USE OF DIGITAL COMPUTERS
IN THE CONTROL ROOMS.

Prepared by the CSNI PWG 1
Operating Experiences and Human Factors

JULY 1988

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USE OF DIGITAL COMPUTERS IN THE CONTROL ROOMS
OF OECD MEMBERS COUNTRIES

Prepared by the
CSNI Task Force on
The Use of Digital Computers in Control Rooms

MAY 1988

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REPORT ON THE SURVEY ON THE
USE OF DIGITAL COMPUTERS IN THE CONTROL ROOMS

MAY 25, 1988

CSNI - PWG 1
TASK FORCE 7
The NEA Committee on the Safety of Nuclear Installations (CSNI) is an international committee made up of scientists and engineers who have responsibilities for nuclear safety research and nuclear licensing. The Committee was set up in 1973 to develop and co-ordinate the Nuclear Energy Agency's work in nuclear safety matters, replacing the former Committee on Reactor Safety Technology (CREST) with its more limited scope.

The Committee's purpose is to foster international co-operation in nuclear safety amongst the OECD Member countries. This is done in a number of ways. Full use is made of the traditional methods of co-operation, such as information exchanges, establishment of working groups, and organisation of conferences. Some of these arrangements are of immediate benefit to Member countries, for example by enriching the data base available to national regulatory authorities and to the scientific community at large. Other questions may be taken up by the Committee itself with the aim of achieving an international consensus wherever possible. The traditional approach to co-operation is increasingly being reinforced by the creation of co-operative (international) research projects, such as PISC and LOFT, and by a novel form of collaboration known as the international standard problem exercise, for testing the performance of computer codes, test methods, etc. used in safety assessments. These exercises are now being conducted in most sectors of the nuclear safety programme.

The greater part of the CSNI co-operative programme is concerned with safety technology for water reactors. The principal areas covered are operating experience and the human factor, reactor system response during abnormal transients, various aspects of primary circuit integrity, the phenomenology of radioactive releases in reactor accidents, and risk assessment. The Committee also studies the safety of the fuel cycle, conducts periodic surveys of reactor safety research programmes and operates an international mechanism for exchanging reports on power plant incidents.

The Committee has set up a sub-Committee on Licensing which examines a variety of nuclear regulatory problems, provides a forum for the free discussion of licensing questions and reviews the regulatory impact of the conclusions reached by CSNI.

* * * * *

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Appendix A - Survey of the Use of Digital Computers in Control Rooms of Nuclear Power Plants

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Appendix E - Questionnaire Results, Section 4: Design Methods and Implementation Techniques
CHAPTER 1

INTRODUCTION

1.0 Background

At the 13th meeting of the Committee on the Safety of Nuclear Installations (CSNI) in November 1985, the Committee endorsed a proposal by Principal Working Group No. 1 to establish a new Task Force for assessing the use of digital computers in control rooms of nuclear power plants. The objective of the Task Force was to provide a basis for exchange of information concerning this subject. It was agreed by the Task Force members that a questionnaire would be prepared for collecting information on various aspects of the use of digital computers in Member countries.

Accordingly, a Task Force Member, Mr. W. G. Kennedy of the US NRC, prepared and revised a draft questionnaire in an attempt to make the survey as complete and comprehensive as possible. The survey was approved a year later at the November 1986 meeting of the Committee and was distributed to Member countries one month later.

1.1 Organization of This Report

This report describes the development and results of the survey on the use of digital computers in control rooms. (A copy of the questionnaire is contained in Appendix A.) The questionnaire was made up of three major sections, each of which is addressed in separate chapters of this report. Chapter 2 addresses the survey results concerning the general application of computers from two perspectives, eight application areas and six characteristics of computer systems. The results of the survey on questions related to topics of specific interest are contained in Chapter 3. Chapter 4 includes the survey results on computer system design methods and implementation techniques. Finally, the summary of results is presented in Chapter 5. Appendices contain the tabulated results to each survey question identifying each country's input.
Statistical analysis of the results of this survey would not produce meaningful information for several reasons resulting from the national orientation of the responses. Regulatory philosophy and approaches to the application of new techniques vary among Members. Some Members can quickly implement new technologies but, for some others, changes come very slowly. Relationships between regulators, vendors, and utilities are different in each Member country. This could result in different national biases for or against specific topics in the questionnaire. Finally, there are very different numbers of nuclear power plants and ages of those plants resulting in very different experience bases. Because none of these factors is part of the questionnaire, the results should not be subjected to mathematical analysis and were therefore discussed individually.

Discussions of survey results attempt to identify general consensuses and identify exceptions by Member countries. Were lists of Members are made, they are intentionally in alphabetical order by country name, not by any other characteristic.

Key words in the discussions of individual questions' results are underlined. This was intended to help the reader locate discussions of specific interest.

1.2 Questionnaire

This questionnaire was initially proposed by the US NRC at the September 1985 meeting of PWG 1. Additional objectives concerning regulatory issues, whether the introduced computerization was supplemental or replacement operator aids, and methods for automating surveillance and testing procedures were suggested. The initial questionnaire was re-drafted by the US NRC to include these objectives and further input from Finland and France prior to the November 1985 CSNI meeting. At that meeting, the Committee endorsed the proposal for a new Task Force on this subject. The draft questionnaire was then circulated to member countries for comments on the questionnaire before it was circulated for use. Many constructive comments were received from Austria, Belgium, Canada, France, Japan, the Netherlands, Norway, Spain,
Switzerland, and the United Kingdom. The input included (1) a comment that it would be hard to summarize the essay questions, (2) additional questions, and (3) suggestions to have separate questionnaires for regulators versus utilities, vendors, etc. The Canadians prepared a quantified version of the questionnaire in two forms, one for regulators and one for industry.

The questionnaire was again revised to respond to these comments and suggestions. The questionnaire was restructured into its present form. The first section requests information on the resources used to answer the questionnaire. The next section contains questions on abstract uses of computers to ensure all potential uses were covered. The third section asks questions on specific applications. The responses requested in the second and third sections were marks on scales judging the appropriateness of the application and the current projection of when the application would be implemented for safety and control uses. The fourth section was effectively yes/no questions for both safety and control uses.

The questionnaire was again distributed for comment in June 1986. This time only minor comments were received and the questionnaire was circulated for use in December 1986. Responses were generally received in the spring and early summer of 1987 with the last response received at the end of 1987.

1.3 Purpose and Scope

This survey was designed to gather information on the international development and use of digital computers in the control rooms of nuclear power plants. The results of the survey will serve a basis for the exchange of information among participating countries.

This questionnaire addressed present and future uses of computers in control rooms under the topics: general areas of application (Section 2), specific applications of particular interest (Section 3), and design methods and implementation techniques (Section 4). An identification of the source of information was in Section 1.
Respondents were requested to answer the questionnaire for their country. The request for national responses rather than separate responses for utilities, vendors, research organizations or regulators was intended to reduce any biases that may occur due to interests in promoting or restricting specific applications. Later efforts can discriminate responses as necessary. The instructions stated that:

(1) Questionnaire responses should represent the country by including the different practices, views, and plans of vendors, utilities, regulators, and research organizations.

(2) Operating power reactors and planned reactors should be included.

(3) All modes of plant operation should be considered.

1.4 Members' Responses

As part of the questionnaire, respondents were asked to identify the source of the survey information. Those countries that commented on the organizations contacted, did demonstrate that the questionnaires were answered for Member countries with inputs from vendors, utilities, and regulators.

Several Members provided comments which provide background on their responses. Austria responded to the questionnaire but only on the research questions because Austria has no operating nuclear power plants. Belgium reported that they did not include microcomputers imbedded in controllers or separate systems used only for administration of work orders. Canada stated that their appropriateness marks were low due to poor practice or little scope for the application. They did include programmable controllers but commented that their computer systems used in safety systems were limited to on/off actions and therefore the questions concerning controllers in these applications were not meaningful. Japan stated that, as a national policy,
it was still too early to use computers in safety-related systems. Spain described the ranges of plant types, manufacturers, and process computer situations. The Spanish input was identified to represent the average situation at their plants. Sweden stated that they do not regulate questions regarding the use of computers in control rooms and Switzerland reported that their response was based on one nuclear power plant but could be considered as representative. Overall, the reference date for the questionnaire was the end of February, 1987.

1.5 Definitions of Terms

Some of the terms used in the questionnaire needed to be defined to promote common understanding of the question and its response. The two most important terms or concepts to define were control and safety applications.

Control Application:

A system or function whose response to an accident condition is not a significant design objective for the plant, i.e., not a safety system. A "control" application is not expected to have the same level of reliability and performance as a "safety" application would. (The term is abbreviated to "control.")

Safety System or Function:

A system or function that responds to an accident condition in some predetermined manner. (Note: It may also have control functions.) These two terms describe two classes of applications with respect to their safety significance. (This term is abbreviated to "safety.")

In the discussion of the results of the survey, several terms were used interchangeably and are not intended to imply different meanings. This was done only to increase the readability of the report by keeping it from being too repetitious. These terms are:
Digital computers, computer systems, computers, and sometimes systems are used. No assumptions are intended as to whether there is one computer system, some specific number or architecture of the system(s), or whether they are microcomputers, mini's, or main frame computers.

Appropriate, in favor, approve, positive, and for are used to indicate responses on the appropriateness scale toward the appropriate end of the scale. Not appropriate, inappropriate, not in favor, disapprove, negative, and against are used for the other end of the scale.

The terms fully and strongly are uses to indicate responses at the far end of the scales.
CHAPTER 2

APPLICATIONS OF DIGITAL COMPUTERS

2.0 Introduction

This chapter discusses the results of the survey Section 2 on general applications of digital computers. The questions in this section were grouped into two collections. The first used an abstract model combining the operators and plant systems with a computer system or systems interfacing between them. The second collection is specific questions of interest to Members on the general uses of computer systems.

2.1 Model of Computer Application Areas

An abstract model of the use of digital computers was developed in an attempt to describe all potential applications. The model consists of one or more digital computers incorporated, generally, in the control function between the operators and the plant processes. The computer system(s) collect data concerning the plant processes and can present information to the operators as raw or processed information concerning the plant conditions. Operator aids may also be provided. In some applications, the computer system(s) are transparent and operator commands are sent as controls directly to the plant process equipment without significant processing by the computer(s). In other applications, the system(s) respond automatically to plant conditions without operator participation. As the data concerning the plant conditions becomes known and control commands issued, the computer system(s) may log this information for recordkeeping or later review.
To collect information in the application areas illustrated by the model, the questions were grouped into the following functions:

- **General plant operations** - a overview or summary of computer applications
- **Data gathering** - obtaining information describing plant conditions
- **Information display** - presentation of raw or processed information to the operators
- **Operator aids** - information processing to support operators decision-making, monitoring functions, etc.
- **Entering commands** - obtaining command input from operators
- **Issuing control signals** - the output of the computer system(s) to control the plant equipment
- **Automatic controllers** - process control without operator participation
- **Data logging** - recording of plant conditions, commands, or control signals issued
2.2 **Standard Questions**

In each of the subsections, the first six questions address the same set of features. This was done to provide assurance that the necessary questions are asked in each area. It must be noted that in some cases the standard question may not seem to fit the application area. They were asked anyway. Where strong responses were obtained on these questions, it would be interesting to know what the respondent was evaluating. These questions address six basic features of digital computers and are described below.

**reliability** - The reliability of digital computers is often considered higher than other technologies.

**replacement** - Digital technologies have been replacing analog approaches for many reasons such as cost, maintainability, response time, and precision. Examples include replacing an operator with a set of automatic controllers, replacing analog displays with computer generated displays, replacing breaker control circuits operated from the control room with computer generated signals to local breaker controllers, and replacing strip-chart event recorders with computer controlled event reports.

**additional** - Digital computers may be added to plants to provide more of the same general functions being performed by other systems. Examples include more sampling of sensor data, additional alarms for single parameters exceeding preset values, computer-based presentation procedures in addition to paper copies, and keyboards entering the same commands to operate valves and pumps.

**new** - The need for capabilities or functions not possible with other technologies may be a reason for the application of computers. Examples include high-speed recording of
sensor data to capture changes occurring faster than current devices allow, computer-generated spoken alarms, 3-dimensional presentation of plant data with 20 minute projections of current trends, and control of components by touching a graphic presentation to start a sequence of operations to change the heat-exchanger in use.

remote - Information converted to a form that can be used by digital computers can support functions away from the source of the information. Examples include displays of specific parameters at the regulating authorities offices, controllers for steam valves far enough away to be safe from a damaging steam environment, and remote controls to allow shutting down the plant if the control room is uninhabitable.

flexibility - Digital computer systems can be significantly more flexible than other technologies. Examples include standardizing computer controllers so that one controller could be reprogrammed to control another system, allowing operators to design their own displays or the sequences of actions to be performed for operator entered commands, and changing the data logged to meet temporary needs.

2.3 Response Structure

Section 2 of the survey requested an evaluation of the appropriateness and current state of digital computer applications.

For each application, Members were requested to evaluate and mark (1) the appropriateness of the application and (2) the state of the implementation. Two scales were used.
Appropriateness       Implementation
Appropriate        Not
Appropriate           Years until implementation:
Never  0  2  4  6  Unknown


For the appropriateness scale, marking was requested to indicate the degree of appropriateness. The mark should indicate a balance of opinion or evidence as to whether or not the application was appropriate for nuclear power plants.

For the description of the implementation, the mark should represent the then current state or plans. The "Never" option was to indicate there were no plans to ever implement the subject application. A mark on the "0" point indicates the application is currently in use. A mark between "6" and "Unknown" means that the application is planned for some time after 6 years from the date of the survey. "Unknown" indicated that no decision had been made on when to implement the application.

Since the applications may have different responses for safety versus control applications as defined in Section 1.5 of this report, responses were requested for both types of applications when appropriate. A tabulation of each Member's response to this section are contained in Appendix C.

2.4 Results Organized by Computer Application Areas

This part of the report discusses the survey result organized by computer application areas. In each area, the standard set of questions on features of computer systems were asked. In some areas, additional questions were included as the Task Force thought appropriate.

2.4.1 General Plant Operations

This first section was intended to be a overview or summary of computer applications. The questions were oriented toward the use of computer systems in an overall sense. Therefore, the questions referred to overall plant
operations and sometimes compared the uses of computer system with the general duties of the operators.

In the area of using computer systems to improve the reliability of overall plant operations, there was general agreement that this was an appropriate application and almost all countries had already implemented systems for this purpose.

Only Canada considered the use of computers as a replacement for operators in safety applications somewhat acceptable and reported the item already implemented. Italy was neutral and the U.S. was willing to consider the possibility. However, even these two countries had no current plans for implementation of such systems. Japan and Sweden considered control uses fully appropriate and Italy joined Canada in considering the control-grade uses appropriate and in reporting current implementations. For both uses, all other countries considered the suggestion inappropriate.

As for providing additional functions similar to those of the human operators in the control room, there was a polarized opinion leaning toward approval. There was also more approval for control uses than safety uses and the same relationship held for the number of countries that had already implemented systems for such functions.

With respect to new operations that are not possible with conventional means, applications were generally thought of as appropriate with the FRG, Netherlands and Switzerland dissenting for both safety and control applications. There was a difference between the results for safety and control uses. There was more approval for control uses and more countries had current implementations. Only a few countries reported current implementation or plans to implement in the next 2 years for control uses.

The potential use of the capability for computer systems to be remote from the systems they control resulted in significantly different responses for safety versus control uses. Safety uses were strongly disapproved by most Members with Canada and Finland approving and France, Japan and the U.S. neutral. Only
Finland and France reported current implementations with Canada estimating 2 years to implementation. There was a polarized response for this application for control uses and only three countries had implemented and no others had plans to.

The use of the flexibility of computer systems question resulted in similar responses to the remote uses but not as strongly polarized. Although Finland and Spain had a safety application implemented, several countries had plans for such applications. However, most had implemented or plans to do such for control systems.

The use of computers in the area of general plant operations was only generally found to be acceptable to increase the reliability or provide new or additional systems. The other potential uses as replacements or to use the flexibility and remote capabilities of computers received mixed and generally negative responses.

2.4.2 Data Gathering

Data gathering is the uses of computer systems in collecting information concerning the plant processes. It does not include significant processing of that information or the presentation of the raw data to operators. The standard set of six questions were asked with one addition. The last question addressed the use of computer processing to validate the data from sensors.

The use of computers to increase the reliability of data gathering systems was considered appropriate by almost all Members with most having implemented such systems. Belgium and Spain thought safety applications were somewhat inappropriate although Spain reported a current implementation. Belgium and the Netherlands, were the only respondents with no known plans for implementation.

As replacement data gathering systems, computer-based systems received only two responses as not appropriate from Spain and Sweden and they were specifically
for safety systems. Although a few Members have implemented systems for this purpose, most had plans to do so.

The use of computers to provide additional data gathering systems was considered appropriate. Although the Netherlands considered the use somewhat appropriate, neither they nor Japan had known plans for implementation. Five countries had implemented systems for control and safety applications and the rest had near-term plans for implementations.

The application of computers for new data gathering systems was considered appropriate by most Members. However, France was neutral on the subject and the Netherlands was definitely against it. Three countries had implemented systems for both safety and control uses with most of the other Members having implemented either safety or control uses or having short-term plans for implementation.

Applications for data gathering remote from the control room was considered appropriate by most Members with Italy and Sweden dissenting. Only three countries had current implementations for both safety and control uses with one more implemented and one with short-term plans for control systems.

The flexibility of computer systems was considered an appropriate reason for use by almost all Members with Belgium and Italy objecting, but not strongly. Six countries had implemented systems for safety or control uses with four implemented both safety and control applications. Most of the others were known to have short-term plans for implementations.

The use of computer systems for data validation was considered appropriate by almost all with no Members considering it at all inappropriate. Five countries had already implemented systems with this capability for both safety and control uses and two additional countries had implemented control uses alone. Spain, Switzerland and the U.S. had plans for implementing such systems in two years.

There was strong approval with more-than half approving all applications in this area and half or more Members had implemented systems in place with one
exception: information gathering remote from the control room. There were a few cases where Members considered an application as not appropriate.

2.4.3 Information Display

The survey questions in the area of information display addressed the function of presenting the information obtained from sensors or the information developed by the computer system(s).

Computer systems were considered appropriate for increasing the reliability of displays by a large majority of Members for both safety and control and all but Belgium and the FRG had implemented or had short-term plans to do so.

Although generally considered an appropriate use, the FRG, Italy, the Netherlands, Spain, and Switzerland did not approve of the use of computers as replacements for information displays. Only a small number, Canada, France, Sweden, and Switzerland, had implemented such systems and the other Members' plans were at least a few years off.

It was overwhelmingly considered appropriate to use computer systems as additional and new displays and many countries had implemented additional displays with the rest having plans to in the next 2 years. Two Members, Spain and Japan, did not know of implementation plans for new display systems.

Using computer systems for information display remote from the control room had the same approval rating and state of implementation as uses for additional and new displays with one exception. Sweden did not consider uses for remote displays appropriate for either safety or control purposes.

The pattern of strong approval and many members having implemented such systems continued for the use of the flexibility of computer systems but with a different exception. Italy did not approve of the use of the flexibility for safety systems and considered it somewhat inappropriate for control systems. However, Italy also reported plans to implement a system for control purposes in about 2 years.
In summary, the use of computer systems for information display received strong approval with current implementations for all uses except as replacements for conventional displays. For a couple of potential uses, remoteness and flexibility, two different countries objected.

2.4.4 Operator Aids

This section of the questionnaire contained the six standard questions and six additional questions on the potential uses of computer-based operator aids.

As many Members considered the use of computers to increase the reliability of operator aids for safety uses appropriate as were neutral or somewhat against and all but three Members had implemented systems or had plans to do so within the next two years. For control uses, there was much more agreement that it was appropriate and six countries reported current applications with three more scheduled within the next two years. Belgium was the least in favor of the use and did not known of any plans to implement.

For safety applications, the attitudes toward the appropriateness of computers as replacements was mixed but leaning toward disapproval with three countries strongly approving, five disapproving and three neutral. The other respondent reported the application somewhat appropriate. Only Canada had implemented a system as a replacement of conventional operator aids and only three other countries were known to have any plans for such a system. There was general approval of systems for control uses with Spain and Switzerland dissenting and Sweden joined Canada having implemented systems. Four other countries reported potential applications for control uses in the next four years.

The use of computer systems as additional operator aids was strongly approved for safety uses and was very strongly approved for control uses with the lone exception of Switzerland dissenting in both cases. Belgium and France reported current implementations for both uses and Spain and Sweden had control applications as well. Several other Members expected implementations within two years.
Nearly all Members considered computer systems fully appropriate for new operator aids and five Members reported current implementations for both safety and control uses with Spain also having current control uses implemented. Three other countries expecting implementations within two years for both safety and control uses. One additional Member reported a current control application.

The uses of computer systems to provide remote operator aids was considered generally appropriate for safety uses but (Sweden dissenting) a polarized response for control uses: seven for and three against. Safety uses also had more Members with current implementations and near term plans than control uses.

The use of the flexibility possible with computer-based operator aids also received strong approval with one exception, Italy. Three countries reported current applications of both safety and control uses and three additional countries reported control uses currently implemented. Most of the other Members expected implementations within two years.

The use of computers to improve control of processes which are difficult to control with conventional means received mixed approval in safety applications and very strong approval for control applications. Only Finland and Sweden reported current implementations but more had plants to implement in the future.

The Members were generally undecided or against the use of computer systems to semiautomatically perform some normal operating sequences but strongly approved of control applications. Italy, Spain and Switzerland did not approve of either use. No Members had currently implemented this capability for safety systems and only Canada had plans to. Canada and Finland had control implementations and Sweden and the U.S. expected future applications.

The ability to semiautomatically execute operating sequences for abnormal station states also received mixed but generally negative responses concerning the appropriateness of this capability for safety uses and no Members had either current applications or even plans. Control uses drew the same response
for approval as the previous question except Belgium switched from full approval to being somewhat against. The distribution of responses on the implementation scale for control uses was exactly the same as the previous question.

The use of computers to maximize safe commercial operations by providing better operator control close to safety margins received a full range of responses for safety uses and a favorable response and near term implementation plans for control uses. Only France and the Netherlands fully approved of safety uses with Canada and the U.S. generally approving. Only Canada had a current safety implementation. The few other Members with plans for safety uses were for two or more years from the date of the survey. Only Belgium was against both uses. Finland, the FRG, Spain and Switzerland were against this application in safety situations but were for it or neutral in control uses.

Administrative functions not related to operation of the plant received a full range of ratings for appropriateness of the safety use with three more countries finding the application acceptable than were against it. While five countries had current safety applications, only one after had any plans for such systems. The control use received strong approval and six countries reported current implementations.

On the use of computers to improve the effectiveness and performance of other than control room operators received mixed but generally approving safety and control uses. Although Italy and Switzerland were the only countries that considered safety uses very inappropriate, they both considered control uses fully appropriate. While six countries had current safety implementations and three more had plans, nine countries had current control implementations. While both Belgium and Canada were neutral on their appropriateness, both had control implementations and Belgium reported a safety implementation.

Therefore, new and additional computer-based operator aids were considered strongly appropriate. Using computer-based operator aids to increase the operation's reliability and for their flexibility were also considered appropriate with somewhat more support for control uses than safety uses. Only as replacements for current systems did they receive mixed reviews. The other
questions on uses associated with semiautomatic controls as operator aids were not supported significantly for safety uses but were supported for control uses.

2.4.5 Entering Commands

To use computer systems(s) as an interface between the operators and the process, the operators must enter commands into the system to control the process. The standard set of six questions were asked for this function.

The use of the computer to increase the reliability of the operators' task of entering commands received mixed and leaning toward negative ratings for the appropriateness of safety uses with shifted toward approval for control uses. Only Finland reported current implementation of safety uses and Canada joined Finland with control implementations. Very few other Members reported any plans for implementation of either use.

Only France approved of the use of computers-based systems as a replacement method of operator inputs for safety uses when all other Members were neutral or against its use. However, even France did not expect a safety implementation until four years after the survey. There was a fairly strong shift toward approval for control uses with Canada, the U.S., Belgium, and France expecting implementations in the future.

Six Members were neutral on the subject of the appropriateness of computers to provide additional methods of command entry for safety and five were for control uses. The safety uses received a few more negative responses and the control uses received a few more positive responses. Only Canada reported a current implementation and it was for a control use. Only two other countries, Finland and the U.S., reported any known plans for future implementations.

The use of computers to provide new methods of command entry received a basically balanced response concerning its appropriateness for safety and a more favorable response for control uses. Netherlands, Spain and Switzerland were against both uses. Canada and Finland were strongly for both uses and were joined by three others in finding control uses fully acceptable. However,
only Finland reported a current implementation (for safety) and there were very few plans for any implementations.

There was strong disapproval of remote safety and control uses of computers for command entry. However, France found both fully appropriate and was joined by Finland and Japan in the appropriate rating for control uses. Only Finland reported a current implementation, for control uses, and no others reported any for the next four years following the survey.

Basically the same pattern of disapproval and status of implementation was reported for the use of the computers' flexibility in command entry with a little more approval of control uses.

A basic pattern of disapproval for safety uses and only some approval for control uses describes the Members' responses on the subject of the use of computers for entry of commands. Finland approved and had implementations for most of these topics and was joined by Canada and France for some of these but only Canada had any current implementations.

2.4.6  Issuing Control Signals

This is the use of computers to issue control signals to the plant processes. It is strongly coupled with the source of the commands, either the operator or a closed loop automatic use.

Most Members generally thought it was inappropriate to use computer systems to improve the reliability of systems issuing controls in safety applications. Canada, Finland and Japan were strongly for it. Canada was the only Member who reported a current application and the next nearest plans were for four years away. On the control side, there was a full range of responses leaning toward approval with Sweden joining Canada in reporting current implementations and Finland expecting implementation in two years.
Replacements for systems issuing commands to the controlled process was generally considered not appropriate for safety uses and there were no implementations expected for five years. There was general approval for control uses with Canada and Sweden expecting implementation within a year of the survey.

Concerning the possible use of computer systems to provide additional control issuing systems, there was again general disapproval for safety uses, but this time no one expected implementation of such systems. The Members were balanced on the appropriateness of such systems for control uses and only Sweden reported a current application. For both application uses, France, the FRG, Netherlands and Switzerland were strongly against it and Finland and Japan for it.

The picture for the potential use of computer systems as new command issuing systems showed the typical pattern for this application area. Finland, France and Japan were strongly in favor of safety uses with most of the other Members against it. There were no implementations or plans. Belgium, Canada and Sweden joined Finland and Japan in favor of the application for control uses and Canada reported current control implementations with Sweden, Finland, and U.S. expecting implementations within two years.

Most countries considered it inappropriate to provide remote command issuing capabilities for safety or control uses. There were no current implementations reported for either use but Finland did expect an implementation in two years.

The flexibility available within computer systems drew a mixed but generally negative response for safety uses and a balanced and polarized response for control uses. Again there were no current or near term plans for safety implementations but Sweden and Finland expected control implementations within two years.

The use of the computer systems ability to validate control signals received mixed approval for safety and some approval for control uses with the FRG, Netherlands, Spain and Switzerland continuing their disapproval of the general use of computers in issuing commands. Canada reported implementations for both
safety and control uses and Sweden, Finland and the U.S. expecting implementations within two years.

Although considered inappropriate for safety uses by most Members and only mixed or neutral attitudes toward control uses, Finland, sometimes joined by Canada and Japan, approved of the use of computers for issuing commands and had or expected implementations in the future.

2.4.7 Automatic Controllers

The potential use of computers as closed-loop or automatic controllers was surveyed. The standard set of six questions were asked except the question on flexibility was divided into two versions and two additional questions were included.

The use of computer-based systems to increase the reliability of automatic controllers received a mixed response for safety uses and a polarized but more toward approval response for control uses. Canada, Finland and Sweden strongly approved of both uses and were joined by Japan for control uses. France, the Netherlands, Spain, and Switzerland strongly disapproved of both uses. Canada and Sweden also had current safety implementations while no others were planned in the short-term. Canada, Finland and Japan reported current control uses with Sweden and the U.S. reporting short-term plans for such applications.

As replacements, computer systems also drew a mixed but negative response for safety uses. But this time, only Sweden was strongly in favor of the uses and no implementations were expected for at least four years. There was a polarized but leaning toward approval response for computer-based control grade replacements and several countries had current or short-term plans for control uses.

As controllers in addition to current systems, most countries were not strongly for or against safety applications and for control uses, a more balanced response was obtained. Finland was the only Member strongly for both uses and was joined by Belgium and Japan for control uses. France and Switzerland were
strongly against both uses. While there were no current implementations or plans for five years to implement safety systems, four countries had current or near term plans for control systems.

There was generally only partial approval for new computer-based safety grade controllers and only Sweden reported current implementation. However, six countries were strongly in favor of computer-based controllers for new control uses. Canada, Finland and Japan reported current control implementations with Sweden expecting an implementation in the next year.

The Members were strongly disapproval of remote controllers for safety applications with no current or planned implementations. Control uses were also considered inappropriate by all Members with one exception. Finland strongly approved and reported a current implementation.

The potential use of computers as controllers to be flexible while in use, or on-line, drew a mixed but leaning toward negative response for safety uses and a positive response for control uses. Sweden reported the only current safety implementation and expected a control implementation within a year. Canada and Finland reported current control implementations. Canada, the FRG, Italy, Spain and Switzerland were strongly against safety uses of this flexibility but only Spain and Switzerland were against control uses.

The flexibility to modify computer-based automatic controllers off-line resulted in nearly the same responses as the ability to change on-line with a slightly more positive response for control uses.

The application of computer-based controllers to automatically take actions in response to abnormal station states received mixed response for safety uses: two countries strongly for, four strongly against, five neutral, and one somewhat against. For control uses, there was much more of a consensus with five countries strongly in favor. Switzerland was the lone strongly dissenting Member. As with some of the other application areas, Sweden had a current safety application with Canada and the U.S. expecting implementations in two years. Canada and Finland reported current control implementations with Sweden expecting an implementation within a year.
Using computer-based automatic controllers to operate close to safety margins to maximize the safe commercial operation was generally found not appropriate by more countries than found it even somewhat appropriate. However, Canada reported the only current (or near-term) implementation. Control uses drew a divided response. Canada, Finland and Sweden reported the only current (or near-term) control use implementations.

The use of computers as automatic controllers drew mixed responses on almost all questions. Canada, Finland, Japan, and sometimes Sweden approved of such applications for at least control systems and often reported current implementations or plans.

2.4.8 Computer Applications in Data Logging

The use of computers as data loggers was nearly universally found to be fully appropriate with current implementations common. The exceptions are the interesting results of the survey. The standard set of questions were asked with one addition.

The use of computers as data loggers to increase the reliability of such systems was found strongly appropriate for both safety and control uses by all but two respondents. Belgium was only somewhat in favor and the Netherlands was strongly against it. All countries but Italy and the Netherlands reported current implementations for both uses and Italy expected implementations in two years.

The use of computer-based data logging as replacements for current systems received nearly unanimous approval for safety and control uses. Only the FRG was strongly against both uses. Six countries reported current implementations for safety and the same number for control uses. For both applications, almost all of the rest of the members expected implementations within two years. Finland did not expect a safety use for four years, Japan had no known plans for any, and the FRG never expected to implement such systems.
As additional data logging systems for both safety and control uses, only the Netherlands did not consider the application fully appropriate. The Netherlands were neutral and, with Japan, did not have any known plans to implement. There were six countries with current applications of each of these uses and two others expected in the near future. Finland expected a safety application in four years.

The distribution of responses to the use of computer systems as new data loggers received the same full approval for both safety and control uses with the Netherlands neutral but fewer (four) countries had current safety implementations. The other safety implementations were expected in two years.

Remote data logging was strongly approved but there were some interesting responses. Sweden reported current implementations for both uses but was only somewhat in favor of safety applications and was strongly against control uses. The Netherlands, who was neutral toward both uses, reported implementations expected within the next year.

The use of the flexibility of computer systems as data loggers also received very strong approval for safety and control uses with the Netherlands again neutral. In this case, seven countries reported current safety implementations and eight reported control implementations. Japan, although strongly approving both uses, did not report knowledge of any implementations or plans.

The additional question in this area dealt with the use of computers for recordkeeping for administration. This was also considered fully appropriate by almost all countries. Canada and the Netherlands were neutral. Six countries reported current implementations for both uses. Canada and the U.S. expected implementations in two years and France and Switzerland expected implementations two years after that.

The use of computers as data logging systems was almost universally accepted and already implemented. However, for all applications except replacements, the Netherlands expressed concerns and the FRG expressed concerns for replacements.
2.5. Results Organized by Standard Questions

This part of the report discusses the responses in each of the application areas by the capabilities or characteristics of the computer-based systems. This alternate organization of the information provides an interesting view of Members' attitudes toward appropriateness and status of implementation. The capabilities or characteristics are reliability, replacements, additions, new, ability to be remote, and flexibility.

2.5.1 Reliability

In the area of using computer systems to improve the reliability of overall plant operations, there was general agreement that this was an appropriate justification and almost all countries had already implemented systems for this purpose.

The use of computers to increase the reliability of data gathering systems was considered appropriate by almost all Members with most having implemented such systems. Belgium and Spain thought safety applications were somewhat inappropriate although Spain reported a current implementation. Belgium and the Netherlands, were the only respondents with no known plans for implementation.

Computer systems were considered appropriate to increase the reliability of displays by a large majority of Members and all but Belgium and the FRG had implemented or had short-term plans to do so.

As many members considered the use of computers to increase the reliability of operator aids for safety uses appropriate as were neutral or somewhat against and all but three Members had implemented systems or had plans to do so within the next two years. For control uses, there was much more agreement that it was appropriate and six countries reported current applications with three more scheduled within the next two years. Belgium was the least in favor of the use and did not have known plans to implement.
The use of the computer to increase the reliability of the operators' task of entering commands received mixed and leaning toward negative ratings for the appropriateness of safety uses with a shift toward approval for control uses. Only Finland reported current implementation of safety uses and Canada joined Finland with control uses. Very few other Members reported any plans for implementation of either use.

Most Members generally thought it was inappropriate to use computer systems to improve the reliability of systems issuing controls in safety applications. Canada, Finland and Japan were strongly for it. Canada was the only Member who reported a current application and the next nearest plans were for four years away. On the control side, there was a full range of responses leaning toward approval with Sweden joining Canada in reporting current implementations and Finland expecting implementation in two years.

The use of computer-based systems to increase the reliability of automatic controllers received a mixed response for safety uses and a polarized but more toward approval response for control uses. Canada, Finland and Sweden strongly approved of both uses and were joined by Japan for control uses. France, the Netherlands, Spain, and Switzerland strongly disapproved of both uses. Canada and Sweden had current safety implementations and there were no others planned in the short-term. Canada, Finland and Japan reported current control uses with Sweden and the U.S. reporting short-term plans for such applications.

The use of computers as data loggers to increase the reliability of such systems was found strongly appropriate for both safety and control uses by all but two respondents. Belgium was only somewhat in favor and the Netherlands was strongly against it. All countries but Italy and the Netherlands reported current implementations for both uses and Italy expected implementation in two years.

Reliability as a reason for using computers was generally considered appropriate for overall plant operations, data gathering, display systems and data logging systems. The other uses in the survey, operator aids, for entry of commands, for issuing commands, and as automatic controllers, received mixed reviews.
2.5.2 Replacements

Only Canada considered the use of computers as a replacement for operators somewhat acceptable for safety applications and reported the item already implemented. Italy was neutral and the U.S. was willing to consider the possibility. However, even these two countries had no current plans for implementation of such systems. Japan and Sweden considered control uses fully appropriate and Italy joined Canada in considering the control grade uses fully appropriate and reported current implementations. All other countries considered the suggestion inappropriate for both uses.

As replacement data gathering systems, computer-based systems received only two responses as not appropriate from Spain and Sweden and they were specifically for safety systems. Although a few Members have implemented systems for this purpose, most had plans to do so.

Although generally considered an appropriate use, the FRG, Italy, the Netherlands, Spain, and Switzerland did not approve of the use of computers as replacements for information displays. Canada, France, Sweden, and Switzerland, had implemented such systems and the other Members plans were at least a few years off.

For safety related operator aids applications, the attitudes toward the appropriateness of computers as replacements was mixed but leaning toward disapproval with three countries strongly approving, five disapproving and three neutral. The other respondent reported the application somewhat appropriate. Only Canada had implemented a system as a replacement of conventional operator aids and only three other countries were known to have any plans for such a system. There was general approval of systems for control uses with Spain and Switzerland dissenting and Sweden joined Canada with implemented systems. Four other countries reported potential applications for control uses in the next four years.

Only France approved of the use of computers-based systems as a replacement method of operator inputs for safety uses when all other Members were neutral or against its use. However, even France did not expect a safety implemen-
tation until four years after the survey. There was a fairly strong shift toward approval for control uses with Canada, the U.S., Belgium, and France expecting implementations in the future.

Replacements for systems **issuing commands** to the controlled process was generally considered not appropriate for safety uses and there were no implementations expected for five years. There was general approval for control uses with Canada and Sweden expecting implementation within a year of the survey.

As replacements for **automatic controllers**, computer systems also drew a mixed response for safety uses. But this time, it was a polarized and leaning toward approval of the safety uses but no implementations were expected for at least four years. There was strong approval of computer-based control replacements and several countries had current or short-term plans for control uses.

The use of computer-based **data logging** as replacements for current systems received nearly unanimous approval for safety and control uses. Only the FRG was strongly against both uses. Six countries reported current implementations for safety and the same number for control uses. For both applications, almost all of the rest of the members expected implementations within two years. Finland did not expect a safety use for four years, Japan had no known plans for any, and the FRG never expected to implement such systems.

In summary, only the applications of computers as replacement, data gathering, display systems and data logging systems were considered appropriate. Replacing automatic controllers and operator aids with computer-based systems drew mixed responses and the Members were against replacing command input and command issuing systems. For completeness, the possibility of replacing operators was asked and received the expected negative response with one notable exception, Canada.
2.5.3 Additions

As for providing additional functions similar to those of the human operators in the control room, there was a mixed opinion leaning toward approval. There was also more approval for control uses than safety uses and the same relationship held for the number of countries that had already implemented systems for such functions.

The use of computers to provide additional data gathering systems was considered appropriate. Although the Netherlands considered the use somewhat appropriate, neither they nor Japan had known plans for implementation. Five countries had implemented systems for control and safety applications and the rest had near-term plans for implementations.

It was overwhelmingly considered appropriate to use computer systems as additional displays and many countries had implemented additional displays with the rest having plans to in the next 2 years. Two Members, Japan and Spain did not know of any implementation plans for new display systems.

The use of computer systems as additional operator aids was strongly approved for safety uses and was very strongly approved for control uses with the lone exception of Switzerland dissenting in both cases. Belgium and France reported current implementations for both uses and Sweden had a control application as well. Several other Members expected implementations within two years.

Six Members were neutral on the subject of the appropriateness of computers to provide additional methods of command entry for safety and five were for control uses. The safety uses received a few more negative responses and the control uses received a few more positive responses. Only Canada reported a current implementation and it was for a control use. Only two other countries, Finland and the U.S., reported any known plans for future implementations.

Concerning the possible use of computer systems to provide additional control issuing systems, there was general disapproval for safety uses, and no one expected implementation of such systems. The Members were balanced on the appropriateness of such systems for control uses and only Sweden reported a
current application. For both application uses, France, the FRG, the Netherlands and Switzerland were strongly against it and Finland and Japan for it.

As automatic controllers in addition to current systems, most countries were not strongly for or against safety applications and for control uses, a more balanced response was obtained. Finland was the only Member strongly for both uses and was joined by Belgium and Japan for control uses. France and Switzerland were strongly against both uses. While there were no current implementations or plans for five years to implement safety systems, four countries had current or near term plans for control systems.

As additional data logging systems for both safety and control uses, only the Netherlands did not consider the application fully appropriate. The Netherlands was neutral and, with Japan, did not have any known plans to implement. There were six countries with current applications of each of these uses and two others expected in the near future. Finland expected a safety application in four years.

As additions to the control of nuclear power plants, computer systems were acceptable in most areas with current implementations. As for providing additional command entry systems, the Members were neutral. Additional automatic controllers also resulted in an overall neutral rating, but Members were more polarized. Only as additional systems for issuing controls was there general disapproval.

2.5.4. New

With respect to new operations that are not possible with conventional means, applications were generally thought of as appropriate with the FRG, the Netherlands, and Switzerland dissenting for both safety and control applications. Only a few countries reported current implementation or plans to implement in the next 2 years for control uses. There was a difference between the results for safety and control uses. There was more approval for control uses and more countries had current implementations.
The application of computers for new data gathering systems was considered appropriate by most Members. However, France was neutral on the subject and the Netherlands was definitely against it. Three countries had implemented systems for both safety and control uses with most of the other members having implemented either safety or control uses or having short-term plans for implementation.

It was overwhelmingly considered appropriate to use computer systems as new displays and many countries had implemented additional displays with the rest having plans to in the next 2 years. Japan and Spain did not know of implementation plans for new systems.

Nearly all Members considered computer systems fully appropriate for new operator aids and five Members reported current implementations for both safety and control uses with Spain also having current control uses implemented. Three other countries expected implementations within two years for both safety and control uses. One additional Member reported a current control application.

The use of computers to provide new methods of command entry received a basically balanced response concerning its appropriateness for safety and a more favorable response for control uses. The Netherlands, Spain and Switzerland were against both uses. Canada and Finland were strongly for both uses and were joined by three others in finding control uses fully acceptable. However, only Finland reported a current implementation (for safety) and there were very few plans for any implementations.

The potential use of computer systems as new command issuing systems drew a full, but basically balanced, range evaluation. Finland, France and Japan were strongly in favor of safety uses while most of the other members were against. There were no current implementations or plans. Belgium, Canada and Sweden joined Finland and Japan in favor of the application for control uses and Canada reported current control implementations with Sweden, Finland, and U.S. expecting implementations within two years.
There was generally only partial approval for new safety grade controllers and only Sweden reported current implementation. Six countries were strongly in favor of computer-based controllers for new control uses. Canada, Finland and Japan reported current implementations with Sweden expecting an implementation in the next year.

The distribution of responses to the use of computer systems as new data loggers received full approval for both safety and control uses with the Netherlands neutral and four countries had current safety implementations. The other safety implementations were expected in two years.

The use of computers to provide new capabilities was considered very appropriate for almost all applications. However, as new systems for issuing commands, the Members' responses were balanced, for and against. Many countries had applications or at least near term plans to provide new capabilities using computer-based systems.

2.5.5. Remoteness

The potential use of the capability for computer systems to be generally remote from the systems they control resulted in significantly different responses for safety versus control uses. Safety uses were strongly disapproved by most Members with Canada and Finland approving and France, Japan and the U.S. neutral. Only Finland and France reported current implementations with Canada estimating 2 years to implementation. There was a polarized response to this application for control uses and only three countries had implemented and no others had plans to.

Applications for data gathering remote from the control room was considered appropriate by most Members with Italy and Sweden descending. Only three countries had current implementations for both safety and control uses with one more implemented and one with short-term plans for control systems.

Using computer systems for information display remote from the control room had a strong approval rating and several implementations with one exception.
Sweden did not consider uses for remote displays appropriate for either safety or control purposes.

The uses of computer systems to provide remote operator aids was considered generally appropriate for safety uses but a polarized response for control uses: seven for and three against. Safety uses also had more Members with current implementations and near term plans than control uses.

There was strong disapproval of remote safety and control uses of computers for command entry. However, France found both fully appropriate and was joined by Finland and Japan for control uses. Only Finland reported a current implementation, for control uses, and no others reported any for the next four years following the survey.

Most countries considered it inappropriate to provide remote command issuing capabilities for safety or control uses. There were no current implementations reported for either use but Finland did expect an implementation in two years.

The Members were strongly disapproval of remote controllers for safety applications with no current or planned implementations. Control uses were also considered inappropriate by all Members with one exception. Finland strongly approved and reported a current implementation.

Remote data logging was strongly approved but there were some interesting responses. Sweden reported current implementations for both uses but was only somewhat in favor of safety applications and was strongly against control uses. The Netherlands, who was neutral toward both uses, reported implementations expected within the next year.

The capability for computer-based systems to be remote from the systems they interact with was seen as appropriate for data gathering, displays and operator aids but not for the other potential application areas.
2.5.6 Flexibility

The general question on the use of flexibility of computer systems resulted in mixed responses but not strongly polarized. Although Finland and Spain had the only implemented safety application, several countries had plans for such applications. Most had implemented or plans for control systems.

The flexibility of computer systems was considered an appropriate reason for use in data gathering by almost all Members with Belgium and Italy objecting, but not strongly. Six countries had implemented systems for safety or control uses with four implemented both safety and control applications. Most of the others were known to have short-term plans for implementations.

The pattern of strong approval and many members having implemented display systems continued for the use of the flexibility of computer systems but with an exception. Italy did not approve of the use of the flexibility for safety applications and considered it somewhat inappropriate for control systems. However, Italy also reported plans to implement a system for control purposes in about two years.

The use of the flexibility possible in computer-based operator aids also received strong approval with the same exception, Italy. Three countries reported current applications of both safety and control uses and three additional countries reported control uses currently implemented. Most of the other Members expected implementations within two years.

Basically the same patterns of disapproval of command entry uses was repeated for the use of the computers' flexibility in command entry with a little more approval of control uses.

For the function of issuing commands, the flexibility available within computer systems drew a mixed but generally negative response for safety uses and a balanced and polarized response for control uses. Again there were no current or near term plans for safety implementations but Sweden and Finland expected control implementations within two years.
The potential uses of computers as automatic controllers to be flexible while in use, or on-line, drew a mixed but leaning toward negative response for safety uses and a positive response for control uses. Sweden reported the only current safety implementation and expected a control implementations. Canada, the FRG, Italy, Spain, and Switzerland were strongly against safety uses of this flexibility but only Spain and Switzerland was against control uses. The flexibility to modify computer-based automatic controllers off-line resulted in nearly the same responses as on-line changes with a slightly more positive response for control uses.

The use of the flexibility of computer systems as data loggers received very strong approval for safety and control uses with the Netherlands again neutral. In this case, seven countries reported current safety implementations and eight reported control implementations. Japan, although strongly approving both uses, did not report knowledge of any implementations or plans.

The use of the potential flexibility of computer-based systems was considered very appropriate for data gathering, displays, operator aids, and data logging systems. There was a more mixed response to the use of the computers' flexibility in systems for issuing commands and as automatic controllers. Including flexibility in command entry systems was generally viewed as inappropriate.
CHAPTER 3
SPECIFIC APPLICATIONS OF DIGITAL COMPUTERS

3.0 Introduction

The questions in this section of the questionnaire were those of specific interest to Members independent of the model used in the questionnaire of computers in operations of nuclear power plants. They were grouped into five topics generally following the previous chapters' topics. The topics are displays, automated assistance, computer control, data logging, and maintenance assistance.

3.1 Displays

The first section dealt with displays and included four questions on their uses. The first question addressed the use of computers to organize or prioritize alarms and annunciators or to organize data. All countries considered this a fully appropriate use of computer systems in both safety and control uses except Sweden. Sweden was neutral. Seven countries reported current implementations of both uses with three more expected within 2 years. Japan and Sweden reported not knowing of any plans.

There was unanimous agreement that providing on-line display of numeric and trend data and other plant variables or states was appropriate for safety and control uses. All respondents but four reported current implementations. Italy, the Netherlands and Spain reported their implementations were expected within two years. The FRG did not expect implementation for four years.

Although there was fairly strong approval of the display of standard or abnormal procedures, there were four countries that had any known plans for such systems and only Finland reported a current implementation for control use. The U.S. expected systems in two years and France, the FRG and Spain expected systems in four years.
The last question in the area of displays was on displays used for flow sheets and related plant data. This was evaluated as fully appropriate for safety and control uses by almost all Members. Italy, Sweden and Switzerland were neutral. Four Members reported current implementations for both safety and control uses. Spain also had current implementation for control uses and implementation was expected in the Netherlands within a year and the FRG, Sweden and the U.S. expected some implementations after that.

3.2 Automated Assistance

The first question in this area was on the use of computers to provide sequential display and tracking of manually executed sequences of control actions. This was strongly approved for safety uses, with Italy and Switzerland dissenting, and strongly approved without any dissent for control uses. France and Japan reported current implementations for both uses with Sweden having a safety implementation. Sweden as well as Canada and Finland had control implementations. There were a few others expected in the future.

The second question in this area dealt with the computer system providing automated sequencing of operator actions. This drew a mixed response on its appropriateness for safety uses with a more countries considering it fully appropriate than not. Control uses were more strongly approved with the FRG and Switzerland being somewhat against it. Only France reported a current system for safety and control uses while Canada and Finland joined in reporting control uses. The U.S. was the only country to report having plans for such systems.

France reported the only current implementation of deterministic or expert systems assisting operators as decision aids for diagnosing abnormal conditions or in assessing the consequences of proposed actions. Six countries considered this application fully appropriate for both safety and control uses. Canada and the FRG were neutral on both uses. Switzerland was strongly against such systems for safety uses and was neutral on control uses. The Netherlands considered both uses somewhat inappropriate. The next implementations after the current French applications for both uses were
expected in Italy in two years for both uses and in Spain and the U.S. in four years.

The use of deterministic or expert systems to assess plant or system states, integrity or redundant systems received almost the same generally positive response as the previous question. The appropriateness of both applications was the same except the Netherlands was neutral this time and the U.S. and Switzerland moved one unit away from strong approval. The implementations status was exactly the same.

3.3 To Provide Direct or Indirect Digital Computer Control

The use of computers to provide direct control of one or more reactivity mechanisms drew a full range of responses for safety uses with a few more Members leaning toward disapproval than approval. Canada, France and Sweden found this to be a fully appropriate application while Belgium, the FRG, Spain and Switzerland considered it fully inappropriate. The other respondents were between these two groups. Canada, the Netherlands and Sweden reported current applications and the only plans were reported by the U.S. and were expected in about four years. Although not requested by the survey, Canada provided a response for control uses. They considered it fully appropriate and reported that they had implemented systems.

The question on using computers to indirectly control reactivity mechanisms through control of setpoints for other reactivity mechanism control loops drew a mixed response also leaning toward disapproval on its appropriateness. There were some interesting changes in Member responses with respect to the previous question on direct control of such systems. Canada switched from full approval to finding this use not at all appropriate and Belgium went from full disapproval to a neutral evaluation. Sweden reported the only current implementation with French and U.S. implementations expected in the future. Canada again reported approval and a current implementation of such a system for control uses.
The use of computers as direct controllers of processes resulted in a polarized response for safety uses and a full range, but more in favor, for control uses. For safety uses, five countries were strongly in favor while six disapproved with the FRG, Spain, Switzerland, strongly disapproving. Sweden reported the only current implementation with Canada expecting one in two years. For control uses, there was a general shift toward approval with five countries finding it fully appropriate. Canada and Finland reported current implementations with Sweden's expected in a year.

For the indirect control of processes by controlling setpoints for other controllers, there was general approval of safety uses and strong approval for control uses. Canada, one of three who found safety uses fully inappropriate, considered control uses fully appropriate. Sweden reported the only safety use with Italy expecting implementation in two years. Canada and Finland again reported current implementations with Sweden, Italy and the U.S. expecting implementations within two years.

3.4 Data Logging

There was total agreement that the use of computers to provide logged plant variables in a hard copy form for safety and control uses and almost every country reported current safety and control implementations. Italy expected a safety implementation in two years and the U.S. was two years behind that and two years behind all the others who reported current implementations for control uses.

There was also unanimous approval of the providing of logged plant variables in a machine readable form for both safety and control uses. All but four countries reported current implementations of both uses with the others, except the U.S. for safety uses, expected within 2 years.

The last question on data logging involved using computers for event recording systems to record the timing of a sequence of discrete events. This was also found fully appropriate by all respondents with almost all again reporting current implementations. The U.S. was again the last expecting implementation of such systems.
3.5 Maintenance Assistance

The use of computers to scheduling support for routine maintenance drew nearly unanimous approval. Canada and the Netherlands were neutral on both safety and control uses. Four countries reported current safety implementations with four more expected in two years. Six countries reported current control implementations.

Providing deterministic or expert systems for the diagnosis by maintenance personnel of component or system faults in or out of the control room received polarized but generally favorable evaluations of its appropriateness for both safety and control uses. Members were either strongly for or weakly against this application. Switzerland was the only Member strongly against safety uses but was strongly in favor of control uses and had the only implementation, for control use. No other implementations were expected for four or more years.

Sweden reported the only use of computers to display maintenance procedures and it was reported for both safety and control uses. There was not a majority that felt strongly in either direction on this question but the majority did generally find the application appropriate for safety and control uses. Switzerland again strongly disapproved of the safety application but strongly approved of the control use. Finland, Spain and the U.S. expected systems to be implemented in their countries in about two years.

No Members expected implementations of computer systems to perform maintenance procedures automatically for safety purposes and Finland reported implementation expected in two years for control uses. Only Finland and Japan considered this application at all appropriate and they thought it strongly appropriate. The others were negative with the exception of the FRG and U.S. which were neutral on the subject.
CHAPTER 4

DESIGN METHODS AND IMPLEMENTATION TECHNIQUES

4.0 Introduction

The questions in this section addressed approaches to the development and evaluation of computer-based systems. The topics were specifications, development methods, design options, and testing items. There was also a set of questions to collect Members' experiences in this process and a set to identify research needs.

4.1 System Specifications

All countries reported thorough testing of end products to assure the acceptability of the hardware of computer systems in control uses and all but Belgium and Japan use the same techniques for safety uses. Over half of the countries ensured the acceptability of hardware systems by controlling the development process. Complete specifications were used by six countries for both safety and control uses with Finland using them only for safety uses and Belgium and Japan using them only for control uses. The French reported that they did not use complete formal specifications for hardware at all and it is unknown whether Switzerland used formal specifications or not. Italy reported using all these techniques with one addition, validation.

Members reported using the same approaches to assure the acceptability of software that they used for hardware except for this question. The FRG and France joined those controlling the development process and Switzerland joined those who used complete formal specifications and Italy added the use of validation and verification procedures.

When asked what plans were prepared, all Members reported using some of the plans listed and most used all four: quality assurance plans, software verification plans, software test plans, and programming conventions. Japan
reported not using the quality assurance plan for safety uses and Belgium and the FRG did not use it at all. Belgium did report using the software verification plan for control but not for safety uses and a software verification plan was not used at all in Canada or France. Canada did report using a software test plans for safety only and Belgium used one for control only. Programming conventions were the least use item in the list, but still being used by six Members. Three additional plans were reportedly used: software validation plans by Canada, software management plans by Italy, and system test plans by Sweden.

The next question was on what design review techniques were used. Although the FRG's use of these techniques was unknown, all other respondents reported using a preliminary design review for control systems and all but Belgium and Japan reported using the same techniques for safety systems. Critical design reviews were used less than preliminary design reviews with six countries using them for both safety and control uses. Canada, Italy, and the U.S. reported using critical design reviews and code walkthroughs for both uses, while France and Switzerland used the critical design reviews but did not know if code walkthroughs were used. Finland used critical design reviews and code walkthroughs but for safety systems only. For both applications, Spain used preliminary design reviews and critical critical design reviews only. Two countries provided other techniques for design reviews. Sweden reported also using reviews of system or module designs and the U.S. reported using of code inspections and configuration audits.

With few exceptions, respondents reported preparing human factors engineering specifications for all areas listed in the questionnaire: displays; input devices; interactions between input devices and displays; arrangements of input devices and displays; and interaction dialog requirements. Although Japan did use all of them for control uses, Japan was the only Member who did not prepare them for both safety and control applications. Sweden also reported having human factors requirements for the overall control room design.

The question on the methods used for the design of the human-computer interface did not show universal acceptance of the methods listed. Operator function and task analysis was used for both safety and control uses by four Members, not
used at all by four others, and another three used them for either safety or control applications. Only Italy used a human factors engineering test and evaluation program for both control and safety systems while five other Members were divided on its use for either control or safety systems. Workload analysis was used only by Japan and the U.S. and human reliability analyses were used only by Canada and the Netherlands. The most common method was static or pseudo-dynamic function mock-up studies: seven Members, six of which used them for both safety and control uses. The next most common methods used were operator performance or plant dynamic simulator studies, also used by seven Members of which five used them for both applications. Five countries also reported using studies of failure effects on operator tasks or functions. Only France, Japan and the U.S. reported experimental research on input device and display designs. Belgium did not indicate using any of these methods but reported relying on former experience. Japan used all of the methods except the human reliability analysis. The FRG and Switzerland did not report using any of the methods at all.

4.2 Development Methods

There were three questions asked in this area on the subjects of configuration management, software programming languages, and on programming standards.

The configuration management techniques listed in the questionnaire turned out to be listed in the order of most used to least used. Normal recordkeeping was used by almost all respondents with Belgium and Japan reporting their use for control applications only and Spain reported not using this method at all. All but Belgium and France reported using computerized libraries of application and object codes with Japan using this technique only for control applications. Six Members reported using a computerized library of public source or object codes with Finland reporting this use only in safety applications. Our half of the responding Members reported designation of a software configuration manager for both safety and control applications. Four Members, Finland, Spain, Sweden, and Switzerland, included on-line readable records of software issue information. Having on-line software checks of the issue number compatibility between software elements and between software and firmware media was used by
Finland and Switzerland for both applications and by Canada for safety applications only. The U.S. reported using another technique, a software configuration management plan, as part of the software quality assurance plan for configuration management.

The responses on the identification of software programming languages were diverse. Assembly language was reported as being used by all Members with most using it for both applications. Fortran was the next most commonly used language, mostly for control uses, with all but France using it. Pascal was used by five Members also mostly for control applications. The "C" language was used by four members. Finland and Sweden used it for both uses and by Canada and the U.S. use it for control uses only. Finland was the only country using Ada, Lisp, or Prolog with only Ada being used for safety uses. The Basic programming language was reported used for control applications in Spain.

The third question in this area concerned the use of programming standards. All but Belgium, the FRG, France, and Japan reported using standard header formats and limits on the depth of nesting for routines for both safety and control applications. The FRG used only standard header formats. A limit on the length of a routine was used by six Members. The techniques of a coding format to indicate routines, using single entry, single exits, and no recursive routines were used by five countries with Canada, Finland, Spain, and the U.S. using to all three standards. Finland and Sweden reported using minimum routine lengths and Spain and the U.S. reported restricting the use of "GO TO" statements. The U.S. also reported using standard prologs and comments as well as language coding standards.

4.3 Design Options

The design options addressed in this section of the questionnaire were basically hardware options associated with reliability. The first question was on levels of redundancy. All Members reported using a primary computer which may have redundant inputs and outputs and a backup computer which can automatically take over the functions of the primary computer. This was for control uses and over half of the Members reported the same answer for safety systems. The next most common response was for a single computer which may
have redundant inputs and outputs. This was reported by six Members for control uses and four of those reporting the same for safety applications. Triplicated computers which function through a 2-out-of-3 voting circuit was reported as used in Canada, Finland and Sweden for safety uses with Finland and Sweden also using this design for control uses. Only Italy and the U.S. reported using four computers which function through a voting circuit and these were for safety applications only. Finland was the only Member reporting using another configuration, a cluster, and that was for control applications only.

The other three questions in this section addressed the use of a single computer, distributed computers, and data highways. Six countries reported the use of a single computer for control applications, Belgium, France, Spain, the Netherlands, Sweden and the U.S., with France, Spain and Sweden reporting their use in safety applications as well. Almost all countries reported using distributed computers, more (eight) for control than safety (five) applications. Finally, data highways were reported as used in seven Member countries, four for safety uses with three of those also reporting control uses.

4.4 Testing

These questions dealt with what software validation tests were used. All Members but Belgium and Japan reported the preparation of an acceptance or validation test plan for both safety and control applications. Static input/response tests and simulated input/response tests were also used by eleven respondents with most (eight) using them for both control and safety applications. Eight Members also reported using pseudo-dynamic input/response tests but Belgium and Finland reported using this technique only for either safety or control application, respectively. For both applications, seven Members reported using quality assurance function audits and six reported using quality assurance physical audits. Open loop tests were also used by seven Members for both applications. The least used tests were the stress tests with only four Members reporting their use for both applications joined by two additional Members using test for either safety or control exclusively. Sweden used other tests as well, whole systems and total function tests.
When asked which of these tests were automated, Canada, Finland, Italy, and the U.S. reported that some of the tests were automated. Canada reported having automated three tests: the static input/response tests, pseudo-dynamic input/response tests, and the simulated input/response tests. At least one of these was reported automated in each of the other responding countries: Finland - static input/response tests, Italy - simulated input/response test, and the U.S. - both pseudo-dynamic input/response tests and the simulated input/response tests.

The last question in this group asked which tests were repeated for revisions to the systems and most countries reported repeating nearly all of the tests the use originally with three exceptions. The FRG reported repeating only the status and simulated impact response tests. Italy reported repeating only the open loop on-site tests, one of the six tests they reported using for their safety applications. Although using all but 1 of the tests for both uses, Spain reported repeating only the preparation of an Acceptance or Validation Test Plan.

4.5 Applications Experience

This section of the questionnaire included five questions on Members' experience in some specific areas. The first question was whether a human factors engineering study for an application had indicated that a non-dynamic, non-interactive CRT display was the system of choice. Switzerland responded that at least one had done that for both safety and control applications and Canada responded for a safety use.

The second question was designed to discover the characteristics of the most recent control room display designs. All respondents reported that their latest displays were color CRTs with almost all being used for both safety and control applications. All but Switzerland reported that these were a combination of parallel and serial designs (i.e., conventional analog displays and CRT displays, respectively) and only a small number indicated that the designs were principally parallel or serial, three to four, respectively. Only the FRG and Spain responded as using monochromatic displays, with color displays, in their latest design.
The third question addressed the use in the most recent design of various input devices. The responses indicate that keyboards with alphanumeric and special purpose keys were used by all Members in their latest designs and, for all but Finland and Japan, these were for both safety and control applications. Finland and Japan used this type on input device only for control applications. Finland and Japan also used conventional switches only for control applications while Canada and the FRG used them for both applications. Canada and Finland also used cursor control devices for control uses. France, Sweden, and the U.S. reported using cursor control devices for both safety and control applications. Other input devices used included a functional keyboard used in Canada for both safety and control uses and touch pushbuttons, soft keys, and touch sensitive CRTs used in the U.S.

The question on for what period spare parts are stocked to guard against obsolescence disclosed a wide variation among Members. Finland and Switzerland had the shortest time periods, 0-5 years, with Finland keeping spares for safety applications 6-10 years. Belgium, the FRG, Japan and the Netherlands also reported keeping spares in the 6-10 year time period. France reported keeping spares for 11-20 years and Canada and Sweden were in the 21-30 year range. Spain reported relying solely on the manufacturer for spares. The time period used in the U.S. was unknown.

The last question in this group was intended to discover what percentage range of control closed loops with computers use direct digital control. The results were that not very many Members have closed loop controls with computers and those using such systems were at either end of the range of possible responses. Canada and Sweden reported that 75-100% of their safety and control applications use direct digital control. Finland and Italy responded at the other end in the range of 0-25% for both safety and control applications and Japan, the Netherlands, Spain, and Switzerland responded in this range, but only for control uses.
4.6 Research Needs

This question listed research topics and requested indications from Members as to whether they thought the topic needed research for safety or control applications. Although not operating any nuclear power plants, Austria joined the other Members in responding to this question.

Each of the suggested topics was supported by at least six Members. Those receiving the most support were software verification (twelve Members) and software validation (eleven Members). The next grouping were supported by ten Members: software reliability, software design, quality assurance techniques, and human-computer interface design. The large majority of Members supporting these techniques, did so for both safety and control applications. The U.S. suggested a few more areas of research: networking, communications, and acceptance criteria for networking.

The Members were also asked to identify their top three research topics. This also resulted in a wide range of responses with all but four of the twelve suggested topics were listed by at least one Member. Those not supported were software coding techniques, programming languages, configuration management techniques, and input and database integrity.

The two topics listed by the most Members were determination of software reliability (six and listed 1st or 2nd most of the time) and human-computer interface design (six). The next most listed topic was quality assurance techniques, listed by three Members.

4.7 Additional Comments

The last question provided Members the ability to provide any additional comments. Two Members did. Finland provided three comments. The first was that the questionnaire divided safety and control systems into "black and white" which made it difficult to answer in a consistent way since it seemed likely that there would be different "shades of gray" between safety and non-safety systems. Another difficulty described by Finland was that there is
a wide range of computers used, from dedicated microprocessors and programming logics to large clusters of computers. Finally, Finland commented that the questionnaire did touch on several important items which need more study to be understood correctly.

The other country providing comments was Sweden. Their comments were that the questionnaire was very hard to answer and that the questions did not fit "reality." The questions did not ask what functions are computerized or the specific uses of computers.
CHAPTER 5

SUMMARY

5.0 Introduction

This chapter summarizes the results of a survey conducted of OECD Members on the use of digital computers in control rooms of nuclear power plants. The survey contained questions based on a model of operator-computer(s)-plant systems, on applications of specific interest to the Members, and on experiences with design methods and implementation techniques. The questions were repeated for both safety and non-safety (or control) applications and the state of implementation was requested.

Due to the national orientation of the responses, statistical analysis of the results of this survey would not produce meaningful information. Therefore, summaries of the survey results can only identify the general consensus and some exceptions.

Section 5.1 addresses the survey results concerning the general application of computers from two perspectives, application areas and characteristics of computer use. There were eight application areas and six characteristics of computer systems. The summary of the survey questions related to the topics of specific interest to Members is contained in Section 5.2. Section 5.3 includes the summary of the results on computer system design methods and implementation techniques.

5.1 General Applications and Common Uses

5.1.1 Application Areas

A model of the potential uses of one or more computers between control room operators and the plant processes was developed and potential uses of the
computer(s) were grouped into seven application areas with one area for overall use. The eight application areas are: general plant operations, data gathering, information display, operator aids, entry of commands, issuing commands, automatic controllers, and data logging. The six characteristics of the use of computer systems questioned in each application area are: reliability, replacement, additions, new, remote, and flexibility.

The use of computers in the area of general plant operations was found to be acceptable by Members for the purpose of increasing the overall reliability. Computers providing new or additional capabilities received polarized responses (i.e., responses either approving and or disapproving) and replacing operators was strongly disapproved except by Canada and Italy. The other potential uses, i.e., to use the flexibility and remote capabilities of computers received negative responses overall.

For the use of computers in data gathering applications, there was strong approval and half or more Members had current systems in place. However, Italy and Sweden were strongly against data gathering remote from the control room.

The use of computer systems for information display received strong approval with current implementations for all uses except as replacements for conventional displays. As replacements, there were mixed responses with several countries disapproving of the application. New computer-based operator aids were considered strongly appropriate. Using computer-based operator aids to increase the operation's reliability, as additions, and for their flexibility was also considered appropriate with somewhat more support for control uses than safety uses. Only as replacements for current systems did they receive mixed reviews. The other questions on uses associated with semiautomatic controls as operator aids were not supported significantly for safety uses but were supported for control uses.

A basic pattern of disapproval for safety uses and only some approval for control uses describes the Members' responses on the subject of computers used for entry of commands. Finland approved of most uses and had implementations for many. Canada and France joined in approving some of these uses but only Canada had any current implementations.
Although considered inappropriate for safety uses by most Members and only mixed or neutral attitudes toward control uses, Finland, sometimes joined by Canada and Japan, approved of the use of computers for issuing commands, and had a few current or near term implementations planned.

The use of computers as automatic controllers received mixed responses on almost all questions. Canada, Finland, Japan, and sometimes Sweden approved of such applications for at least control systems and reported some current implementations or near term plans.

The use of computers as data logging systems was almost universally accepted and already implemented. However, for all uses but as replacements for current systems, the Netherlands expressed concern for the appropriateness of computer-based data logging. Germany expressed similar concern for these systems as replacements.

5.1.2 Characteristics of Computer-based Systems

This subsection discusses the same information presented in the previous section but this time grouped along the characteristics instead of by their application. This view identifies similarities in approval of computer-based systems based on their characteristics, capabilities, or reasons for using computer-based systems.

Reliability as a reason for using computers was generally considered appropriate for overall plant operations, data gathering, display systems, operator aids, and for data logging systems. The other uses in the survey, i.e., for entry of commands, for issuing commands, and as automatic controllers, received mixed reviews.

Only the applications of computers as replacements for data gathering, display, and data logging systems were considered appropriate. As replacement operator aids and automatic controllers, computer-based systems drew mixed responses and the Members were against systems replacing command input and command issuing systems. For completeness, the possibility of replacing operators was asked and received the expected negative response with one
notable exception. Canada considered replacing operators as somewhat appropriate and reported current implementations.

As additions to the control rooms of nuclear power plants, computer systems were strongly acceptable for applications in data gathering, display, as operator aids, and as data loggers. Uses for entry of commands, issuing commands, and as automatic controllers received generally negative reviews for safety applications and mixed reviews for control applications. The use of computers to provide new capabilities was considered very appropriate for displays, operator aids, and data loggers. Implementing computer systems to provide new data gathering systems was also considered appropriate. However, new systems for command entry, issuing, and as automatic controllers was generally considered inappropriate for both safety and control applications. The question on the overall appropriateness of the use of computer systems for new capabilities received a polarized response for safety uses and approval for control uses.

The capability for computer-based systems to be remote from the systems they interact with was seen as appropriate for data gathering, displays, operator aids, and data logging but not for any of the other potential application areas.

The potential flexibility of computer-based systems was considered very appropriate for the same group of functions: data gathering, displays, operator aids, and data logging. There was a more mixed response leaning toward disapproval toward the use of the computers' flexibility as systems for the other group of functions: entry and issuing of commands and as automatic controllers.

In summary, there was some to strong of approval of computer-based systems for data gathering, information display, operator aids, and data logging with data logging getting the highest ratings. Also, in general, the use of computers to replace current systems or to provide functions remote from the control room received the strongest disapproval independent of what the function except for remote data logging which was fully supported.
5.2 Specific Questions of Interest

Section 3 of the questionnaire contained questions on specific applications of interest to various Members. They were grouped loosely into the areas of display, automated assistance, automatic controllers, data logging, and maintenance assistance.

The specific applications surveyed included organizing and prioritizing alarms, on-line display of variables, display of procedures, and display of flow sheets or related data. All of these applications were strongly supported by almost all Members. With the exception of the display of standard or abnormal procedures, there were several implementations and plans for each application. Finland reported the only current implementation of the display of procedures in control-grade uses with France, Germany, Spain, and the U.S. having future plans.

The suggested applications of computers as automatic controllers resulted in mixed and sometimes polarized responses. Control of reactivity either directly or indirectly (through the automatic adjustment of setpoints for other control systems) received a full range of responses from Members with some current implementations. Direct and indirect control of other processes also drew mixed responses for both safety and control systems but nearly unanimous approval for indirect control of control grade systems. Canada, Finland, and Sweden reported some current implementations.

Nearly all Members approved of the specific capabilities of computer-based data loggers able to provide logged variables in hard copy and machine readable form and discrete event recording. Several reported current implementations of such systems.

Four questions were asked on the subject of computer systems providing assistance in maintenance activities. Scheduling applications were approved strongly by all but two Members. However, the use of expert systems for diagnosis and systems for the display of maintenance procedures received mixed reviews. There was general disapproval of using computers for the performance of maintenance; however, Finland, Japan and Spain considered this application fully appropriate.
5.3 Design Methods and Implementation Techniques

The questions in this section addressed approaches to the development and evaluation of computer-based systems. The first sub-section was on system specifications.

There were five questions in the area of system specification. The first questions were on the methods used to assure the acceptability of hardware and software systems. All Members reported using thorough testing of hardware and more than half controlled the development process to assure acceptability of the hardware systems. For software systems, the same methods were uses with many also using formal specifications. When asked what plans were prepared, all Members reported using some of the listed plans with most using quality assurance plans, software verifications plans, software test plans, and programming conventions.

The next question addressed design review techniques. Almost all Members reported using preliminary design reviews and the majority used critical design reviews. The question on preparing human factors engineering specifications resulted in almost all Members reporting development of specifications for displays, input devices, control room or panel layouts, and interactions between the devices and the operator. However, the question on the design methods for human-computer interaction did not show the same universal use. Of the eight methods listed, only two were used by the majority of the Members: static or pseudo-dynamic function markup studies and operator performance or plant dynamic simulator studies. The other analyses of operator function, task, workload, reliability analyses were used by only a small number of Members.

The next section addressed the software development methods of configuration management, programming languages, and programming standards or conventions. The software configuration management techniques used by the majority of Members were normal record keeping, computerized libraries of applications' source and object codes, and the assignment of a person as a software configuration manager. The programming languages used by the most Members were assembly (by all Members) and Fortran (by all but 1). Finland was the only
user of three of the languages listed: Ada, Lisp and Prolog. Spain was the only user of Basic. There was a wide range of applications of the standardization techniques suggested. The only programming standards used by the majority of respondents were standard headers and limits on the depth of nesting of subroutines.

There were a few questions concerning design options. All Members reported using a single computer with redundant inputs and outputs with an automatic backup computer ready to take over. Over half of the Members reported that this configuration was also used for both safety and control applications and the other applications were for control applications only. The next most common configuration was the same design but without the backup computer. The use of three and four computers with voting logic was reported by Italy and the U.S. Almost all Members also reported using distributed computers and many used "data highways."

The next section addressed software validation testing. All or almost all Members reported using acceptance or validation test plans, input/response tests with static, simulated, and pseudo-dynamic testing, open loop on-site tests, and quality assurance functional audits. When asked which of the tests were automated, Canada reported having automated three, the U.S. two, and Finland and Italy, one each. Most countries also reported repeating almost all the tests used for the first time with two countries repeating only one test each for revisions to the system.

The survey also obtained information on the Members' experience with applications of computer-based technology. All Members reported that their most recent designs included the use of color CRTs, used mostly for safety and control applications, and almost all were a combination display technologies, conventional analog (parallel) and CRT (serial) displays. Spain and Germany were the only Members who reported the use of monochromatic CRTs in their latest designs. Keyboards with special purpose keys were also used by all Members, mostly for both applications. There were only a few applications of other devices such as conventional switches and cursor control devices. When asked about how long spare parts were stocked, there was a wide variation with
the 6-10 year band being only somewhat more common. Only a few Members reported use of a direct digital control in closed-loop controls with Canada and Sweden using them in 75-100% of their control loops closed through a computer.

Members were asked to identify research needs. Of the 13 responses, the most commonly supported areas were: software verification (12), software validation (11), software reliability (10), quality assurance techniques (10), and human-computer interface design (10). When asked to identify their top three, software reliability and human-computer interface design were listed most often.

5.4 Concluding Remarks

This survey was very long and therefore significant efforts by respondents who thoughtfully completed this survey should be recognized. The survey asked many difficult questions concerning a very wide range of applications and methodologies. While there was often agreement among Members, there were also many occasions of wide differences among the Members concerning the appropriateness of suggested applications and state of plans for implementations. The documentation of these similarities and differences provided here and in the full report should provide a useful basis for exchange of information on the use of computers in nuclear power plants.
APPENDIX A

Survey of the Use of Digital Computers in Control Rooms of Nuclear Power Plants
To: Members of CSNI Principal Working Group No. 1

- PHG 1 Task Force 6 -
(Use of Digital Computers in Control Rooms)

At the 13th Meeting of the CSNI held in November 1985, the Committee endorsed the PHG 1 proposal to establish a new Task Force for assessing the Use of Digital Computers in Control Rooms of Nuclear Power Plants.

It was agreed by the Task Force members that a questionnaire would be prepared for collecting information on various aspects of the use of digital computers in Member countries. Accordingly, a Task Force member, Mr. Kennedy of the USNRC, has prepared and revised a draft questionnaire in an attempt to make the survey as complete and comprehensive as possible.

You will find enclosed the final version of the questionnaire thus prepared to be used for the survey of technical specifications. I should be grateful if you would:

1. Distribute it to appropriate persons in the regulatory bodies, research organisations and industrial organisations which are concerned with the use of digital computers in control rooms of nuclear power plants;

2. Collect the necessary information to complete the questionnaire. When you distribute the questionnaire and collect the information, please take care that the information represents a complete picture of the situation in your country, and not just of one specific area, e.g. vendors, utilities, regulatory bodies and research organisations;

3. Send a single response representing the status in your country both to the NEA Secretariat and Mr. Kennedy at the address given below, by 28th February 1987.

.../...
Mr. William G. Kennedy
Human Factors Issues Branch
Division of Human Factors Technology
Office of Nuclear Reactor Regulation
USNRC
Washington DC 20555
United States.

Thank you in advance for your co-operation.

Yours sincerely,

Haruyuki IWABUCHI
Nuclear Safety Division

Encl.
Survey of the Use of Digital Computers in Control Rooms of Nuclear Power Plants

Purpose

This survey is designed to gather information on the international development and use of digital computers in the control rooms of nuclear power plants. The results of the survey will be a basis for the exchange of information among participating countries.

Scope

This questionnaire addresses present and future uses of computers in control rooms under the topics: general areas of application (Section 2), specific applications of particular interest (Section 3), and design methods and implementation techniques (Section 4). An identification of the source of information is Section 1.

General Instructions

Please answer this questionnaire for your country. The request for national responses is intended to reduce any biases that may occur due to interests in promoting specific applications. Later efforts can discriminate responses as necessary.

When completing the questionnaire, please take into account the following:

1. Questionnaire responses should represent the country by including the different practices, views, and plans of vendors, utilities, regulators, and research organizations.

2. Operating power reactors and planned reactors should be included.

3. All modes of plant operation should be considered.

Definitions of Terms

Control Application:
A system or function whose response to an accident condition is not a significant design objective for the plant, i.e., not a safety system. A "control" application is not expected to have the same level of reliability and performance as a "safety" application would. (The term is abbreviated to "control").

Safety System or Function:
A system or function that responds to an accident condition in some predetermined manner. (Note: It may also have control functions.) These two terms describe two classes of applications with respect to their safety significance. (The terms are abbreviated to "safety").
SECTION 2: Applications of Digital Computers

An abstract model of the use of digital computers has been developed to describe all potential applications. The model consists of one or more digital computers incorporated, generally, in the control function between the operators and the plant processes. The computer system(s) collect data concerning the plant processes and present information to the operators as raw or processed information concerning the plant conditions. Operator aids may also be provided. In some applications, the computer system(s) are transparent and operator commands are sent as controls directly to the plant process equipment without apparent use of the computer. In other applications, the system(s) respond automatically to plant conditions without operator participation. As the data concerning the plant conditions becomes known and control commands issued, the computer system(s) may log this information for recordkeeping or later review.

To collect information in the application areas illustrated by the model, the questions are grouped in the following subsections:

2.1 General plant operations - a overview or summary of computer applications

2.2 Data gathering - obtaining information describing plant conditions

2.3 Information display - presentation of raw or processed information to the operators

2.4 Operator aids - information processing to support operators decision-making, monitoring functions, etc.

2.5 Entering commands - obtaining command input from operators

2.6 Issuing control signals - the output of the computer system(s) to control the plant equipment

2.7 Automatic controllers - process control without operator participation

2.8 Data logging - recording of plant conditions, commands, or control signals issued
In each of the subsections, the first six questions are address the same set of features. This is done to provide assurance that the necessary questions are asked in each area. These questions address the basic features of digital computers.

**reliability** - The reliability of digital computers is often considered higher than other technologies.

**replacement** - Digital technologies have been replacing analog approaches for many reasons such as cost, maintainability, response time, and precision. Examples include replacing an operator with a set of automatic controllers, replacing analog displays with computer generated displays, replacing breaker control circuits operated from the control room with computer generated signals to local breaker controllers, and replacing strip-chart event recorders with computer controlled event reports.

**additional** - Digital computers may be added to plants to provide more of the same general functions being performed by other systems. Examples include more sampling of sensor data, additional alarms for single parameters exceeding preset values, computer-based presentation procedures in addition to paper copies, and keyboards entering the same commands to operate valves and pumps.

**new** - The need for capabilities or functions not possible with other technologies may be a reason for the application of computers. Examples include high-speed recording of sensor data to capture changes occurring faster than current devices allow, computer-generated spoken alarms, 3-dimensional presentation of plant data with 20 minute projections of current trends, and control of components by touching a graphic presentation to start a sequence of operations to change the heat-exchanger in use.

**remote** - Information converted to a form that can be used by digital computers can support functions away from the source of the information. Examples include displays of specific parameters at the regulating authorities offices, controllers for steam valves far enough away to be safe from a damaging steam environment, and remote controls to allow shutting down the plant if the control room is uninhabitable.

**flexibility** - Digital computer systems can be significantly more flexible than other technologies. Examples include standardizing computer controllers so that one controller could be reprogrammed to control another system, allowing operators to design their own displays or the sequences of actions to be performed for operator entered commands, and changing the data logged to meet temporary needs.
This section requests an evaluation of the appropriateness and current state of digital computer applications.

For each application, please evaluate and mark (1) the appropriateness of the application and (2) the state of the implementation. Two scales are provided:

<table>
<thead>
<tr>
<th>Appropriateness</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appropriate</td>
<td>Never</td>
</tr>
<tr>
<td>Not Appropriate</td>
<td>Years until implementation:</td>
</tr>
</tbody>
</table>

Never | 0 | 2 | 4 | 6 | Unknown |

For the appropriateness scale, please circle the mark indicating the evaluated degree of appropriateness. The mark should indicate a balance of opinion or evidence as to whether or not the application is appropriate for nuclear power plants.

For the description of the implementation, please circle the mark representing the current state or plans. The "Never" option indicates there are no plans to ever implement the subject application. A mark on the "0" point indicates the application is currently in use. A mark between "6" and "Unknown" means that the application is planned for some time after 6 years from now. "Unknown" indicates that no decision has been made on when to implement the application.

Since the applications may have different responses for safety versus control applications, responses are requested for both types of applications when appropriate.

Example: Consider the following example regarding the use of digital computers in data gathering:

2.2.6) To utilize the flexibility of computers in information display functions:

<table>
<thead>
<tr>
<th>Scales:</th>
<th>Appropriate</th>
<th>Not Appropriate</th>
<th>Years until implementation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
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<td>Appropriate</td>
<td>Never</td>
</tr>
<tr>
<td>Control</td>
<td></td>
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</tbody>
</table>

For this example, consider that the conditions in your country are that operators are currently allowed to use the flexibility of the computer in designing their own information displays for control applications but standard displays are used for safety systems and parameters. Therefore, the description of implementation is as marked.

For the evaluation of the appropriateness, suppose that the use of the flexibility for control systems has improved operator understanding of the information for which they designed the display but is a distraction from their regular duties, has hampered communications between operators, and has caused operators not to review all the information that should be regularly reviewed. Therefore, for control systems, the appropriateness is toward the "not appropriate" side and for safety systems, the consensus is that the application of digital computers in not appropriate.
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:
   - Name:
   - Country:
   - Organization:
   - Address:

1.2 Please provide the reference date for the responses:
   - Date:

1.3 Please describe the resources upon which these responses are based:
Scales: Appropriate | Not Appropriate | Years until implementation: Never 0 2 4 6 Unknown

<p>| | | |</p>
<table>
<thead>
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<tbody>
<tr>
<td>Safety</td>
<td>Control</td>
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</tbody>
</table>

2.1 General Plant Operations

In the area of general plant operations, please indicate the appropriateness and the state of the implementation of computers:

1) To increase the **reliability** of overall plant operations:

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<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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</table>

2) To provide a **replacement** for operator(s) in the control room:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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<tbody>
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</table>

3) To provide **additional** functions similar to those of human operators in the control room:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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</table>

4) To provide **new operations not possible with conventional means**:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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</table>

5) To provide routine or emergency control of plant operations **remote** from the control room:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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</thead>
<tbody>
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</table>

6) To utilize the **flexibility** of computers in the overall plant control:

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<th>Safety</th>
<th>Control</th>
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</tbody>
</table>

```
2.2 Computer applications in data gathering

In the area of data gathering, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of data gathering systems:
   - Safety: 
   - Control: 

2) To provide replacement data gathering systems:
   - Safety: 
   - Control: 

3) To provide additional data gathering systems independent from current systems:
   - Safety: 
   - Control: 

4) To provide new data gathering not possible with conventional means:
   - Safety: 
   - Control: 

5) To provide information data gathering remote from the control room:
   - Safety: 
   - Control: 

6) To utilize the flexibility of computers in data gathering functions:
   - Safety: 
   - Control: 

7) To utilize the data validation capabilities, such as complex rationality checks and cross checks with other data:
   - Safety: 
   - Control: 

2.3 Computer applications in information display

In the area of information displays, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of information displays:
   - Safety : . . . :  
   - Control : . . . : 

2) To provide replacement information displays:
   - Safety : . . . :  
   - Control : . . . : 

3) To provide additional information displays independent from current systems:
   - Safety : . . . :  
   - Control : . . . : 

4) To provide new information displays not possible with conventional means:
   - Safety : . . . :  
   - Control : . . . : 

5) To provide information displays remote from the control room (e.g. shift supervisor's office, emergency control room, engineering offices):
   - Safety : . . . :  
   - Control : . . . : 

6) To utilize the flexibility of computers in information display functions:
   - Safety : . . . :  
   - Control : . . . : 

Scales: Appropriate Not Appropriate Years until implementation: 1 2 4 6 Unknown
<table>
<thead>
<tr>
<th>Scale:</th>
<th>Appropriate</th>
<th>Not Appropriate</th>
<th>Years until implementation:</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Never 0 2 4 6 Unknown</td>
</tr>
</tbody>
</table>

2.4 Computer applications as operator aids

In the area of operator aids, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of operator aids:
   - Safety: 
   - Control: 

2) To provide replacement operator aids:
   - Safety: 
   - Control: 

3) To provide additional operator aids independent from current systems:
   - Safety: 
   - Control: 

4) To provide new operator aids not possible with conventional means:
   - Safety: 
   - Control: 

5) To provide operator aids remote from the control room (e.g. shift supervisor's office, emergency control room, engineering offices):
   - Safety: 
   - Control: 

6) To utilize the flexibility of computers in operator aid functions:
   - Safety: 
   - Control: 

7) To improve the control by operators of processes which are difficult for operators to control, such as non-linearities or non-minimum phase effects:
   - Safety: 
   - Control: 
### APPENDIX A

<table>
<thead>
<tr>
<th>Scales:</th>
<th>Appropriate</th>
<th>Not Appropriate</th>
<th>Years until implementation:</th>
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<tbody>
<tr>
<td></td>
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<td></td>
<td>Never 0 2 4 6 Unknown</td>
</tr>
<tr>
<td></td>
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<td>1 2 3 4 5 6</td>
</tr>
</tbody>
</table>

8) To provide replacement for some operator actions by semi-automatically doing a sequence of actions during normal operations as directed by operators (e.g., as the valve manipulations to switch operating pumps in a fluid system):

- **Safety**: 5
- **Control**: 3

9) To provide replacement for some operator actions by semi-automatically doing a sequence of steps in response to abnormal station states as directed by operators (e.g., response to a minor alarm condition):

- **Safety**: 5
- **Control**: 3

10) To maximize safe commercial operation of operator controlled processes by providing better operator control close to the safety margins:

- **Safety**: 5
- **Control**: 3

11) To provide administrative functions for operators not related to operations of the plant:

- **Safety**: 5
- **Control**: 3

12) To improve the efficiency and performance of the other than control room operators, such as maintenance staff:

- **Safety**: 5
- **Control**: 3
<table>
<thead>
<tr>
<th>Scales:</th>
<th>Appropriate</th>
<th>Not Appropriate</th>
<th>Years until implementation:</th>
<th>Never</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>Unknown</th>
</tr>
</thead>
</table>

2.5 Computer applications in entering operator commands

In the area of entering operator commands, please indicate the appropriateness and state of implementation of computers:

1) To increase the **reliability** of the entering of operator commands:

   Safety  : . . . . :  
   Control : . . . . :  

2) To provide **replacement** methods of entering commands:

   Safety  : . . . . :  
   Control : . . . . :  

3) To provide **additional** methods of entering commands independent from current systems:

   Safety  : . . . . :  
   Control : . . . . :  

4) To provide **new** methods of entering commands not possible with 'conventional means':

   Safety  : . . . . :  
   Control : . . . . :  

5) To provide command entering **remote** from the control room:

   Safety  : . . . . :  
   Control : . . . . :  

6) To utilize the **flexibility** of computers in changing the methods of entering commands:

   Safety  : . . . . :  
   Control : . . . . :  

2.6 Computer applications in issuing control signals

In the area of issuing control signals, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of control issuing systems:

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<th>Safety</th>
<th>Control</th>
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2) To provide replacement control issuing systems:

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<th>Safety</th>
<th>Control</th>
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3) To provide additional control issuing systems independent from current systems:

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<th>Safety</th>
<th>Control</th>
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</table>

|   |   |   |   |   |   |   |   |   |   |   |

4) To provide new control issuing not possible with conventional means:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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5) To provide control issuing remote from the control room:

<table>
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<th>Safety</th>
<th>Control</th>
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|   |   |   |   |   |   |   |   |   |   |   |

6) To utilize the flexibility of computers the methods of issuing controls:

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<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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<tbody>
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|   |   |   |   |   |   |   |   |   |   |   |

7) To utilize the control signal validation capabilities, such as complex rationality checks and cross checks with other information:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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<tbody>
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|   |   |   |   |   |   |   |   |   |   |   |
### Scales:

<table>
<thead>
<tr>
<th>Appropriate</th>
<th>Not Appropriate</th>
<th>Years until implementation:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Never 0 2 4 6 Unknown</td>
</tr>
</tbody>
</table>

### 2.7 Computer applications as automatic controllers within plant systems

In the area of automatic controllers, please indicate the appropriateness and state of implementation of computers:

1) To increase the **reliability** of automatic controllers:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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<tbody>
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</table>

2) To provide **replacement** automatic controllers:

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<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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<tbody>
<tr>
<td>:</td>
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</table>

3) To provide **additional** automatic controllers independent from current systems:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td>:</td>
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</table>

4) To provide **new** automatic controllers not possible with conventional means:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td>:</td>
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</table>

5) To provide automatic controllers **remote** from control functions normally performed in the control room (e.g. shift supervisor's office, emergency control room, engineering offices):

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>:</td>
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</table>

6) To utilize the on-line **flexibility** of computers, such as to change the control of processes in progress:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>:</td>
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</table>

7) To utilize the off-line **flexibility** of computers, not necessarily by operators, such as for modification of control algorithms, control constants, etc.:

<table>
<thead>
<tr>
<th>Safety</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>:</td>
<td>:</td>
</tr>
</tbody>
</table>
Scales:  Appropriate | Not Appropriate | Years until implementation:  
\[ \begin{array}{cccccc} 
\text{Appropriate} & \text{Not Appropriate} & \text{Never} & 0 & 2 & 4 & 6 & \text{Unknown} \\
\text{1} & \text{3} & \text{1} & \text{2} & \text{3} & \text{4} & \text{5} & \text{6} \\
\end{array} \]

8) To provide replacement for some operator actions by taking fully automatic corrective control action in response to abnormal station states (e.g., reduce reactor power on boiler low level):

- Safety:  
  - : : : : :
  - Control:  
    - : : : : : :

9) To maximize the safe commercial operation of the process by automatically operating close to the safety margins:

- Safety:  
  - : : : : :
  - Control:  
    - : : : : : :

2.8 Computer applications in data logging

In the area of data logging, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of data logging systems:
   Safety : . . . :           : . . . . . . . .
   Control : . . . :           : . . . . . . . .

2) To provide replacement data logging systems:
   Safety : . . . :           : . . . . . . . .
   Control : . . . :           : . . . . . . . .

3) To provide additional data logging systems independent from current systems:
   Safety : . . . :           : . . . . . . . .
   Control : . . . :           : . . . . . . . .

4) To provide new data logging systems not possible with conventional means:
   Safety : . . . :           : . . . . . . . .
   Control : . . . :           : . . . . . . . .

5) To provide data logging outputs remote from the control room (e.g. shift supervisor's office, emergency control room, engineering offices):
   Safety : . . . :           : . . . . . . . .
   Control : . . . :           : . . . . . . . .

6) To utilize the flexibility of computers in data logging functions:
   Safety : . . . :           : . . . . . . . .
   Control : . . . :           : . . . . . . . .

7) To provide record keeping for operators administration (e.g. work orders, abnormal plant states, flow sheets, operating procedures):
   Safety : . . . :           : . . . . . . . .
   Control : . . . :           : . . . . . . . .
SECTION 3: Specific Applications of Digital Computers of Interest:

This section is similar to Section 2, but includes specific applications of interest. The same instructions apply.

Scales:  Appropriate  Not Appropriate  Years until implementation:

<table>
<thead>
<tr>
<th></th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>Unknown</th>
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</table>

3.1 Display Uses

1) To organize or prioritize alarms and annunciations to limit overloading of operators or to otherwise organize the data:


2) To provide on-line display of numeric and trend data and other plant variables or states:


3) To display of standard and/or abnormal operating procedures:


4) To display of flow sheets and related plant data:


3.2 Automated Assistance

1) To provide sequential display (i.e. prompting) and tracking of manually executed sequence of control actions (e.g. testing of safety systems, startup of turbines):


2) To provide automated sequencing of operator actions (e.g. testing of safety systems, startup of turbines):

### Scales: Appropriate Not Appropriate

<table>
<thead>
<tr>
<th>Years until implementation:</th>
<th>Never</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>Unknown</th>
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</table>

3) To provide deterministic or expert systems as decision aids to assist the operator in diagnosing abnormal conditions or in assessing the consequences of proposed actions:

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<tr>
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<tr>
<td>Control</td>
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</tbody>
</table>

4) To provide deterministic or expert system to assess plant or system states, integrity and/or redundant systems:

<table>
<thead>
<tr>
<th>Safety</th>
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### 3.3 To Provide Direct and Indirect Digital Computer Control

1) To provide direct digital control of one or more reactivity mechanisms:

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<th>:</th>
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</table>

2) To provide indirect digital computer control through control of the setpoint for one or more analog reactivity mechanism control loops:

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<tr>
<th>Safety</th>
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<th>:</th>
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</table>

3) To provide direct digital control of one or more processes (e.g. flows, pressures):

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<tr>
<th>Safety</th>
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<th>:</th>
<th>:</th>
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<tbody>
<tr>
<td>Control</td>
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</table>

4) To provide indirect digital computer control through control of the setpoint for one or more analog process control loops (e.g. flows, pressures):

<table>
<thead>
<tr>
<th>Safety</th>
<th>:</th>
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<tr>
<td>Control</td>
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</table>
### 3.4 Data Logging

1) To provide data logging of plant variables and states in a hard copy form for control or safety purpose:

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appropriate</strong></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Not Appropriate</strong></td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Years until implementation</th>
<th>Never</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>Unknown</th>
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<tbody>
<tr>
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</tbody>
</table>

2) To provide data logging of plant variables and states in a machine readable form:

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td><strong>Appropriate</strong></td>
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<tr>
<td><strong>Not Appropriate</strong></td>
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<table>
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<tr>
<th>Years until implementation</th>
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<th>4</th>
<th>6</th>
<th>Unknown</th>
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</tr>
</tbody>
</table>

3) To provide event recording systems to record the timing of a sequence of discrete events:

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appropriate</strong></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Not Appropriate</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Years until implementation</th>
<th>Never</th>
<th>0</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>Unknown</th>
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<tbody>
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</tbody>
</table>

### 3.5 Maintenance Assistance

1) To support scheduling of routine maintenance:

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appropriate</strong></td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Not Appropriate</strong></td>
<td>0</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Years until implementation</th>
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<th>2</th>
<th>4</th>
<th>6</th>
<th>Unknown</th>
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</tbody>
</table>

2) To provide deterministic or expert systems for the diagnosis by maintenance personnel of component or system faults in or out of the control room:

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Appropriate</strong></td>
<td>0</td>
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<tr>
<td><strong>Not Appropriate</strong></td>
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<table>
<thead>
<tr>
<th>Years until implementation</th>
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</table>

3) To display maintenance procedures:

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td><strong>Appropriate</strong></td>
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<tr>
<td><strong>Not Appropriate</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Years until implementation</th>
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<th>2</th>
<th>4</th>
<th>6</th>
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</tr>
</tbody>
</table>

4) To perform maintenance procedures automatically:

<table>
<thead>
<tr>
<th></th>
<th>Safety</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td><strong>Appropriate</strong></td>
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<tr>
<td><strong>Not Appropriate</strong></td>
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</tbody>
</table>

<table>
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<th>4</th>
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<td>0</td>
</tr>
</tbody>
</table>
Section 4: Digital Computer System Design Methods and Implementation Techniques:

For this section, please indicate whether the method or technique is used for safety and control applications, is not used, or is unknown by circling either "S" for safety applications, "C" for control applications, "N" for not used, "U" if unknown.

Please do not include applications that are only under evaluation or being experimented with. Please add to the lists as necessary to describe the methods and techniques in your country.

4.1 System Specifications

1) Please identify which of the following techniques are used to assure the acceptability of the hardware of computer systems:
   a) Complete formal specifications  
   b) Control of the development process  
   c) Thorough testing of the end product  
   d) Other (specify):

         S   C   N   U

2) Please identify which of the following techniques are used to assure the acceptability of the software of computer systems:
   a) Complete formal specifications  
   b) Control of the development process  
   c) Thorough testing of the end product  
   d) Other (specify):

         S   C   N   U

3) Please identify which of the following plans are prepared:
   a) Quality Assurance Plan  
   b) Software Verification Plan  
   c) Software Test Plan  
   d) Programming Conventions Plan  
   e) Other (specify):

         S   C   N   U
4) Please identify which of the following design review techniques are used:
   a) Preliminary design review: S C N U
   b) Critical design review: S C N U
   c) Code walk-through: S C N U
   d) Other (specify): S C N U

5) Please identify for which of the following areas human factors engineering specifications are prepared:
   a) Display requirements S C N U
   b) Input device requirements S C N U
   c) Input device and display interaction requirements S C N U
   d) Control room or panel layouts, and input device and display arrangement requirements S C N U
   e) Operator input device and display interaction dialog requirements S C N U
   f) Other (specify): S C N U
6) Please identify which of the following methods are used in the design of the human-computer interface:

a) Operator function and task analysis
b) Human factors engineering test and evaluation program
c) Workload analysis
d) Human reliability analysis
e) Static or pseudo-dynamic function mock-up studies
f) Operator performance or plant dynamics simulator studies
g) Studies of hardware or software failure effects on operators tasks and functions
h) Experimental research on input device and display design
i) Other (specify):

4.2 Development Methods

1) Please identify which of the following software configuration management techniques are used:

a) Normal record keeping
b) A computerized library of application source and object codes
c) A computerized library of public source codes (if available) and object codes (e.g. operating system, compiler, editor)
d) Designation of a software configuration manager
e) Including on-line readable record of its issue information
f) On-line software checks(s) of the issue number compatibility of software with software, and of software and firmware media
g) Other (specify):
2) Please identify which programming languages are used:

<table>
<thead>
<tr>
<th>Language</th>
<th>S</th>
<th>C</th>
<th>N</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Assembly</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>b) Ada</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>c) Basic</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>d) C</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>e) Fortran</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>f) Lisp</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>g) Pascal</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>h) Prolog</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>i) Other (specify):</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

3) Please identify which of the following programming standards are used:

<table>
<thead>
<tr>
<th>Standard</th>
<th>S</th>
<th>C</th>
<th>N</th>
<th>U</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) A coding format to indicate routines</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>b) Single entry, single exit of a routine</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>c) No unconditional GO TO statements</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>d) No Recursive routines</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>e) Limited nesting depth for routines</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>f) Maximum routine length</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>g) Minimum routine length</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>h) Standard header format for routines</td>
<td></td>
<td></td>
<td>S</td>
<td>C</td>
</tr>
<tr>
<td>i) Other (specify):</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Design Options

1) Please identify which of the following levels of redundancy are used:

   a) A single computer which may have redundant inputs and outputs  

   b) A primary computer which may have redundant inputs and outputs and has a duplicate backup computer which can automatically take over the functions of the primary computer

   c) Triplicated computers which function through a two-out-of-three voting circuit

   d) Four computers which function through one or more, two out of three voting circuits; (one computer may be rejected by its own action or by the combined action of the other three)

   e) Other (specify):

2) Is a single computer used

3) Are distributed computers used

4) Are data highways used

### Testing

1) Please identify which of the following software validation tests are used

   a) Preparation of an Acceptance or Validation Test Plan

   b) Static input/response tests

   c) Pseudo-dynamic input/response tests (e.g. ramp inputs through their ranges)

   d) Simulated input/response tests

   e) Open loop, on site tests

   f) Stress tests (e.g. outside the input voltage limits, excessive input data rates)

   g) Quality Assurance Functional Audit

   h) Quality Assurance Physical Audit

   i) Other (specify):
2) Please identify which of the above are automated:
   a b c d e f g h i

3) Please identify which are repeated for revisions to the systems:
   a b c d e f g h i

4.5 Applications Experience

1) Has a human factors engineering study for an application indicated that a non-dynamic, non-interactive CRT display was the system of choice (i.e., fixed format with periodic data updates)?
   S C N U

2) Please identify which of the following characteristics described in the most recent control room display designs:
   a) Principally all parallel (i.e., conventional analog display) S C N U
   b) Principally all serial (i.e. CRT displays) S C N U
   c) A combination of parallel and serial S C N U
   d) Monochromatic CRT's S C N U
   e) Colour CRT's S C N U
   f) Other (specify): S C N U

3) Please identify which of the following characteristics describes the digital computer input devices used on the most recent designs:
   a) Conventional switches (e.g., pushbutton, knobs, and switches) S C N U
   b) Keyboards with alphanumeric and special purpose keys S C N U
   c) Cursor control devices (e.g., joysticks, mouse, and roller ball) S C N U
   d) Other (specify): S C N U
4) For what period of time are spare parts stocked (i.e. to guard against obsolescence)?

   a) Up to 5 years
      b) 6 to 10 years
      c) 11 to 20 years
      d) 21 to 30 years

   S C N U
   S C N U
   S C N U
   S C N U

5) Of the control loops closed through a digital computer, what percentage currently use direct digital control?

   a) 75% - 100%
   b) 50% - 75%
   c) 25% - 50%
   d) 0% - 25%

   S C N U
   S C N U
   S C N U
   S C N U

4.6 Research Needs

1) Determination of hardware reliability
   2) Determination of software reliability
   3) Software design techniques
   4) Software verification techniques
   5) Software coding techniques (including programming languages)
   6) Software validation techniques
   7) Software documentation techniques
   8) Configuration management techniques
   9) Software maintenance techniques

   S C N U
   S C N U
   S C N U
   S C N U
   S C N U
   S C N U
   S C N U
   S C N U

"S" for safety applications
"C" for control applications
"N" for not used
"U" if unknown
10) Quality assurance techniques
   \( \text{S for safety applications} \)
   \( \text{C for control applications} \)
   \( \text{N for not used} \)
   \( \text{U if unknown} \)

11) Human-computer interface design techniques

12) Input and database integrity techniques

13) Other (specify):

14) Please prioritize the top three research topics:
    1st priority:
    2nd priority:
    3rd priority:

4.7 Additional Comments
APPENDIX B

Questionnaire Results, Section 1: Respondents
RE: PWG 1 Task Force 6

Dear Sir,

in reply to the CSNI-letter EN/S/1731 from Dec. 22nd, 1986 I am sorry to say that I am not able to collect information about the "Use of Digital Computers in Control Rooms of NPPs" in my country, since we don't have NPP, as commonly known. I can only give our priorities to the research topics (point 4.6 of SINDOC (86) 199), since this is also valid to a certain extent to conventional plants in our country.

Yours sincerely

(H. Roggenbauer)

Encl.
March 9, 1987

Mr. William G. KENNEDY  
Human Factors Issues Branch  
Division of Human Factors Technology  
Office of Nuclear Reactor Regulation  
U.S.N.R.C.  
US - WASHINGTON D.C. 20555

Dear Mr. Kennedy,

Subject: Survey of the use of Digital Computers in Control Rooms of Nuclear Power Plants.

Please find enclosed the completed survey.

May we draw your attention on page 2, mentioning that only main frame computers have been considered. However, and depending on the plant, several micro- or mini computer systems are in use for particular purposes.

Sincerely yours,

[Signature]

B. DECKERS,  
Principal Engineer.

cc. OECD - Mr. IWABUSHI
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

Name:  B. DECKERS
Country:  BELGIUM
Organization:  VINCOTTE
Address:  AVENUE DU ROI  157
          B - 1060  BRUSSELS

1.2 Please provide the reference date for the responses:

Date: February 1987

1.3 Please describe the resources upon which these responses are based:

- Nuclear Power Plants :
  - Doel 1-2-3-4
  - Tihange 1-2-3

1.4. Assumptions made :

It is important to note that in this survey only the main frame computers have been considered, although other dedicated computerized systems are in use:

- microprocessors in the control cabinets (e.g. steam generator level control);
- data acquisition systems with high frequency multiplexer;
- remote data acquisition by the chemical laboratory;
- multichannel analyzers for calibration of radiation monitoring equipment;
- computerized automatic testers of the protection logic or of the instrumentation channels serving as input to the latter;
- separate multiuser computer system for workorder management.
April 6, 1987

Mr. H. Iwabuchi
Nuclear Energy Agency
Nuclear Safety Division
Organization for Economic Cooperation & Development
38, boulevard Suchet
75016 Paris, France

Mr. William G. Kennedy
Human Factors Issues Branch
Division of Human Factors Technology
Office of Nuclear Reactor Regulation
U.S. NRC
Washington, DC 20555
USA

Gentlemen:

Re: Survey on the Use of Digital Computers in Control Rooms of Nuclear Power Plants

Please find attached the survey mentioned above, duly completed by the appropriate specialists of the Safety Evaluation Division of the Canadian Atomic Energy Control Board (AECB). This response represents a consolidation of the views of Atomic Energy of Canada Limited (designer/consultant), Ontario Hydro (the largest Canadian utility that owns and operates CANDU reactors) and the AECB (the regulatory body).

I apologize for failing to meet the deadline of February 28, 1987.

Yours sincerely,

[Signature]

G. Ishack
Head, Event Analysis
and Generic Review Group

Attach.
GENERAL

1) An application may score lower on the "appropriate" scale for one of two reasons:
   - poor practice;
   - little or no scope for application.

2) We have included Programmable Controllers (PC) as digital computers.

Section 2.1

2) Control systems should not "replace" operators; they should supplement and assist him. They should do such tasks as:
   - boring, repetitive, obvious functions;
   - functions which require very fast responses;
   - responses to well defined abnormal conditions to move the system into a safe state and await operator action.

5) We assume this question means: "to provide control function remote from the control room".

2.4 We assume an "operator aid" is any application that assists the operator e.g. display of computer variables, comparisons of two variables.

2.7 Canadian safety systems are on/off devices so controller is not meaningful. However in 8) and 9) control has been interpreted as shutdown, for example.

3.3 1) and 3) the on/off control of reactivity and flows in safety systems have been considered to be control.

3.3 1) and 2) we have added the line for an answer on control systems.

G11/31
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

Name: James D. Kendall
Country: Canada
Organization: Atomic Energy Control Board
Address: PO Box 1046
Ottawa, Ontario
K1P 5S9
(613) 995-3782

1.2 Please provide the reference date for the responses:

Date: March 1987

1.3 Please describe the resources upon which these responses are based:

1) Respondent with E.L. Gorrell and M. Grandal
2) A.H. Stretch and Others at Atomic Energy of Canada Limited.
3) M.T. McPhedran and Others at Ontario Hydro
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

   Name: BJÖRN WAHLSTRÖM
   Country: FINLAND
   Organization: TECHNICAL RESEARCH CENTRE OF FINLAND
   Address: OTAKAARI 7 B, 02150 Espoo Finland

1.2 Please provide the reference date for the responses:

   Date: 15.2.1987

1.3 Please describe the resources upon which these responses are based:

Draft response prepared 5.1.1987
circulated for comments to
   L. Reiman, Finnish Centre for Radiation Protection
   E. Rinttilä, Imatran Voima Oy
   L.E. Häät, Teollisuuden Voima Oy

Comments obtained 30.1.1986 and integrated into the answer
PWG 1, Task Force 6: Use of Digital Computers in Control Rooms

Dear Mr. Iwabuchi,

attached you will find the questionnaire on the use of digital computers in control rooms of nuclear power plants for the FRG.

Yours sincerely

Gesellschaft für Reaktorsicherheit (GRS) mbH
- Abteilung Betriebsverhalten -

- i.A: Dr. Kotthoff -   - i.A. Voswinkel -

Enclosed
Mr. William G. Kennedy
Human Factors Issues Branch
Division of Human Factors Technologie
Office of Nuclear Reactor Regulation
USNRC
Washington DC 20555
United States of America

Dear Sir,

You will find enclosed the French answer to the Task Force n° 6 questionnaire.

As it is indicated the answer covers French PWR units
i.e. 900 MW PWR
1300 MW PWR
and 1400 MW PWR (N4 project with full computerized control room).

Yours sincerely,

[Signature]
M. Gomolinski
Chef du Laboratoire
d'Etude du Facteur Humain

Copie:
H. Iwabuchi
Division Sûreté Nucléaire
OCDE
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

Name: M. GOMOLINSKI
Country: FRANCE
Organization: CEA/IPSN/DAS/LEFH
Address: CENTRE D'ETUDES NUCLEAIRES DE FONTENAY-aux-ROSES
         B.P. 6
         92265 - FONTENAY-aux-ROSES CEDEX France

1.2 Please provide the reference date for the responses:

Date: 25/2/1987

1.3 Please describe the resources upon which these responses are based:

All Electricité de France PWR units
i.e. - 900 MW PWR
      - 1300 MW PWR
      - 1400 MW PWR (N4 project with a full computerized control room)

Other French reactors (gas-graphite, fast breeder, experimental) are not taken into account.
Subject: Questionnaire on the Use of Digital Computers in Control Rooms.

Enclosed you will find the answers to the CSNI questionnaire on the Use of Digital Computers in Control Rooms of Nuclear Power Plants.

Best regards.

encl: 1
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

Name: Department of Operating Plant
Country: Italy
Organization: ENEA/DISP
Address: Via V. Brancati, 48 - 00144 ROMA

1.2 Please provide the reference date for the responses:

Date: 28/2/1987

1.3 Please describe the resources upon which these responses are based:

The answers are based on information about:
1) Caorso Nuclear Power Plant (BWR, in operation);
2) Alto Lazio Nuclear Power Plant (BWR, in construction);
3) Trino Vercellese 2 (PWR, to be built).
March 6th, 1987

Mr. William G Kennedy  
Human Factors Issues Branch  
Division of Human Factors Technology  
Office of Nuclear Reactor Regulation  
USNRC, Washington, D.C. 20555  
U.S.A.

Re: Response for Questionnaire by PWG-1 Task Force 6

Dear Mr. Kennedy,

Enclose please find a copy of a response for the questionnaire (final version distributed by EN/S/1731 dated 22nd, December, 1986)

We are sorry for the delay of response which should be due on 28th of February, 1987.

In general, as we have mentioned in the previous responses, consideration of Japanese Government is that since the reliability of computers is not yet established, application for safety related matters is still too early and may need R&D efforts.

Data acquisition and limited field of plant/system controls are seemed feasible and applications this field including for maintenance and test procedures are being expanded.

We appreciate your activity on this respect and expect good result in final report for this issue.

Sincerely yours

Y. Nishiwaki

Y. Nishiwaki  
Deputy Director for Technical Affairs  
Nuclear Power Safety Administration  
Division
Dear Mr. Kennedy,

In answer to your letter EN/5/1731 dd. 22nd December 1986 please find attached the completed questionnaire on the use of digital computers in Control Rooms of Nuclear Power Plants. Please send any further information to Mr. J. Versteeg of the Nuclear Department of the Ministry of Social Affairs.

Yours Sincerely,

[Signature]

Verzoek bij beantwoording ons kenmerk en datum te vermelden
en uitsluitend te adresseren: Directeur-Generaal van de Arbeid, Postbus 69, 2270 MA Voorburg
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

Name: Mr. J. P. Kroon
Country: Netherlands
Organization: NV PZEM
Address: Postbus 48
         4330 AA Middelburg

1.2 Please provide the reference date for the responses:

Date: 

1.3 Please describe the resources upon which these responses are based:
Dear Mr. Iwabuchi:

Please find enclosed the response from Spain to the "Survey of the Use of Digital Computers in Control Rooms of Nuclear Power Plants". For any clarifications please contact Mr. Villota (see SECTION 1) or myself.

Sincerely yours

[Signature]

J. Reig.
PWG 1 member.

C/c E. González, CSNI member.
L. Echávarri, CSNI member.
J. I. Villadóniga, PWG 1 member.

March, 3rd, 1987
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

Name: M. CARLOS VILLOTA  
Country: SPAIN  
Organization: UNEESA (ELECTRIC UTILITIES ASS.)  
Address: FRANCISCO CELVA 3  
28020 MADRID

1.2 Please provide the reference date for the responses:

Date: 31st DECEMBER 1996

1.3 Please describe the resources upon which these responses are based:

Members of: Nuclear Safety Authority  
PUR Owners Group  
BWR Owners Group  
UDESA
Mr William G. Kennedy  
Human Factors Issues Branch  
Div. of human Factors Technology  
Office of Nuclear Reactor Regulation  
USNRC  
Washington DC 20555  
USA

Reg. Questionsnaire on "Use of Digital Computers in Control Rooms".

Dear Mr Kennedy

I have in order to get a "Swedish answer", sent a copy of the questionnaire to all swedish utilities and to the vendor ASEA-ATOM. The Swedish Simulator Training Center did also get a copy.

I have also recieved comments regarding research needs and that is: the importance to get the users into design - and constructionphases when developing new operator aids.

The Swedish Nuclear Power Inspectorate does not regulate questions regarding the use of digital computers in control rooms.

We are however planning, from a human factors point of view, to evaluate the effects of computarization and automatization on the operators' task and job, in a researchproject called 'studies on operators' work and control room'.

Yours sincerely,

Irené Blom

Copy to: Haruyuki Iwabuchi, NEA  
Nuclear Safety Division
Use of Digital Computers in Control Rooms

Sirs,

Please find enclosed the answers to the questionnaire prepared by Mr. Kennedy. The answers are based on a specific power plant, but they might be considered as representative for the situation in Switzerland.

Regards,

R. Gilli

Enclosure
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

Name: Gilli Roman
Country: Switzerland
Organization: Hauptabteilung für die Sicherheit der Kernanlagen (HSK)
Address: CH - 5303 Würenlingen

1.2 Please provide the reference date for the responses:

Date: 24. 2. 1987

1.3 Please describe the resources upon which these responses are based:

The responses are based on the NPP Muehleberg, BWR, in operation since 1972. The existing computer, which was mainly used for core physics and thermo-hydraulics, has been replaced by a new computer system. This system has more flexibility and will also be used as a "Safety Parameter Display System".
SECTION 1: Identification of the Source of Survey Information:

This section requests identification of the sources used in responding to this questionnaire.

1.1 Person answering questionnaire:

Name: William G. Kennedy
Country: USA
Organization: U.S. Nuclear Regulatory Commission
Address: N.R. Mail Stop AR-5221
US Nuclear Regulatory Commission
Washington, DC 20555

1.2 Please provide the reference date for the responses:

Date: 28 February 1987

1.3 Please describe the resources upon which these responses are based:

The survey was sent to the four major vendors (Westinghouse, General Electric, Combustion Engineering, and Babcock and Wilcox), the Institute for Nuclear Power Operations (INPO), the Electric Power Research Institute (EPRI), several nuclear utilities, and the organizations of licensing and research within the NRC. The answers marked represent the personal opinions of respondents from 3 of the 4 vendors, both industry organizations, one utility, and the NRC. The method used to combine the input was as follows.

For the appropriateness scale of Section 2 and 3, the extremes at both ends of the inputs were dropped and the remaining inputs were averaged.

For the estimated years to implementation scale of Section 2 and 3:

if the appropriateness mark was fully "Not Appropriate", then a response of "never" was marked,

if there were 2 or more inputs in the range of 0-6+ years, then their average was marked,

otherwise, "unknown" was marked.

For Section 4, a simple majority of the inputs was used for marking each of the S, C, N, or U possible answers with three exceptions. For questions 4.4.2, 4.4.3, and 4.6.14, a voting system was used to rank the responses.
APPENDIX C

Questionnaire Results, Section 2: General Areas
APPENDIX C

This appendix is a listing of each respondent's markings for Section 2 of the questionnaire. Letter codes are used for each country to allow a bar-chart display since mathematical analysis is not possible. The letter codes are:

A - Austria I - The Netherlands
B - Belgium J - Norway
C - Canada K - Spain
D - Finland L - Sweden
E - France M - Switzerland
F - Fed. Rep. of Germany N - The United Kingdom
G - Italy O - The United States
H - Japan
Scales: Appropriate  Not  Years until implementation:
Appropriate  Never  0  2  4  6  Unknown

2.1 General Plant Operations

In the area of general plant operations, please indicate the appropriateness and the state of the implementation of computers:

1) To increase the reliability of overall plant operations:

   Safety
   Control

2) To provide a replacement for operator(s) in the control room:

   Safety
   Control

3) To provide additional functions similar to those of human operators in the control room:

   Safety
   Control
Scales:  Appropriate  Not  Years until implementation:
Appropriate  Never  0  2  4  6  Unknown

4) To provide new operations not possible with conventional means:

5) To provide routine or emergency control of plant operations remote from the control room:

6) To utilize the flexibility of computers in the overall plant control:
2.2 Computer applications in data gathering

In the area of data gathering, please indicate the appropriateness and state of implementation of computers:

1) To increase the **reliability** of data gathering systems:

2) To provide **replacement** data gathering systems:

3) To provide **additional** data gathering systems independent from current systems:
Scales: Appropriate Not
Appropriate Never 0 2 4 6 Unknown

4) To provide **new** data gathering not possible with conventional means:

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<thead>
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<th>Control</th>
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<tbody>
<tr>
<td>L</td>
<td>O</td>
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<tr>
<td>H</td>
<td>F</td>
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</table>

5) To provide information data gathering **remote** from the control room:

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<th>Control</th>
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<tr>
<td>L</td>
<td>O</td>
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<td>H</td>
<td>F</td>
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6) To utilize the **flexibility** of computers in data gathering functions:

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<th>Control</th>
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Scales: Appropriate Not Years until implementation: 
Appropriate Never 0 2 4 6 Unknown

7) To utilize the data validation capabilities, such as complex rationality checks and cross checks with other data:
2.3 Computer applications in information display

In the area of information displays, please indicate the appropriateness and state of implementation of computers:

1) To increase the **reliability** of information displays:

   - **Safety**
     - Letters: L, F, B
     - Numbers: 5, 1
     - Scale:
       - 0: Low
       - 5: High
   
   - **Control**
     - Letters: L
     - Numbers: 5
     - Scale:
       - 0: Low
       - 5: High

2) To provide **replacement** information displays:

   - **Safety**
     - Letters: L, M, K
     - Numbers: 5, 1
     - Scale:
       - 0: Low
       - 5: High
   
   - **Control**
     - Letters: D, K, B, F
     - Numbers: 5
     - Scale:
       - 0: Low
       - 5: High

3) To provide **additional** information displays independent from current systems:

   - **Safety**
     - Letters: L, F, B
     - Numbers: 5, 1
     - Scale:
       - 0: Low
       - 5: High
   
   - **Control**
     - Letters: H, D, K, B, C
     - Numbers: 5
     - Scale:
       - 0: Low
       - 5: High
4) To provide **new** information displays not possible with conventional means:

```
Scales:  Appropriate  Not  Years until implementation:  Appropriate  Never 0 2 4 6 Unknown
```

```
Safety
```

```
Control
```

5) To provide information displays **remote** from the control room (e.g., shift supervisor's office, emergency control room, engineering offices):

```
Scales:  Appropriate  Not  Years until implementation:  Appropriate  Never 0 2 4 6 Unknown
```

```
Safety
```

```
Control
```

6) To utilize the **flexibility** of computers in information display functions:

```
Scales:  Appropriate  Not  Years until implementation:  Appropriate  Never 0 2 4 6 Unknown
```

```
Safety
```

```
Control
```
2.4 Computer applications as operator aids

In the area of operator aids, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of operator aids:

2) To provide replacement operator aids:

3) To provide additional operator aids independent from current systems:
Scales: Appropriate  Not  Years until implementation:  
Appropriate  Never  0  2  4  6  Unknown

4) To provide new operator aids not possible with conventional means:

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5) To provide operator aids remote from the control room (e.g. shift supervisor's office, emergency control room, engineering offices):

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6) To utilize the flexibility of computers in operator aid functions:

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</table>
Scales: Appropriate  Not  Years until implementation:
Appropriate  Never 0  2  4  6  Unknown

7) To improve the control by operators of processes which are difficult for
operators to control, such as non-lineairities or non-minimum phase effects:

8) To provide replacement for some operator actions by semi-automatically doing a
sequence of actions during normal operations as directed by operators (e.g.,
as the valve manipulations to switch operating pumps in a fluid system):

9) To provide replacement for some operator actions by semi-automatically doing a
sequence of steps in response to abnormal station states as directed by
operators (e.g., response to a minor alarm condition):
Scales: Appropriate Not Years until implementation: Never 0 2 4 6 Unknown

10) To maximize safe commercial operation of operator controlled processes by providing better operator control close to the safety margins:

Safety

Control

11) To provide administrative functions for operators not related to operations of the plant:

Safety

Control

12) To improve the efficiency and performance of the other than control room operators, such as maintenance staff:

Safety

Control
2.5 Computer applications in entering operator commands

In the area of entering operator commands, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of the entering of operator commands:

2) To provide replacement methods of entering commands:

3) To provide additional methods of entering commands independent from current systems:
4) To provide **new** methods of entering commands not possible with 'conventional means':

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<th>Safety</th>
<th>Control</th>
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<tbody>
<tr>
<td>E</td>
<td>C I I I</td>
<td>M K I F B C</td>
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<tr>
<td>D</td>
<td>E</td>
<td>E</td>
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5) To provide command entering **remote** from the control room:

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<td>K</td>
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<td>M K I B F C</td>
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<td>I</td>
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<td>D D D D</td>
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6) To utilize the **flexibility** of computers in changing the methods of entering commands:

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<tbody>
<tr>
<td>E</td>
<td>M I I I</td>
<td>M K I B F C B I</td>
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<td>D</td>
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<td>M</td>
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<td>M K I B F C</td>
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<td>I</td>
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<td>D D E</td>
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Years until implementation: Never 0 2 4 6 Unknown
2.6 Computer applications in issuing control signals

In the area of issuing control signals, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of control issuing systems:

   Safety
   Control

2) To provide replacement control issuing systems:

   Safety
   Control

3) To provide additional control issuing systems independent from current systems:

   Safety
   Control
4) To provide new control issuing not possible with conventional means:

5) To provide control issuing remote from the control room:

6) To utilize the flexibility of computers the methods of issuing controls:
Scales: Appropriate Not Years until implementation: 
Appropriate Never 0 2 4 6 Unknown

7) To utilize the control signal validation capabilities, such as complex rationality checks and cross checks with other information:

Safety

Control
Scales:  Appropriate  Not  Years until implementation:
        Appropriate  Never 0  2  4  6  Unknown

2.7 Computer applications as automatic controllers within plant systems

In the area of automatic controllers, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of automatic controllers:

```
Safety
  L  D  C  M  E  K  F  E  L  C  D  G  I

Control
  M  D  C  C  L  I  I  I  I  I  I  I
```

2) To provide replacement automatic controllers:

```
Safety
  L  D  C  M  E  K  F  E  B  I  G  O  D

Control
  M  D  C  L  G  F  E  M  L  D  C  I  F
```

3) To provide additional automatic controllers independent from current systems:

```
Safety
  D  L  H  M  K  G  B  E  I  I  I  I  I

Control
  M  D  B  C  L  I  I  I  I  I  I  I  I
```
Scales: Appropriate Not Appropriate Years until implementation: Never 0 2 4 6 Unknown

4) To provide new automatic controllers not possible with conventional means:

5) To provide automatic controllers remote from control functions normally performed in the control room (e.g. shift supervisor's office, emergency control room, engineering offices):

6) To utilize the on-line flexibility of computers, such as to change the control of processes in progress:
7) To utilize the off-line flexibility of computers, not necessarily by operators, such as for modification of control algorithms, control constants, etc.:

8) To provide replacement for some operator actions by taking fully automatic corrective control action in response to abnormal station states (e.g., reduce reactor power on boiler low level):

9) To maximize the safe commercial operation of the process by automatically operating close to the safety margins:
2.8 Computer applications in data logging

In the area of data logging, please indicate the appropriateness and state of implementation of computers:

1) To increase the reliability of data logging systems:

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2) To provide replacement data logging systems:

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3) To provide additional data logging systems independent from current systems:

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Scales: Appropriate  Not  Years until implementation:  
Appropriate  Never  0  2  4  6  Unknown

4) To provide **new** data logging systems not possible with conventional means:

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5) To provide data logging outputs **remote** from the control room (e.g. shift supervisor’s office, emergency control room, engineering offices):

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6) To utilize the **flexibility** of computers in data logging functions:

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<td>C</td>
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</table>
Scales:  Appropriate  Not  Years until implementation:  Appropriate  Never 0 2 4 6 Unknown

7) To provide record keeping for operators administration (eg. work orders, abnormal plant states, flow sheets, operating procedures):
APPENDIX D

Questionnaire Results, Section 3: Specific Questions
APPENDIX D

This appendix is a listing of each respondent’s markings for Section 3 of the questionnaire. Letter codes are used for each country to allow a bar-chart display since mathematical analysis is not possible. The letter codes are:

A - Austria  I - The Netherlands
B - Belgium  J - Norway
C - Canada  K - Spain
D - Finland  L - Sweden
E - France  M - Switzerland
F - Fed. Rep. of Germany  N - The United Kingdom
G - Italy  O - The United States
H - Japan
SECTION 3: Specific Applications of Digital Computers of interest:

This section is similar to Section 2, but includes specific applications of interest.

Scales:  Appropriate  Not  Years until implementation:
         Appropriate  Never  0  2  4  6  Unknown

3.1 Display Uses

1) To organize or prioritize alarms and annunciations to limit overloading of operators or to otherwise organize the data:

   Safety
   Control

2) To provide on-line display of numeric and trend data and other plant variables or states:

   Safety
   Control

3) To display of standard and/or abnormal operating procedures:

   Safety
   Control
Scales: Appropriate Not Years until implementation:
Appropriate Never 0 2 4 6 Unknown

4) To display of flow sheets and related plant data:

3.2 Automated Assistance

1) To provide sequential display (i.e. prompting) and tracking of manually executed sequence of control actions (e.g. testing of safety systems, startup of turbines):

2) To provide automated sequencing of operator actions (e.g. testing of safety systems, startup of turbines):
Scales: Appropriate Not Appropriate

Years until implementation:
Never 0 2 4 6 Unknown

3) To provide deterministic or expert systems as decision aids to assist the operator in diagnosing abnormal conditions or in assessing the consequences of proposed actions:

4) To provide deterministic or expert system to assess plant or system states, integrity and/or redundant systems:

3.3 To Provide Direct and Indirect Digital Computer Control

1) To provide direct digital control of one or more reactivity mechanisms:
2) To provide indirect digital computer control through control of the setpoint for one or more analog reactivity mechanism control loops:

Scales: Appropriate Not Appropriate Years until implementation: Never 0 2 4 6 Unknown

Safety

Control

3) To provide direct digital control of one or more processes (e.g. flows, pressures):

Safety

Control

4) To provide indirect digital computer control through control of the setpoint for one or more analog process control loops (e.g. flows, pressures):

Safety

Control
3.4 Data Logging

1) To provide data logging of plant variables and states in a hard copy form for control or safety purpose:

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2) To provide data logging of plant variables and states in a machine readable form:

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3) To provide event recording systems to record the timing of a sequence of discrete events:

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3.5 Maintenance Assistance

1) To support scheduling of routine maintenance:

```
Scales: Appropriate  Not  Years until implementation:
         Appropriate  Never  0  2  4  6  Unknown
```

2) To provide deterministic or expert systems for the diagnosis by maintenance personnel of component or system faults in or out of the control room:

```
Scales: Appropriate  Not  Years until implementation:
         Appropriate  Never  0  2  4  6  Unknown
```

3) To display maintenance procedures:
4) To perform maintenance procedures automatically:

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APPENDIX E

Questionnaire Results, Section 4: Design Methods and Implementation Techniques
APPENDIX E

This appendix is a listing of each respondent's markings for Section 4 of the questionnaire. Letter codes are used for each country to allow a bar-chart display since mathematical analysis is not possible. The letter codes are:

A - Austria  
B - Belgium  
C - Canada  
D - Finland  
E - France  
F - Fed. Rep. of Germany  
G - Italy  
H - Japan  
I - The Netherlands  
J - Norway  
K - Spain  
L - Sweden  
M - Switzerland  
N - The United Kingdom  
O - The United States
Section 4: Digital Computer System Design Methods and Implementation Techniques:

For this section, respondents were asked to indicate whether the method or technique is used for safety and control applications, is not used, or is unknown. The symbols used here to indicate responses are:

"B" for both safety and control applications
"S" for safety applications
"C" for control applications
"N" for not used
"U" if unknown

Applications that are only under evaluation or being experimented with were not to be included and respondents were asked to add to the lists as necessary to describe the methods and techniques in their country.

4.1 System Specifications

1) Please identify which of the following techniques are used to assure the acceptability of the hardware of computer systems:

a) Complete formal specifications
b) Control of the development process
c) Thorough testing of the end product
d) Other (specify):
   G: Validation
4.1 System Specifications (continued)

2) Please identify which of the following techniques are used to assure the acceptability of the software of computer systems:

a) Complete formal specifications

b) Control of the development process

c) Thorough testing of the end product

d) Other (specify):
   G: Verification and Validation Procedure

3) Please identify which of the following plans are prepared:

a) Quality Assurance Plan

b) Software Verification Plan

c) Software Test Plan
4.1 System Specifications (continued)

3) d) Programming Conventions Plan

e) Other (specify):
   C: Software Validation Plan, G: Software Management Plan,
   L: System Test Plan

4) Please identify which of the following design review techniques are used:

a) Preliminary design review:

b) Critical design review:

c) Code walk-through:

d) Other (specify):
   L: System or module design review,
   O: Code inspection and Configuration audits

5) Please identify for which of the following areas human factors engineering specifications are prepared:

a) Display requirements

b) Input device requirements

c) Input device and display interaction requirements
4.1 **System Specifications** (continued)

5) d) Control room or panel layouts, and input device and display arrangement requirements

    e) Operator input device and display interaction dialog requirements

    f) Other (specify):
        L: Overall control room design requirements

6) Please identify which of the following methods are used in the design of the human-computer interface:

    a) Operator function and task analysis

    b) Human factors engineering test and evaluation program

    c) Workload analysis

    d) Human reliability analysis

    e) Static or pseudo-dynamic function mock-up studies

    f) Operator performance or plant dynamics simulator studies
4.1 System Specifications (continued)

6) g) Studies of hardware or software failure effects on operators tasks and functions

h) Experimental research on input device and display design

i) Other (specify):
   B: Former experience
   L: Interviews
   O: Operator model, analytic tood development
4.2 Development Methods

1) Please identify which of the following software configuration management techniques are used:

a) Normal record keeping

b) A computerized library of application source and object codes

c) A computerized library of public source codes (if available) and object codes (e.g. operating system, compiler, editor)

d) Designation of a software configuration manager

e) Including on-line readable record of its issue information

f) On-line software checks(s) of the issue number compatibility of software with software, and of software and firmware media

g) Other (specify):

0: Software configuration management plan (part of the software quality assurance plan)
4.2 Development Methods (continued)

2) Please identify which programming languages are used:

a) Assembly

b) Ada

c) Basic

d) C

e) Fortran

f) Lisp

g) Pascal

h) Prolog

i) Other (specify):
   E: PL 16
   G: PLM
   O: PL/M 86
4.2 Development Methods (continued)

3) Please identify which of the following programming standards are used:
   a) A coding format to indicate routines
   b) Single entry, single exit of a routine
   c) No unconditional GO TO statements
   d) No Recursive routines
   e) Limited nesting depth for routines
   f) Maximum routine length
   g) Minimum routine length
   h) Standard header format for routines
   i) Other (specify);
      O: Standard prologs, standard comments, language coding standards
4.3 Design Options

1) Please identify which of the following levels of redundancy are used:

   a) A single computer which may have redundant inputs and outputs

   b) A primary computer which may have redundant inputs and outputs and has a duplicate backup computer which can automatically take over the functions of the primary computer

   c) Triplicated computers which function through a two-out-of-three voting circuit

   d) Four computers which function through one or more, two out of three voting circuits; (one computer may be rejected by its own action or by the combined action of the other three)

   e) Other (specify):
      D: Cluster:

2) Is a single computer used

3) Are distributed computers used

4) Are data highways used
4.4 Testing

1) Please identify which of the following software validation tests are used

a) Preparation of an Acceptance or Validation Test Plan

b) Static input/response tests

c) Pseudo-dynamic input/response tests (e.g. ramp inputs through their ranges)

d) Simulated input/response tests

e) Open loop, on site tests
   O: self testing: input-ready display

f) Stress tests (e.g. outside the input voltage limits, excessive input data rates)

g) Quality Assurance Functional Audit

h) Quality Assurance Physical Audit

i) Other (specify):
   L: Whole system and functional tests
2) Please identify which of the above are automated:
   C: b,c,d        D: b        G: d        O: c,d

3) Please identify which are repeated for revisions to the systems:
   C: b,c,d,e,g,h  D: a,b,e,f,g,h  G: e        L: a,c,d,e,f,i
   M: a,b,d,g,h    K: a        O: a,b,c,d,e,g,h  F: b,d

4.5 Applications Experience

1) Has a human factors engineering study for an application indicated that a non-dynamic, non-interactive CRT display was the system of choice (i.e., fixed format with periodic data updates)?

2) Please identify which of the following characteristics described in the most recent control room display designs:
   a) Principally all parallel (i.e., conventional analog display)
   b) Principally all serial (i.e., CRT displays)
   c) A combination of parallel and serial
   d) Monochromatic CRT's
   e) Colour CRT's
   f) Other (specify);
      none
3) Please identify which of the following characteristics describes the digital computer input devices used on the most recent designs:

a) Conventional switches (e.g., pushbutton, knobs, and switches)

b) Keyboards with alphanumeric and special purpose keys

c) Cursor control devices (e.g., joysticks, mouse, and roller ball)

d) Other (specify):
   C: Functional keyboard
   O: Touch pushbuttons, soft keys, touch CRT

4) For what period of time are spare parts stocked (i.e. to guard against obsolescence)?

a) Up to 5 years

b) 6 to 10 years

c) 11 to 20 years

d) 21 to 30 years

5) Of the control loops closed through a digital computer, what percentage currently use direct digital control?

a) 75% - 100%

b) 50% - 75%

c) 25% - 50%

d) 0% - 25%
4.6 Research Needs

1) Determination of hardware reliability

2) Determination of software reliability

3) Software design techniques

4) Software verification techniques

5) Software coding techniques (including programming languages)

6) Software validation techniques

7) Software documentation techniques

8) Configuration management techniques

9) Software maintenance techniques
10) Quality assurance techniques

11) Human-computer interface design techniques

12) Input and database integrity techniques

13) Other (specify):
   O: Networking, communications

14) Please prioritize the top three research topics:

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4.7 Additional Comments

D: The black and white division between safety and control makes it difficult to answer the questionnaire in a consistent way. It seems also likely that there will be different shades of gray between safety grade and non-safety graded systems. Another difficulty in answering the questionnaire lies in the very different computers which will be used ranging from dedicated microprocessors and programmable logics to large clusters of computers. The questionnaire is however touching on several important items which may require more meat on the bones to be understood correctly.

K: 1. The nuclear power plants (NPP) in operation and under construction in Spain are of different types and from different suppliers (Westinghouse and KWU as PWRs, GE as BWR, and French GCR).

Moreover, their technology corresponds to the state of the art of the years in which they were constructed with the improvements and backfitting which have been incorporated since then.

For that reason the answers to the questionnaire represent an average situation of the Spanish NPPs.

2. Among the Spanish NPPs it is possible to find the following situations:
   - NPPs with a conventional Process Computer.
   - NPPs that additionally to the Process Computer have other computers for specific purposes (SPDS, PAMS, TRA, etc.).
   - NPPs with a Process Computer which comprises all the purposes quoted above.
   - A KWU NPP with a Process Computer of a different philosophy.

3. In all NPPs the Process Computer is not safety related but it receives, stores, displays and processes information from safety systems.

4. Pages 10, 15, 18: Administrative tasks are performed by specific computers and not by the Process Computer.

5. Page 13: In general, the Process Computer does not perform control actions, but there are also other computers in plant with specific purposes. These computers control some systems or processes, such as condensate polishing, turbine control, etc.

M: Many of the questions are very hard to answer and the questions do "not fit" reality. Some of the questions must be related to what functions are computerized in a plant and the use of computers in specific applications. None of the questions asks for that information.