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UPGRADE OF THE HUNTERSTON B AGR OPERATOR TRAINING SIMULATOR

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Abstract

Nuclear power plant simulators provide a vital tool in the training of operational staff in the statutory procedures and operational requirements of the nuclear industry. Scottish Nuclear, and its predecessor the South of Scotland Electricity Board, recognised the value such facilities offered to safety and efficiency, and commissioned the construction of the Hunterston Operator Training Simulator as early as 1980. The simulator is a full scope, total plant, and real time system, with a complete 'as plant' replication of the operator interface, together with extensive instructor and tutorial facilities. Its uses have extended beyond the operator training role into plant engineering post incident analysis, evolving to be an essential feature of the station as a whole. Operation of the simulator for the foreseeable life of the station was the main driving force behind the current simulator update project, and whilst the need to move to a new computing platform, avoiding impending obsolescence problems, was the prime reason, the retention of 17 years of software development was seen as a valuable legacy to preserve. This paper discusses the main criteria considered during the simulator upgrade programme, highlighting the main technical issues and risks involved.

1. Introduction

The Hunterston B Advanced Gas-cooled Reactor operator training simulator was initially completed in 1985. The computing technology applied to the original simulator was based on the 1970's and early 80's vintage of the Marconi Graduate and Intel processing systems. The initial system comprised 52 Graduate MK 2 processors and 16 Intel 8080/8086 processors.

Throughout the late 80's and early 90's the advances in Graduate processing technology, and their introduction into the simulator environment, resulted in the replacement of the original 52 with a total of 10 MK4 and MK5 processors covering all of the mathematical modeling and tutorial tasks. The Mk4 and MK5 systems were designed to be largely upward compatible with the original MK2 and hence much of the software investment in the MK2 system was retained. At this time the Intel processing system communicated the I/O between the operator desks and panels and the modeling computer system. This comprised approximately:-

(a) 1000 analogue outputs.
(b) 6 analogue inputs
(c) 6000 digital outputs.
(d) 4000 digital inputs.

Figure 1 shows the computer system diagram in simplified block diagram form.

The decision was taken three years ago to upgrade the computing environment to an 'open systems' platform such that the simulators' high training fidelity and availability could be preserved and further developed well into the future. The key factors in the decision were:-

(a) The hardware environment was no longer being manufactured or developed and the obsolescence problems encountered, over the last few years in some areas, would gradually spread to all of the hardware.
(b) Availability of software support skills in the SOUL (Simulation Oriented Utility Language) language used was rapidly diminishing.
(c) The computer system processing capacities were not adequate to support the implementation of foreseeable power plant modifications, e.g. replacement control systems, on the simulator.

2. Strategy

At the outset of the upgrade programme a number of potential areas of risk were identified and are detailed as follows.

2.1. Specialised hardware

The existing computer system comprised a number of hardware elements substantially tailored to meet the demanding processing and communications requirements of the real time simulation environment.

Where possible, given the advances in modern computing technology, the upgrade process would utilise standard products and facilities. This would ensure that future developments, and the support of such activities, could be maintained without the necessity to rely on the specialist knowledge required by the original system.

2.2. Intellectual property and copyright issue

The original simulator was developed by Marconi simulation in conjunction with Scottish Nuclears' predecessor, the South of Scotland Electricity Board. Much of the mathematical modeling software was the result of a joint effort between the two parties and the question of ownership was never concluded. This aspect had to be resolved before any action could be taken to upgrade the mathematical modeling elements of the environment, so that as much as possible of the high value legacy of the original models could be retained, and that Scottish Nuclear could avail itself of a competitively tendered upgrade contract.

2.3. Legacy investment

Over the life of the simulator, considerable investment had been made in the development of the mathematical models in pursuit of the evolving operator training requirements. The plant models encapsulate engineering effort and ingenuity, expended in the original designs, and in over a decade of modification, improvement and feedback of user experience in the development of the training programme. The functional capability that they currently deliver is regarded as having a considerable legacy value.

It was recognised at an early stage that retention of such an investment was of prime importance in any form of system migration to a new hardware/software platform. Therefore a staged upgrade procedure where comparative testing with the previous versions becomes the acceptance criteria for new versions was set as the main development guideline.

In addition, Scottish Nuclear had also developed another real time simulation environment, the Workstation Engineering Simulator (WES), which had been extensively used to test major plant modifications prior to their installation on plant. This system was based on the original Hunterston simulator concepts but provided an environment in which the interfacing and control of the system was accomplished via a standardised client/server arrangement. With the variety of equipment interfacing requirements that existed on the Hunterston simulator it was felt prudent to include the principles of WES in the control of these interfaces.

2.4. Fall back arrangements

A project priority was to ensure that the high volume of operator training would not be disrupted during the development and commissioning stages of the upgrade project. To this effect, the plan for each stage included a fall back procedure, engineered into the design from the outset, such that all items crucial to training support could be identified and accommodated. The monitoring, evaluation and reduction of risks in this area have been a continual preoccupation of the project team.

2.5. System enhancements

The development of the simulator over its lifetime has shown the need to provide for considerable enhancement from the initial design. These enhancements are largely driven by the modifications that have taken place on the real plant, although the expansion of the operator training envelope and improvements in the tutorial tools have also played had a major influence. Moving the simulator to a new platform should include consideration of these developments in the choice of hardware, operating systems, proprietary applications, and software languages.

3. Implementation

3.1. Background

The development programme was based on the following guidelines:-

(a) Order the activities according the priorities of obsolescence.
(b) Maintain availability for training.
(c) Maximise incorporation of the legacy value of the existing simulator installation.
(d) Provide sufficient spare capacity throughout the system to incorporate future updates.

Item (a) dictated the major milestones that had to be achieved during the upgrade process. This indicated that the most immediate requirement was to replace the Intel 8080/8086 I/O processing system followed by the Marconi Graduate mathematical modeling / tutorial facilities processors.

Item (b) could be satisfied by the establishment of parallel communication routes between old to old and old to new equipment and/or processes. i.e. the fallback arrangement could easily be switched to, in the event of 'new system' failure.

Item (c) could be provided for through emulation of the existing Graduate software/hardware environment in a modern computer system.

Item (d) was simply a case of ensuring that the chosen architecture provided sufficient processing and communications capacity.

3.2. Staged Migration

About three years ago urgent obsolescence problems were being encountered on the Intel I/O scanning system which necessitated its early replacement. The design study, which examined the problem also, uncovered the impending obsolescence in the plant mathematical modeling computer system.

To overcome the technical issues, a staged programme of design, implementation and validation was chosen whereby straightforward reversion to the existing system could be invoked at any time during commissioning. The purpose of this approach was to maintain simulator availability for training and, simultaneously, facilitate verification of each stage of the upgrade against the performance of the existing system.

Consequently, the upgrade process was divided into two major stages each of which being designed according to these principles. The stages were:-

(a) Replacement of the control room desk & panel instrumentation I/O scanning computer system.
(b) Replacement of the mathematical modeling/instructor/tutor facilities computer system

Item (a) was accomplished through the procedure described in sections 3.3 and 3.4 below, and essentially provided a new VME I/O system which operated, for some time, in parallel with the old Intel system until verification of its performance allowed the old system to be completely removed.

Item (b) was sub-divided into further stages in order to ensure that the high legacy performance values of the old system were conserved into the overall upgrade to the new system. These stages were as follows:-

(i) Emulation
(ii) Conversion
(iii) Replacement

Figure 4 shows the migration pathways for this procedure.

3.3. The I/O processing system

The Intel based processing system, which communicated the I/O to and from the desks and panels, included many pieces of equipment specifically design for the simulator. In choosing a development route to new equipment, the priority lay with the inclusion of equipment which would allow multiple sourcing of spares and future additions, and which also complied with international standards of specification against which application software construction could be referenced.

Obviously, when considering the amount and frequency of the I/O update process, a high-speed communications bus system was required. The final choice, based on the variety of available processing elements and the wide range of I/O card manufacturers, was the 6U VME system. The processor chosen was the VME dual HyperSPARC, manufactured by Themis, which in addition to providing the simulator I/O function was also capable of simultaneously running application software, designed by the station reactor physics section, utilising some of the simulators' functionality. With the power of the VME SPARC processor, it was decided to double the update rate of the I/O system to 10/sec. with a view to accommodating future enhancement of the plant modeling processes.

The I/O software processes are table driven, each derived from a common database, and hence future changes to the system can be accomplished by updating the database and regenerating the tables. Little, or no, future software changes, other than updating the database, will therefore be required.

The system also included the installation of the new plant alarm logging system, the Contact Alarm Scanner (CAS), running 'as plant' software interfaced to the I/O processor via a local 10Mbit Ethernet connection. Figure 2 shows the revised architecture at this stage in simplified block diagram from.

3.4. Workstation Engineering Simulator

The Workstation Engineering Simulator (WES) was built to provide support and verification facilities to major plant modification projects. It consists of a central server control process to which may be connected a wide range of client activities via a predetermined, whilst still reconfigurable, interface.

To date, the range of clients include:-

(a) Mathematical models of the real plant.
(b) Control room soft desk and panel displays.
(c) Parameter trending displays.
(d) Animated plant mimic construction and display.
(e) I/O systems to other manufactures equipment, e.g. Honeywell TDC.
(f) Interfaces to other proprietary engineering applications, e.g. MatrixX.

The WES system architecture was therefore imposed upon the updated Hunterston simulator architecture, as shown in Figure 3, to provide the interconnection and I/O facilities required by the system as a whole.

3.5. Plant modeling System

The design study, which examined this area of the update process, concluded that emulation technology based on a GRADUATE/SOUL Virtual Machine concept operating within an Open computing platform should be employed. The Legacy value of the current simulator software is preserved by mapping INCODE (executable code) files from the current system, automatically into LITCODE (Legacy Interpretative CODE), which then runs in the new environment.

The design study also concluded that the Intel Pentium processor range and the Windows NT operating system could adequately accommodate the requirements of such an emulator and in particular the 200MHz versions could provide up to 50% spare processing capacity.

3.5.1. Existing models

The existing plant modeling computer system comprises a number of interconnected processing elements arranged to reflect segregation of the main plant into its major components, e.g. reactor, boiler, turbine.

The current performance of the simulator has been achieved over an extensive period of model development and system enhancement largely dictated by the progressive requirements of operator training. It was felt prudent to preserve the current simulator attributes in any computer system update process such that the availability and performance with regard to operator training remained largely unchanged. The emulation of the existing computer system environment on modern equipment, in which the current plant models remain largely unchanged, would satisfy this requirement.

In addition, the high volume of traffic between the emulation of the modeling processes, the new Honeywell auto control system and the instructor facility, required a more intimate connection of these elements. Hence the grouping of these elements, known as the Legacy Emulation System (LES), and the interconnection between this and the WES system, has been achieved via a combination of 100Mbit and 10Mbit Ethernet connections between the LES Pentium processor systems and the WES VME processor systems.

A number of other specially design interfaces, primarily to the existing Ferranti data logger Peribus interface and the desk and panel synchroscope instrumentation, have been designed using standard VME equipment tailored to suit these particular requirements.

3.5.2. Plant model enhancements

The desirability of having a substantial spare capacity in any simulator system has been adequately demonstrated by the continuous software development activity at Hunterston, in attempting to follow the ever-increasing demands of operator training. There have also been several recent major changes to the real plant whose implementation on the simulator will impose a further computing load.

Some of these changes are to be implemented immediately following the update of the computer system, and therefore provision has to be made within the initial design. These changes will include:-

(a) Replacement of the existing DC/pseudo AC, electrical network model with a fully functional AC network model.
(b) The simulation of the main turbine governor new computer based system.
(c) The simulation of the new Honeywell TDC 3000 reactor/turbine control system.
(c) Nuclear data set import utility.
(e) Turbine model modifications to match recent reblading on the plant.

Items (a) and (b) will be implemented via software written to directly simulate the effects of these requirements; while item (c) will be simulated using a proprietary emulation of the Honeywell computer system environment within which the 'as plant' software may be run.

In addition to the above, there are a significant number of minor plant modifications which must be taken account of in the design and loading of the simulator plant modeling computer system.

Consequently, a contract to update the simulator plant modeling computing platform to an open systems Pentium processor arrangement running Windows NT was placed with SAST in April 1997, and is forecast to achieve completion over an approximate 12 month period.

3.6. Enhanced instructor facilities

The initial update of the simulator computer system provides an instructor facility which closely resembles the functionality of the previous system, thus ensuring a smooth transition of operator training following the system update, as well as allowing the tutors to become comfortable with the new hardware.

The enhanced facilities will capatilise on the sophisticated graphics capabilities made available via the new hardware platform and software environment.

3.7. Migration to C

This stage deals with migration from the SOUL/GRADUATE to an 'Open' C environment. This process has yet to be started but many of the tools developed earlier in the project will facilitate this migration pathway.

4. Tools and skills

4.1. SPARC VME system

The operating system used, Solaris 2.4, provided many of the workstation tools required during the construction process, including:-

(a)	SPARCWORKS	-	Development environment
(b)	SCCS	-	Source Code Control System
(c)	XVIEW	-	Graphics tool kit
(d)	XLIB	-	Graphics drawing functions

In addition, tools constructed in house during the development process, were used to provide accelerated means of building the application software, including:-

(a)	LINKER	-	Client data interconnection facility.
(b)	Data base parsers	-	Configuration table generators.
(c)	Standard interface functions	-	Client/Server interconnection facilities.

4.2. Pentium processor system

The operating system, Windows NT 4, and Microsoft products provide the following tools:-

(a)	MS OFFICE 97 Pro	- -	Documentation & project database.
(b)	MS Visual C++	-	Software porting.
(c)	MS Visual Basic pro	-	Off-line database applications and tools.
(d)	Paint Shop Pro	-	Graphical Support.

Additional tools provided under the contract are:-

(a)	SPI	-	Project Support Pack of On-line help files.
(b)	LIFT	-	Legacy Import File Transfer.
(c)	Pre-C/C compiler	-	SOUL to LITCODE compiler

Other tools to support the software source code migration will be developed during the project.

6. VALIDATION

Full system testing has been carried out off-line the using a development simulator, which includes a soft emulation of the control room desk and panels, to generate an effective and efficient test environment. The desks and panels and the training scenarios are based on standard video capturing techniques, utilising the toolset provided by WindowsNT.

Simulator tutors have been involved at each demonstration and testing point to ensure that the look and feel of the new simulator resembles the existing equipment. A period of operator training will commence shortly, based on the emulation of the existing system. The feedback from this training will be taken account of during the enhancement phase of the simulator upgrade project as described in Section 3.5.2.

7. CURRENT PROJECT STATUS

The legacy emulation on the new platform is currently being commissioned and will be used for operator training commencing December 1997. The legacy enhancements are currently being constructed and will be commissioned in May 1998. This will complete the migration process to the new hardware platform.

To address the software migration process, the port from SOUL to C will be completed by September 1998. This process will follow the same guidelines as the hardware migration, using comparison with the SOUL/Graduate emulation performance as the criteria for acceptance. In this case, however, switching between them, for comparison or fall back to maintain training availability, will be easily accomplished via a software switch.

8. CONCLUSION

The incremental design approach provides a secure guarantee that each stage of the migration can be fully validated to the satisfaction of the simulator tutoring and engineering staff, while the commissioning procedures involved easily accommodate conformation of performance via reversion to the legacy system. Hence the migration of a system to a modern computing platform should not lose the legacy value of the existing system or result in any loss of training capability.

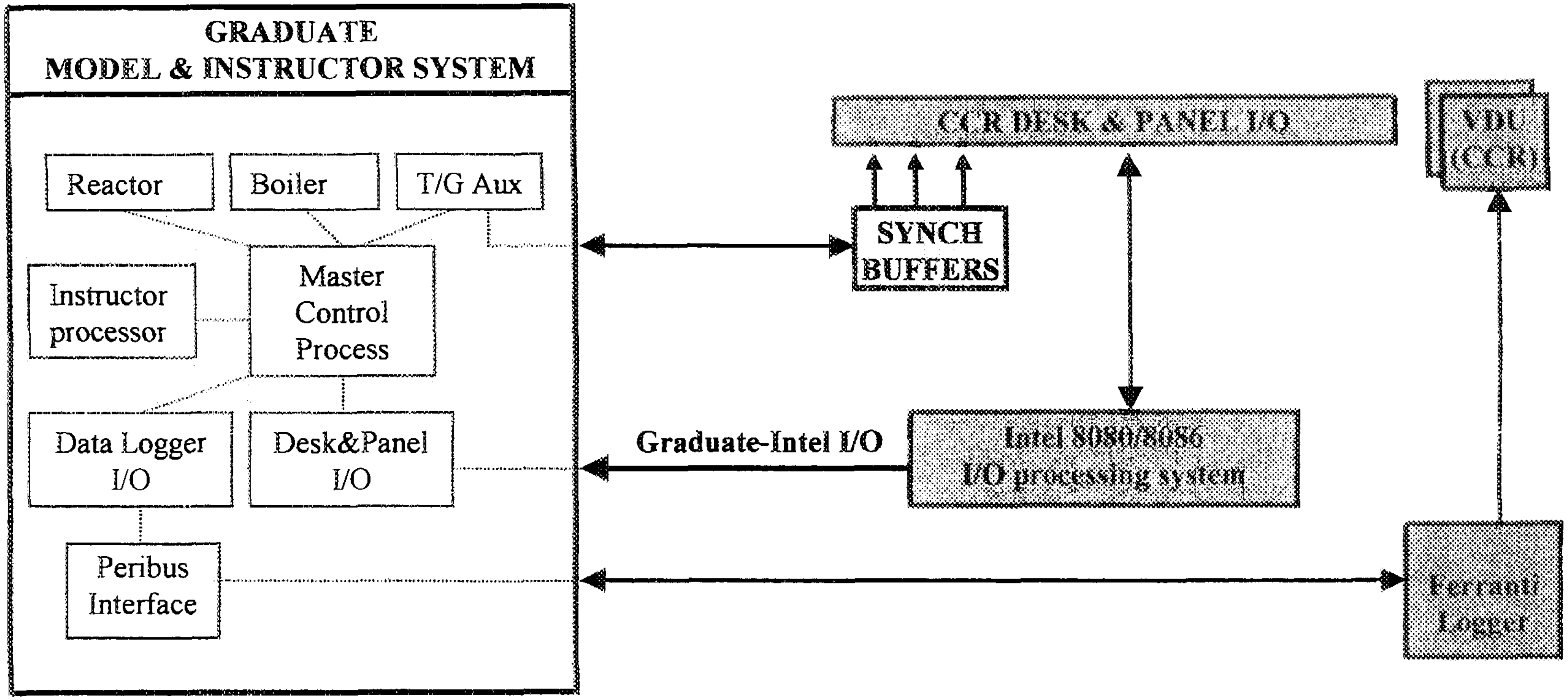
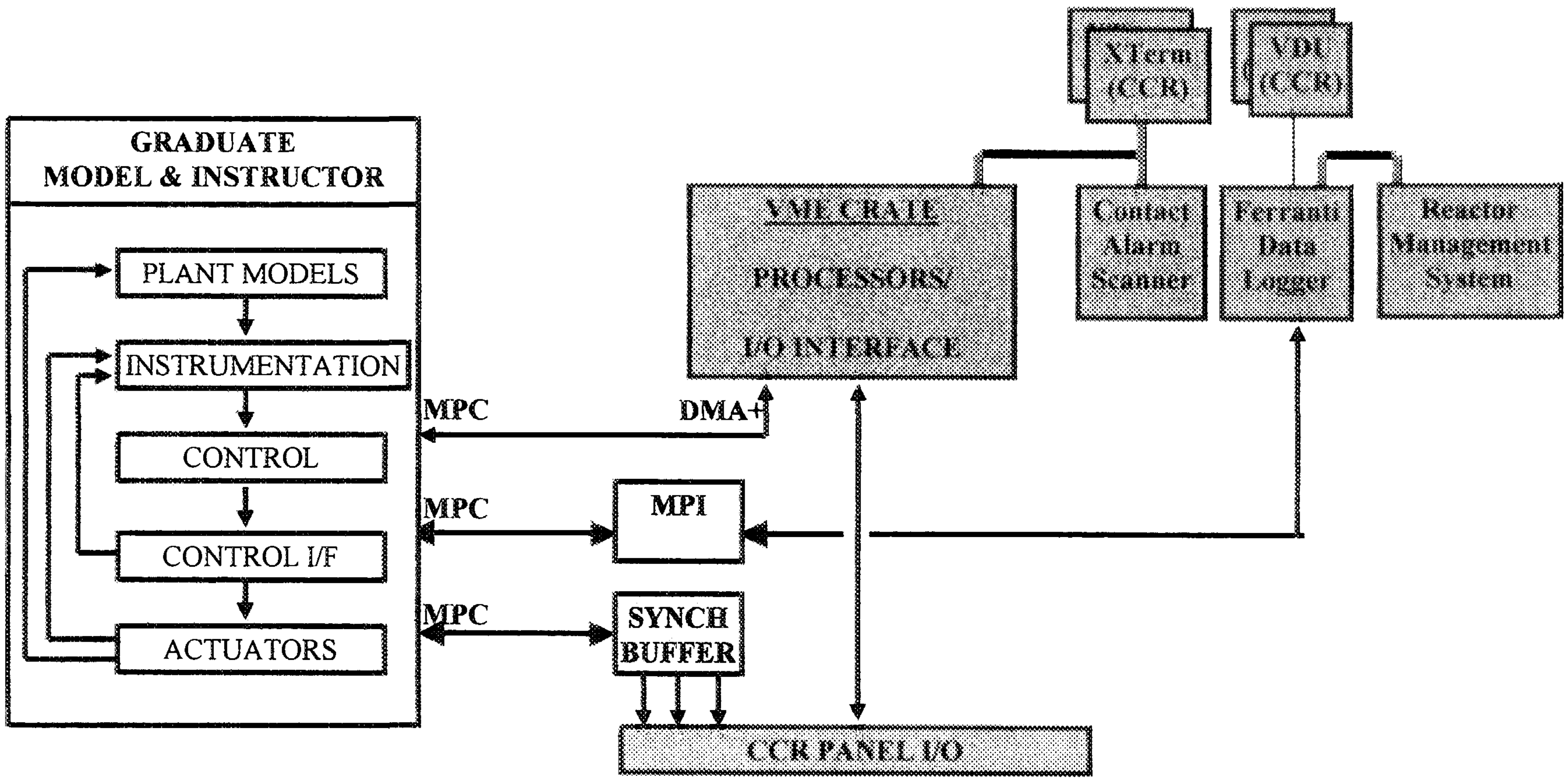


FIGURE 1 – GRADUATE/INTEL SIMULATOR ARCHITECTURE
(BLOCK DIAGRAM)



KEY:

MPC	GRADUATE GPBI Control Card
MPI	Marconi PERIBUS Interface
DMA+	SNL Engineered GPBI DMA Card
	Serial Links
▬	Ethernet

FIGURE 2 – GRADUATE/VME SIMULATOR ARCHITECTURE
(BLOCK DIAGRAM)

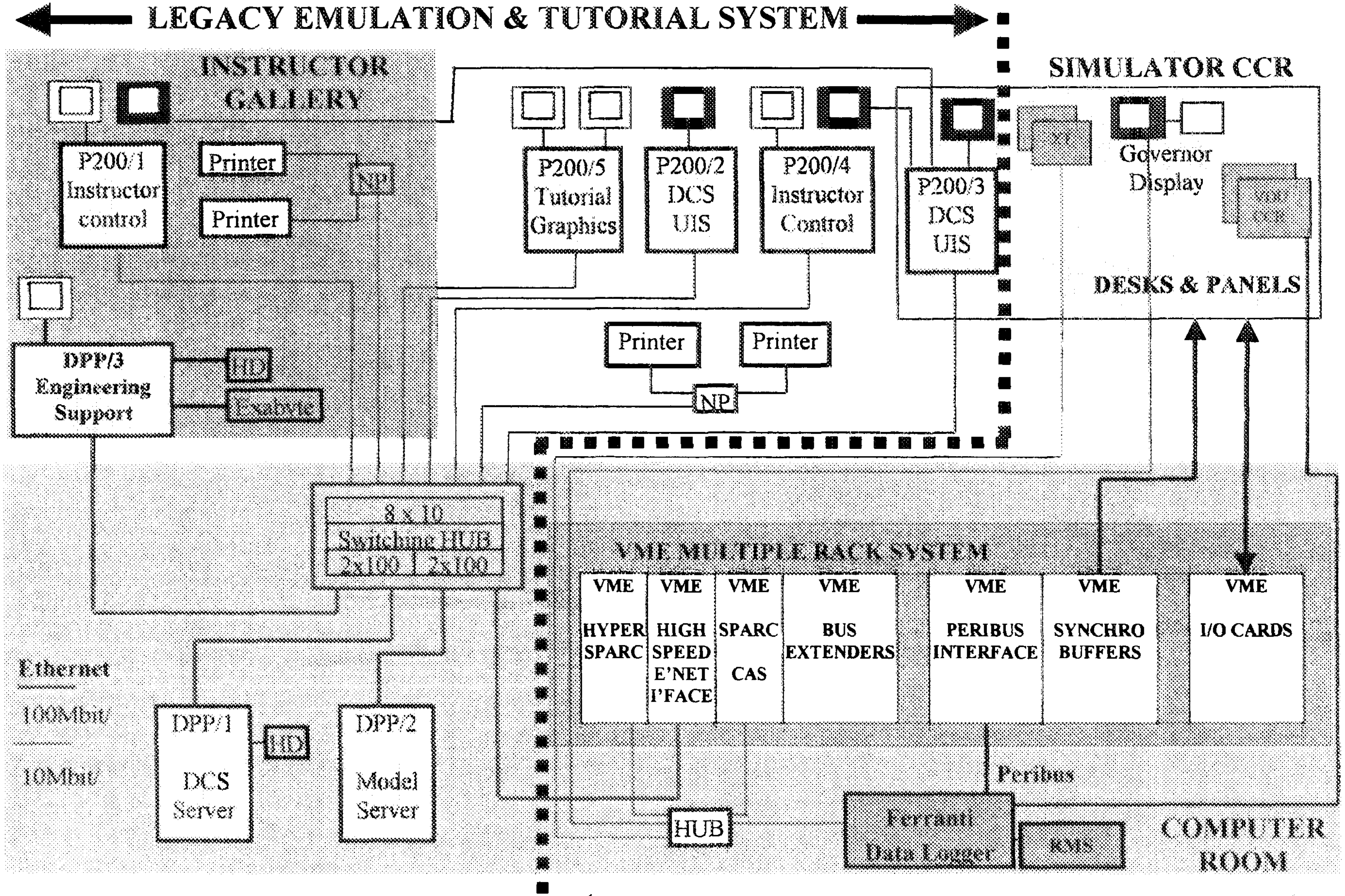


FIGURE 3 – EMULATOR/VME SIMULATOR SYSTEM SCHEMATIC

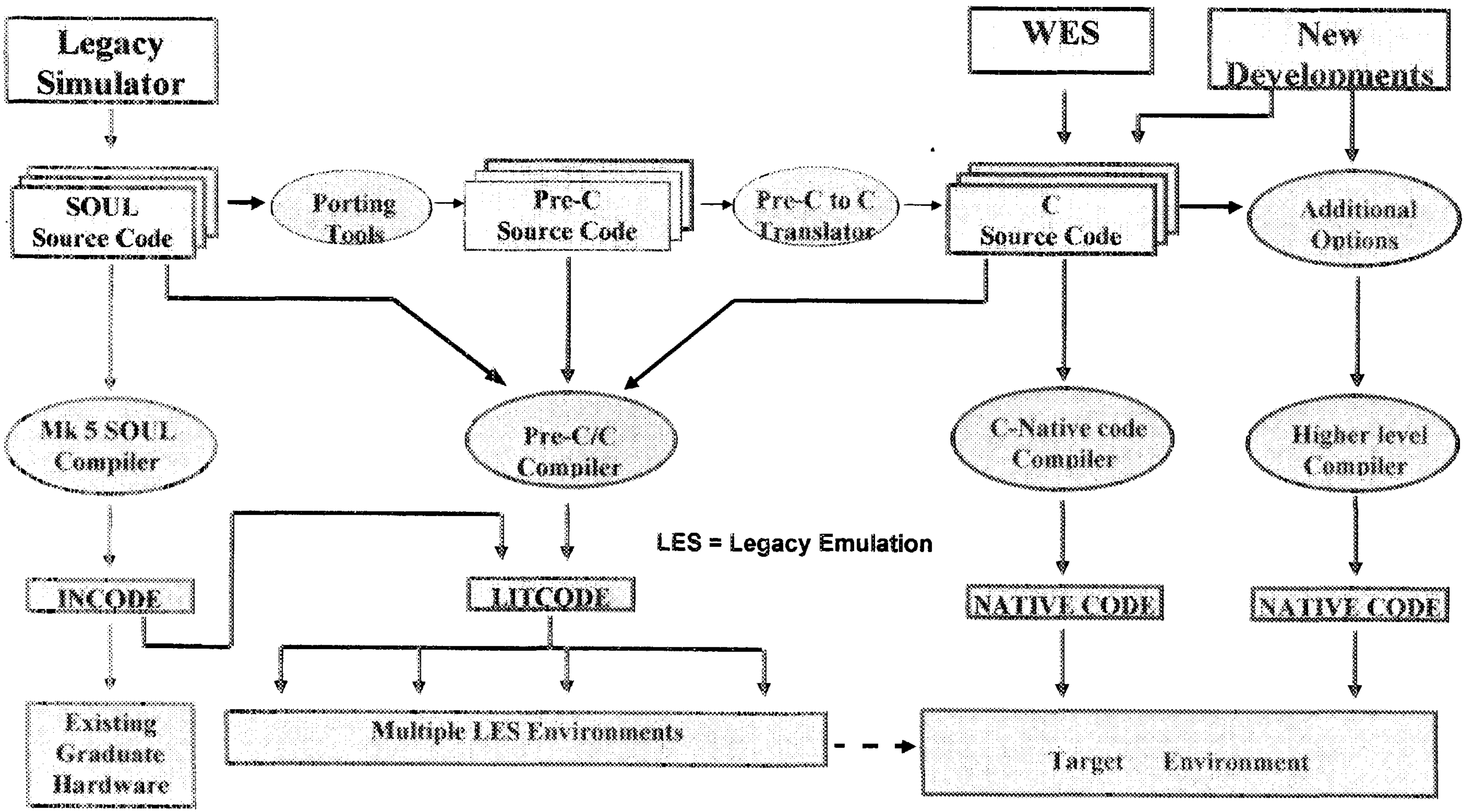


FIGURE 4 – LEGACY CODE MIGRATION PROCESS

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