipment access and offer the same application interface at every level and for every different type of equipment (MIL-1553, GPIB/IEEE-488, BITBUS, MPX, CAMAC, RS-232/422, ...). An equipment is uniquely defined by a family_member string giving its name. An application in a workstation will access an equipment by specifying its name, an action and data to read/write. The SL-EQUIP library will then search a database to find out to which front-end processor this equipment is physically connected and to get the physical addresses (such as BC/RT for MIL-1553). A Remote Procedure Call (RPC) is then made to the front-end into a special process (called Message Handler) which will route the request. A MIL-1553 request, for instance, will be sent to the MIL-1553 bus via the local drivers and libraries. Response will in turn be forwarded to the calling application. Error handling is made by returning the first problem encountered.

A set of standard accesses to supported fieldbuses such as MIL-1553, GPIB/IEEE-488, BITBUS, etc. are implemented inside the Message-Handler. This means that no extra code has to be written in the front-end processor to make these standard accesses.

An important feature of the SL-EQUIP Package is the possibility of accessing "Pseudo Equipment". This "Pseudo Equipment" consists of a piece of software running anywhere in the SL control infrastructure and which is accessed using the SL-EQUIP interface, by its name, an action and data to read/write. In this manner industrial systems are interfaced through a dedicated "pseudo equipment" process or library.

7. - Industrial Equipment Alarms: the SL-ALARM Package.

Problems detected at the ECA, FE, server machine or industrial installation level can be described in a standard way, referred to as a 'Fault State' (FS), and passed to the alarm system using part of the SL-EQUIP package. All FS's must pass through a 'Standard Surveillance Program' (SSP), which is the responsibility of the alarm team. The topology between the SSP layer and the detecting environment is described by data held in a database which is used by the operational software to direct FS's to the appropriate SSP. This gives great flexibility in configuring the topology and allows both distributed or central processing at the SSP level.

Each type of equipment system: LEP Power Converters, LEP Cooling & Ventilation, SPS RF, etc.... have their own specific SSP which can contain corresponding logic for that system. All SSP's offer a set of general alarm facilities such as: reduction, removal of oscillating FS's, conditioning of FS's according to the mode of the accelerator and the possibility of placing FS's into maintenance. The result of any conditioning within the SSP is passed to the CAS.

Using a standard alarm 'Man-Machine Interface' (MMI) all information concerning FS's can be visualized according to the 'interest' as specified by the operator/user. Details of any reduction performed in the SSP can be retrieved on demand via the MMI. It is important that any reduction of FS information done by users in any part of the system should be made available, preferable via the MMI, to enable operators/users to understand fully the problem.

8. - Man-Machine Interface

The development of the CERN SL and ST Man-Machine Interfaces is based since 1994 on a new X-Window User Interface Management System (XUIMS). This modular and highly evolutive software development environment allows the interactive creation of Man-Machine Interfaces based on the OSF/Motif industry standard. Continuously enriched with the most recent commercial products (widgets) available on the market, it offers consistent solutions for the development of both industrial and scientific graphical user interfaces.

The development of synoptics, the visualization and direct interaction with 2D and 3D scientific data, the display of relational database data, and the direct access to MIL-1553, GPIB/IEEE-488, BITBUS, and RS-232/422 equipment via the SL-EQUIP package are addressed by this software development environment.

The guarantee of consistency across the applications and the encapsulation of complex functionalities in re-usable and user friendly components has also been implemented through the development of home made widgets and templates.

Based on the OSF/Motif widget set and the X Toolkit intrinsic (Xt), the style and interactions offered in the applications are fully compatible with commercial user interfaces. This compatibility makes possible the coexistence of commercial and home-made Man-Machine Interfaces in the accelerators and services control system.

9. - Central Workstations, Servers and X-Terminals.

These are essentially industrial equipment as is, and ruggedized versions are usually available at only a small additional cost. The extra cost may be justified for installations in hostile areas where humidity and dust concentrations are high.

By nature, these machines are networked, as such they can be installed wherever technically feasible. Modern X-Window technology allows the installation of the man-machine interface elsewhere as required by human considerations. Both remote supervision and local operation can be envisaged using this technology.

Provided that the industrial application integrates into the workstation as a normal software application, the system privileges and system configurations can be kept as close to the standard as possible. This would allow the Controls Group to support the industrial installation as a normal workstation which can be integrated into the rest of the controls installation without a substantial increase in manpower.

10. - Local Access for Equipment Control

The CERN Accelerators and Services networks allow local access to equipment via standard X-Terminals in all buildings where an Ethernet segment is installed. This infrastructure is available to any industrial system manufacturer who provides TCP/IP and X11 protocols with his equipment.

In the case of proprietary systems the manufacturer may connect any local console of his choice to its own local fieldbus to survey, to service, to maintain and to debug his installation. It may be a fixed or portable PC, a hand-held terminal or any kind of specialized test-box. The communication of this type of diagnostic tool is usually strictly limited to the local cluster of private equipment and does not have the capacity to communicate over the controls network to access similar equipment in another building on the CERN site.

11. - Support provided by SL/CO Group to Users of Industrial Systems.

The Technical Specification for industrial equipment must clearly define what level of integration is to be achieved for each project: Control Room, Network, Process or Equipment Level. The Controls Group is at the disposal of the Equipment Groups to discuss their requirements and to contribute to the writing of their Technical Specification for the part concerning the interfacing of the industrial equipment into the accelerators and services control system.

For a project where the interface is to be done at the Control Room Level the Controls Group should be involved in the discussion with the manufacturers on how the SL-EQUIP and SL-ALARM software packages are to be ported to the tenderer's supervisory stations. It should be defined who will do this work: CERN, the selected manufacturer or a third party company. Is this work included or not in the tenderer's offer, if not who will pay for it?

Discussions should also take place with the manufacturers to ensure compatibility of their network communication with the TCP/IP protocol of the CERN controls network. On request of the Equipment Groups, the Controls Group can make compatibility tests in liaison with the manufacturers before the contract is signed; provided he is informed in advance and is given the time to do these tests. If this compatibility test fails then modifications to the manufacturer's product must be identified and the cost of these modifications must be included in the contractor's price.

Integration of industrial equipment at the Network Level implies that the industrial equipment is designed to work in the UNIX environment and that open communication protocols conforming to International Standards only are used by the manufacturer, (see Sect. 4.2.). On request, the Controls Group can check the communication compatibility by connecting private supervisory stations and master PLCs onto CERN controls network and verify that these stations communicate well among themselves and do not perturb other equipment sharing the same network. The ability to communicate across multi-protocol bridges and routers must also be verified.

The accelerators and services network is actually supervised and monitored by using the SNMP protocol. This network management protocol allows the diagnostic of any communication problem among any workstation, front-end processor, file server or VME platform. Similarly, to be completely integrated an industrial process controller or supervisory station must support SNMP. This functionality can be checked by the Controls Group.

In addition, as for industrial equipment integrated at the Control Room Level, both SL-EQUIP and SL-ALARM software packages have to be ported to manufacturer's equipment.

Integration at the Process Level requires the Controls Group or preferably the manufacturer to provide the LynxOS software driver in the FE for the specific fieldbus supplied. As mentioned in Section 4.3, several fieldbus drivers exist already under LynxOS: MIL-1553, GPIB/IEEE-488, BITBUS and RS-232/422. A VMEbus interface module or possibly a PC board for the proprietary fieldbus must be available from the manufacturer.

The LynxOS software driver for this private fieldbus should preferably be provided by the contractor who best knows the specificity and the mode of operation of his equipment. Alternatively the fieldbus specific LynxOS driver can also be provided by a third party software house.

The Technical Specification for this type of industrial equipment should also include the installation and the maintenance of the private fieldbus components and the PLCs as the knowledge required does not exist in the Controls Group neither in the Equipment Groups.

Integration at the Process Level is the method which provides complete and straight-forward integration into a global supervision of both CERN existing systems and new industrial systems. This method is particularly recommended for extension of existing systems for which a large software investment exist and is already operational. On the contrary for complete new systems, not yet integrated into the control system, this method requires the writing of all new application programs.

Integration at the Equipment Level allows control of PLCs or any kind of industrial equipment via an RS-232/422 link connected either directly to a FE or to an RS-232/MIL-1553 interface box. As more than 150 MIL-1553 links with some 3.300 ECAs are presently operational in SPS, LEP, CPS and in most services buildings on the Meyrin Site, it is simple and straight forward to connect any industrial PLC to this fieldbus via an RS-232/422 port.

It is particularly economical to use the existing infrastructure in the case of new single PLCs dispersed in the accelerators and services buildings as this infrastructure is fully supported and maintained by the SL Controls Group. One could transport data blocks from PLCs to FEs and do alarm analysis as we do already for AT/CV in LEP. Nevertheless, to control industrial PLCs at the equipment level requires understanding their functioning and writing control, surveillance and alarm programs, much in the same way as for any other ECA.

CONTROL SYSTEM ARCHITECTURE

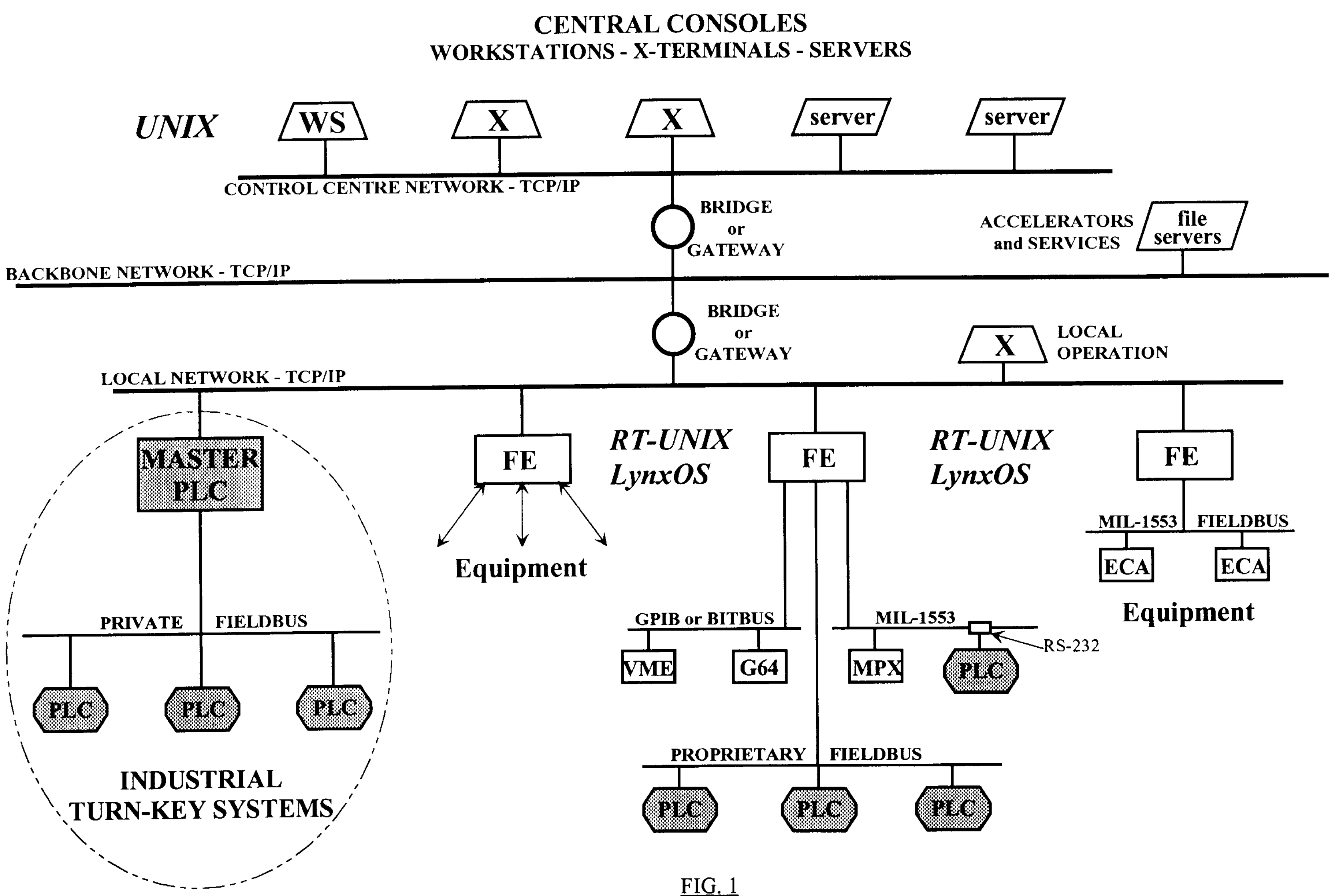

FIG. 1

R.R. -SL/CO- 3/95

INTERFACING at CONTROL ROOM LEVEL

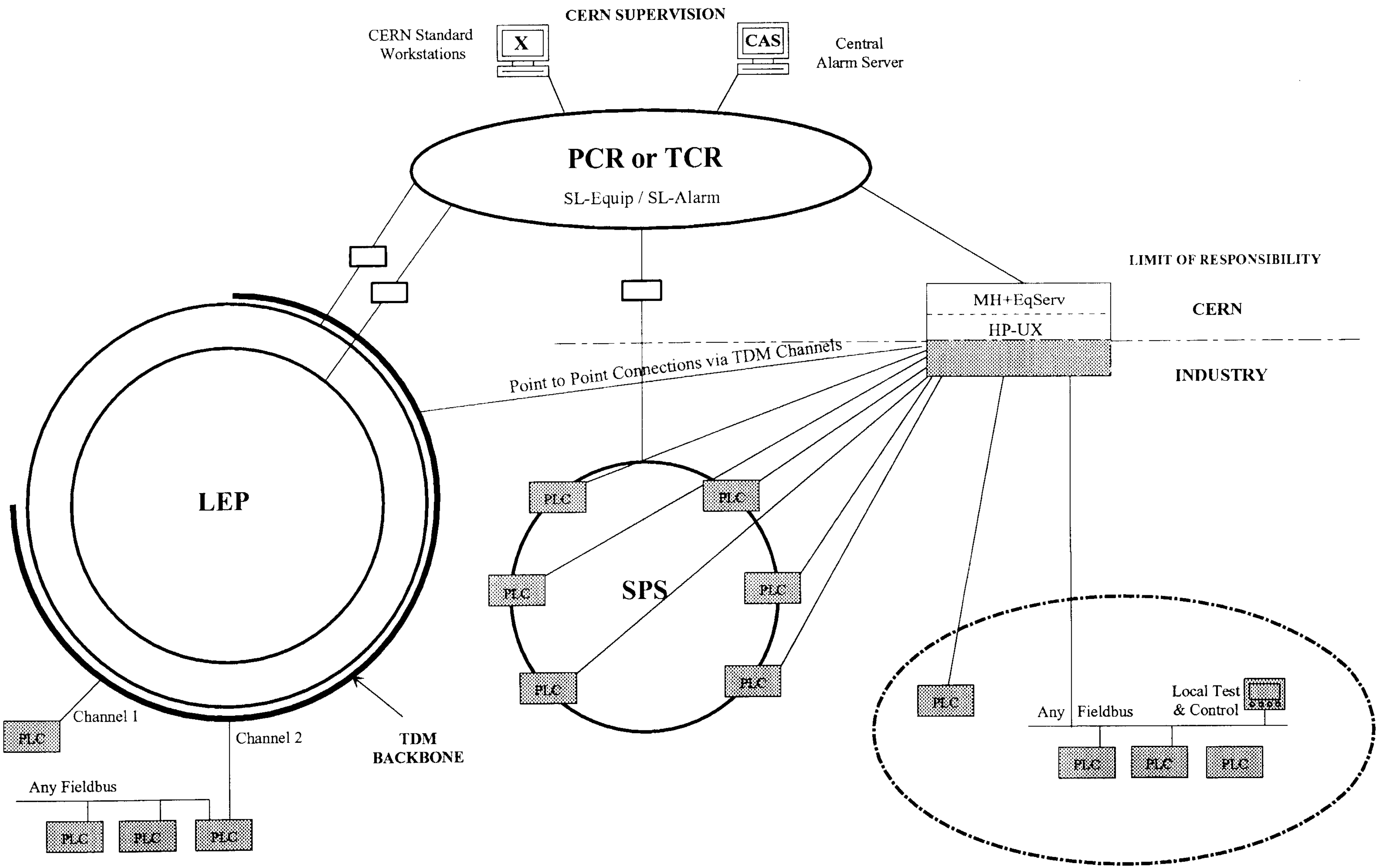

FIG. 2

R.R. -SL/CO- 3/95

INTERFACING at NETWORK LEVEL

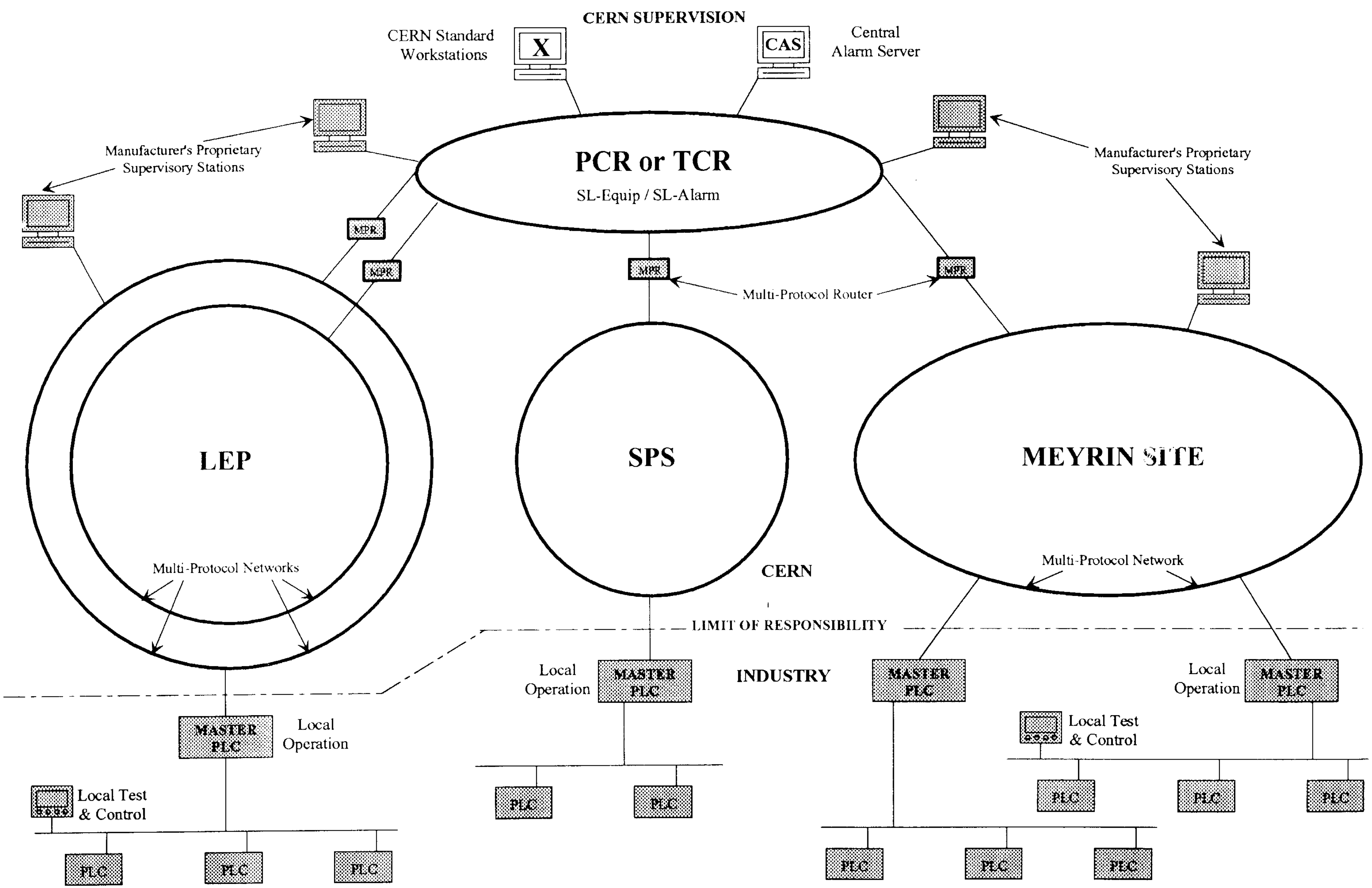

FIG. 3

R.R. -SL/CO- 3/95

INTERFACING at PROCESS LEVEL

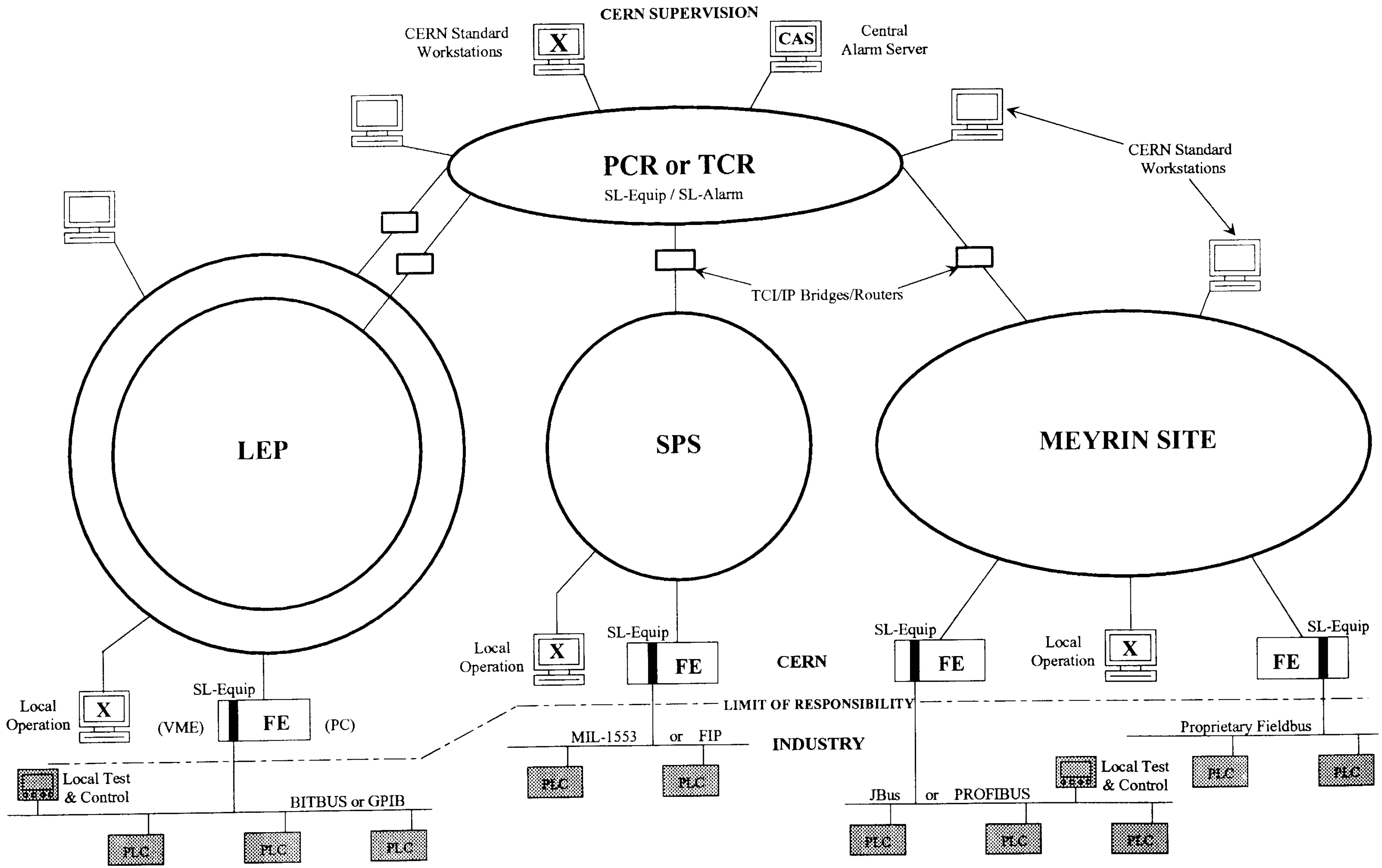

FIG. 4

R.R. -SL/CO- 3/95

INTERFACING at EQUIPMENT LEVEL

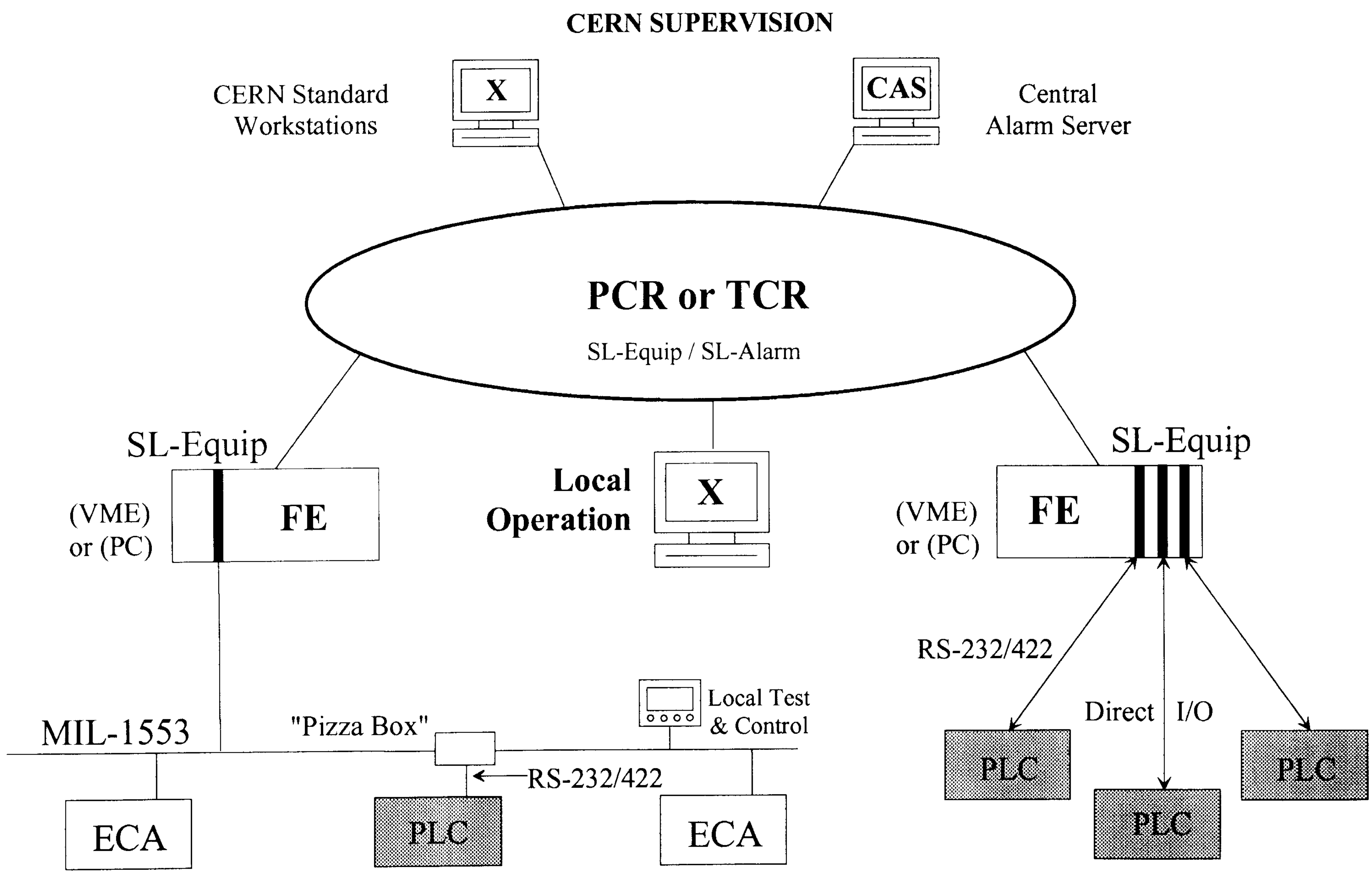

FIG. 5

R.R. -SL/CO- 3/95

SL-EQUIP
Schematic Overview

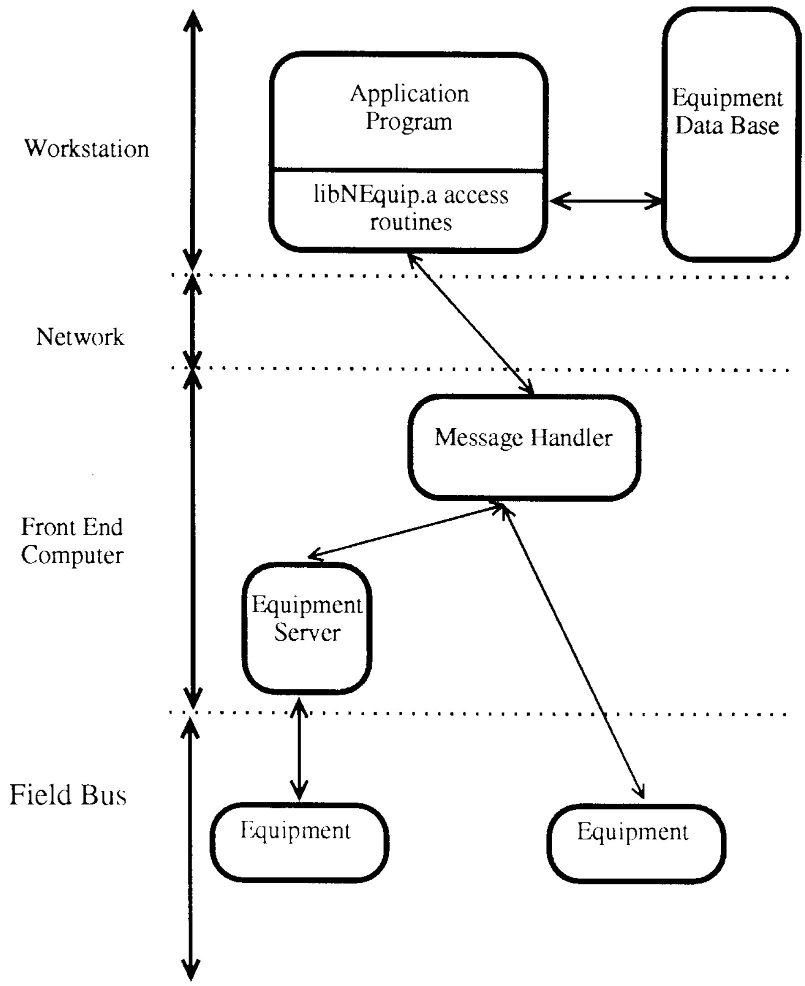

FIG. 6