DESCRIPTION

OF THE

HUMAN FACTORS PROGRAM PLAN

FOR THE

SYSTEM 80+ (TM)

STANDARD PLANT DESIGN

COMBUSTION ENGINEERING, INC.

February, 1992

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1-Introduction

1.1 PURPOSE AND SCOPE

1.1.1-Purpose

The Human Factors Program Plan (HFPP) for System 80+ describes the human engineering program for the System 80+ standard plant design certification, identifies its elements, and explains how the elements are managed. The purpose of the document is to define, in easily understood terms, both what human factors (HF) activities have been done to date for Nuplex 80+, and what activities will be performed as part of the ongoing human factors engineering program for the System 80+ Standard Plant Design.

The intent is to provide a consolidated basis for review of C-E's human factors plans and progress. The purpose of this document is not to revise or add to those human factors efforts that were necessary to bring the design to its present state, rather this HFPP documents what has been done to date in the design process and relates past activities to those which are planned as the design of System 80+ progresses.

1.1.2-Scope

This document describes activities relating to the design of the man-machine interface (MMI) for ABB-CE's Nuplex 80+ advanced control complex to be used on the System 80+ standard plant as well as related MMI considerations for the balance of the System 80+ standard plant design. System 80+ refers to the entire plant including the Nuplex control complex. Nuplex 80+ refers to the control room, the technical support center, and the remote shutdown panel.

A description of the design team including C-E and its subcontractors is provided, as well as descriptions of the activities themselves. In addition, the products which have been generated or are planned as a result of future human factors activities are described. The scope of the document includes:

Organization of HF personnel and activities and Integration into the Project

Human Factors Efforts by Subcontractors

Human Factors and Systems Analysis

Human Factors Engineering in MMI (Equipment Detail) Design

Human Factors Tests and Evaluations

Other HF Efforts (incl. personnel, training and procedures)

Both past and future efforts including the resulting products in these areas will be described.

C-E's approach to the program plan is to describe activities and documents which have been done previously and will not be altered because they are considered to represent a good design practice which will be pursued in the future. If any area is found to require changes during the continual re-evaluation of the man-machine interface which occurs during the design process, the design may be modified but the previous human factors engineering process will not be changed. The program plan also describes the future HF program (evaluations, analyses, and design work) based on the design process developed to date.

1.2 APPROACH

The System 80+ standard plant is an **evolutionary** plant design, where plant systems and their operation do not differ substantially from previously licensed plants, specifically System 80. As such, the baseline system and operator functions of the plant do not differ notably and, thus, the information and control requirements of Nuplex 80+ are not significantly different from those of System 80 plants. It is prudent to take credit for information derived from existing plants in HF activities such as task analysis and function allocation. These will be referenced and referred to during the description of the seminal HF activities in this program plan.

1.2.1-Organization of Design Team

1.2.1.1-Internal Organization

The human factors engineering effort at Combustion Engineering is an integrated part of the entire design process. Full time human factors specialists are employed by C-E and participate in every step of the design of the man-machine interface. Hence, human factors work for the Nuplex 80+ is not performed by outside consultants, nor is it merely an after the fact review function.

An integrated group was chosen because it assured that human factors engineers were participants in the design process and not merely consultants. They belong to what, effectively, is one design organization. This leads to the most efficient design process and makes the human factors specialists more effective because their incremental and continual input enables design modification and development without extensive backfit.

The exact number of human factors engineers working on Nuplex 80+ at any given time varies depending on schedules, work in progress, and other projects which require human factors

involvement. There are currently two groups at C-E which include human factors engineers; the Nuclear Services Human Factors Group and the Nuclear Systems I&C Control Complex Engineering Group. It is this latter group which has the primary responsibility for Nuplex 80+ design with the services group providing support and loan of staff members on an as-needed basis.

There has always been at least one human factors engineer working full time on the Nuplex 80+ design. Currently there are two. At certain points in the design, such as during Functional Task Analysis (FTA) there have been as many as four. The human factors specialists at C-E bring a diverse background to the design including nuclear navy, utility, and architect/engineer experience. The HF specialists are part of a group of eleven man-machine interface designers dedicated to System 80+ work. These include experienced navy and commercial operators, individuals with expertise in display development, I&C systems, and control panel fabrication. In summary, the HF specialists are part of a larger group dedicated to the MMI design.

Minimum requirements for qualified HF specialists on the project include either a Bachelor's degree in engineering or a human factors related field and five years human factors experience in the nuclear industry or a Master's degree in a human-factors related field. All of C-E's current human factors specialists possess significantly more experience than these minimum requirements.

As previously noted, the exact staffing level of human factors engineers dedicated to System 80+ and related projects varies, hence no exact number of man-months/yr can be given. However, for comparison purposes, it can be noted that for the final 6 months of 1991 there were three human factors engineers working nearly full-time on NUPLEX 80+ and related projects, with one additional engineer providing support and supervision.

The I&C department contains numerous engineers and specialists outside of the human factors discipline. CESSAR/DC Table 18.2-1 provides design team staffing information. The staff of senior reactor operators and HF specialists has been expanded since the time this table was prepared. Experienced former LWR licensed operators and navy operators contribute greatly to the MMI design, especially in the walk-through and analysis portions. Software specialists, experts in control board design, and I&C systems engineers also add input. In short, human factors efforts are part of the larger integrated design team approach to the entire System 80+ product.

The reporting structure at C-E has varied over the course of the design of System 80+. Currently, the human factors engineers permanently assigned to the project report to the manager of ALWR design who reports to the Director of Nuclear Systems I&C. Other

designers report to the same manager. HF specialists on loan from the Nuclear Services group similarly report to the I&C ALWR manager. However, when the Nuclear Services group performs independent HF tasks (such as the FTA) for the design, they remain within their normal Nuclear Services reporting structure: HF specialist to HF group supervisor, etc. and up the Nuclear Services management chain, which meets the I&C ALWR group's reporting authority at the President of ABB-CE Nuclear Power.

1.2.1.2-Design Process

The Nuplex 80+ MMI design process is illustrated in Figures 1.2-1 through 1.2.5. These show the relationships among 'conventional' human factors analyses, i.e., functional decomposition, design reviews, rapid prototypes, standardized panel layouts, and other design methods employed in the Nuplex 80+ MMI development.

The Nuplex 80+ design process utilizes other approaches in addition to conventional human factors analyses. One of the most common and effective is the Design Review Meeting (DRM). In these meetings, the engineer(s) assigned to a particular aspect of design present their work for critique and input from other design team members. Typically, such meetings include ten to twenty individuals including implementers, system designers, operators, and HF specialists. This process is akin to what EPRI calls the "boiler room" approach, where design details are "sweated out".

The DRM can also be seen as the 'test' phase of the design team's hypothesis and test cycle. Human Factors specialists take advantage of these meeting both to assure that all aspects of the design receive HF input and to subject their own work to multidisciplinary scrutiny. This approach is an important means of ensuring that the development of the design proceeds in a consistent and feasible fashion. Goals of the DRM include assuring that the design is useable, feasable, and consistent with design practice throughout the project. Further details on the DRM process can be found in Section 5.1.

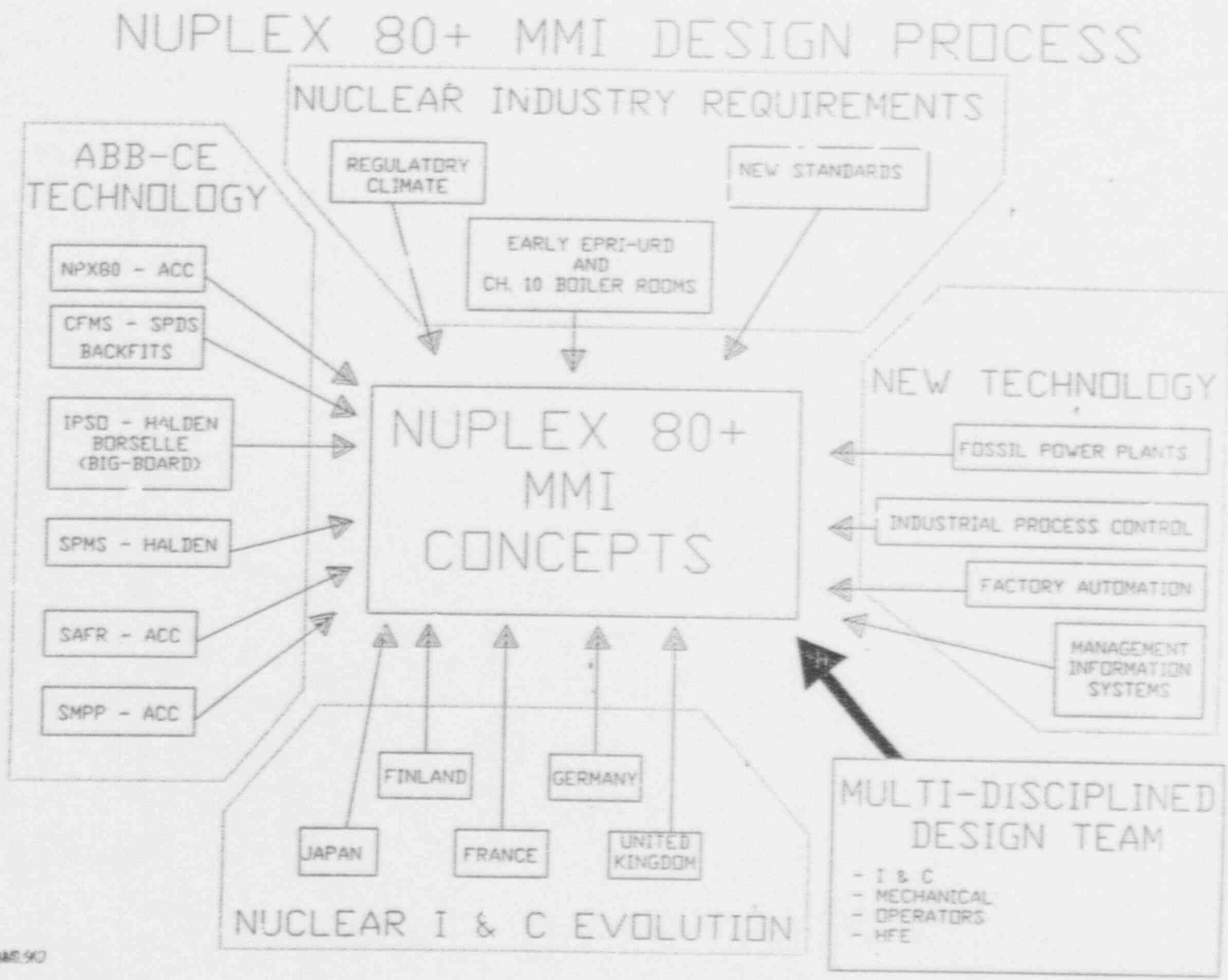

NUPLEX 80+ MMI DESIGN PROCESS
NUCLEAR INDUSTRY REQUIREMENTS
REGULATORY CLIMATE
NEW STANDARDS
EARLY EPRI-URD AND CH. 10 BOILER ROOMS
ABB-CE TECHNOLOGY
NPX80 - ACC
CFMS - SPDS BACKFITS
IPSO - HALDEN BORSELLE (BIG-BOARD)
SPMS - HALDEN
SAFR - ACC
SMPP - ACC
NUPLEX 80+ MMI CONCEPTS
NEW TECHNOLOGY
FOSSIL POWER PLANTS
INDUSTRIAL PROCESS CONTROL
FACTORY AUTOMATION
MANAGEMENT INFORMATION SYSTEMS
FINLAND
GERMANY
JAPAN
FRANCE
UNITED KINGDOM
NUCLEAR I & C EVOLUTION
MULTI-DISCIPLINED DESIGN TEAM
- I & C
- MECHANICAL
- OPERATORS
- HFE

Figure 1.2-1

NUPLEX 80+ MMI DESIGN PROCESS

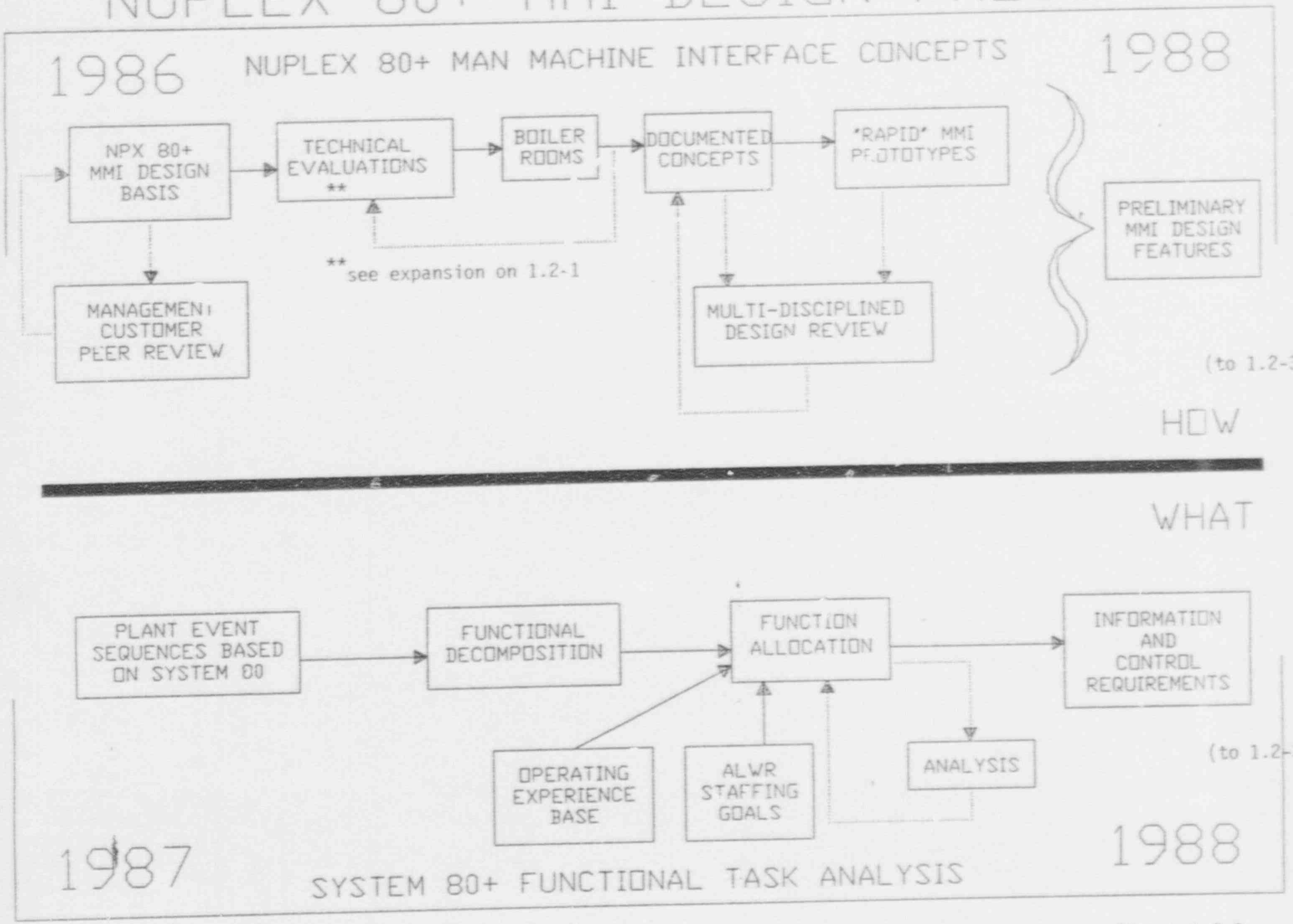
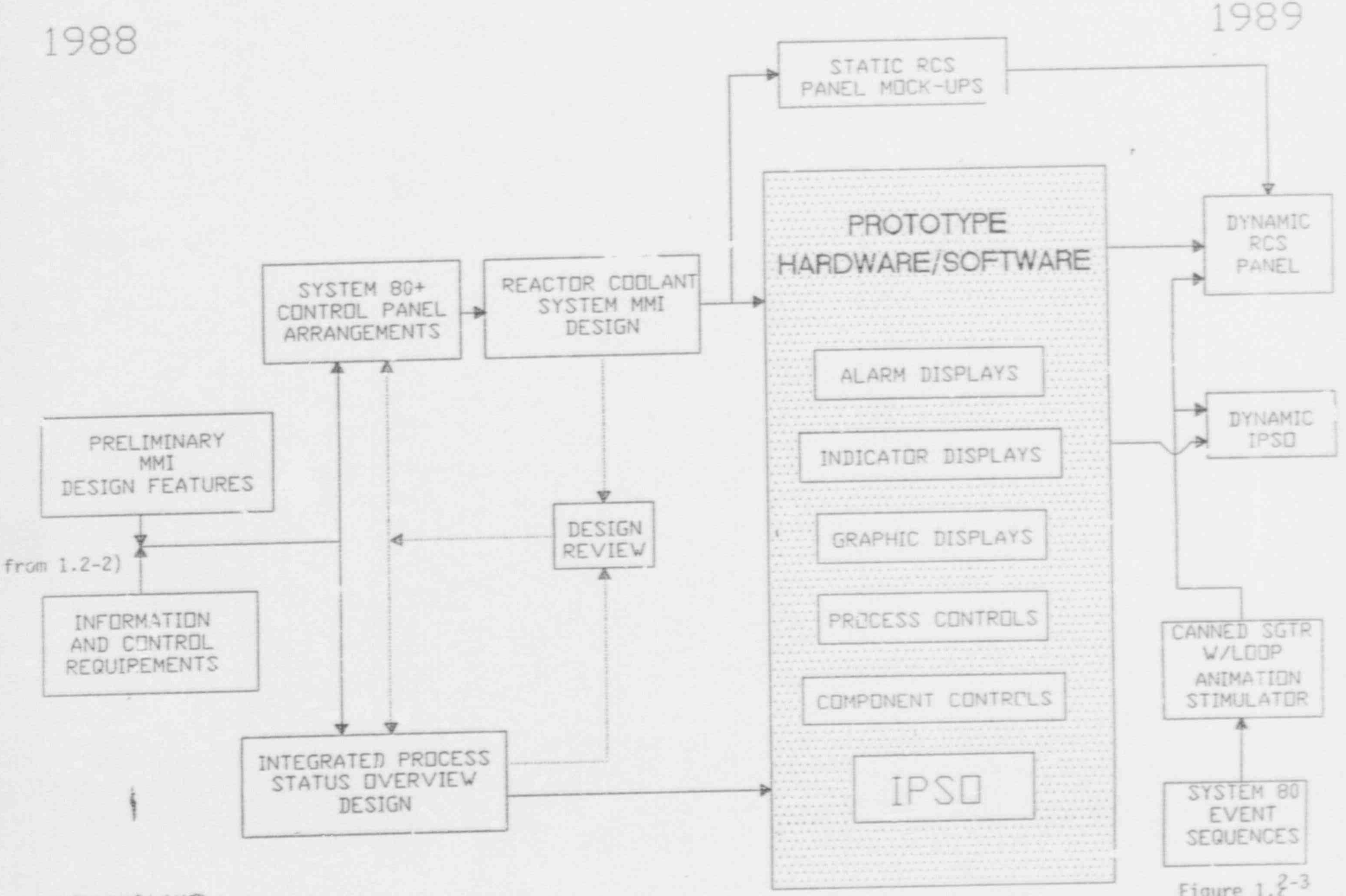


Figure 1.2-2

NPXMMI2SKD

NUPLEX 80+ MMI DESIGN PROCESS



NPXMMI3A.SKD

Figure 1.2-3

NUPLEX 80+ MMI DESIGN PROCESS

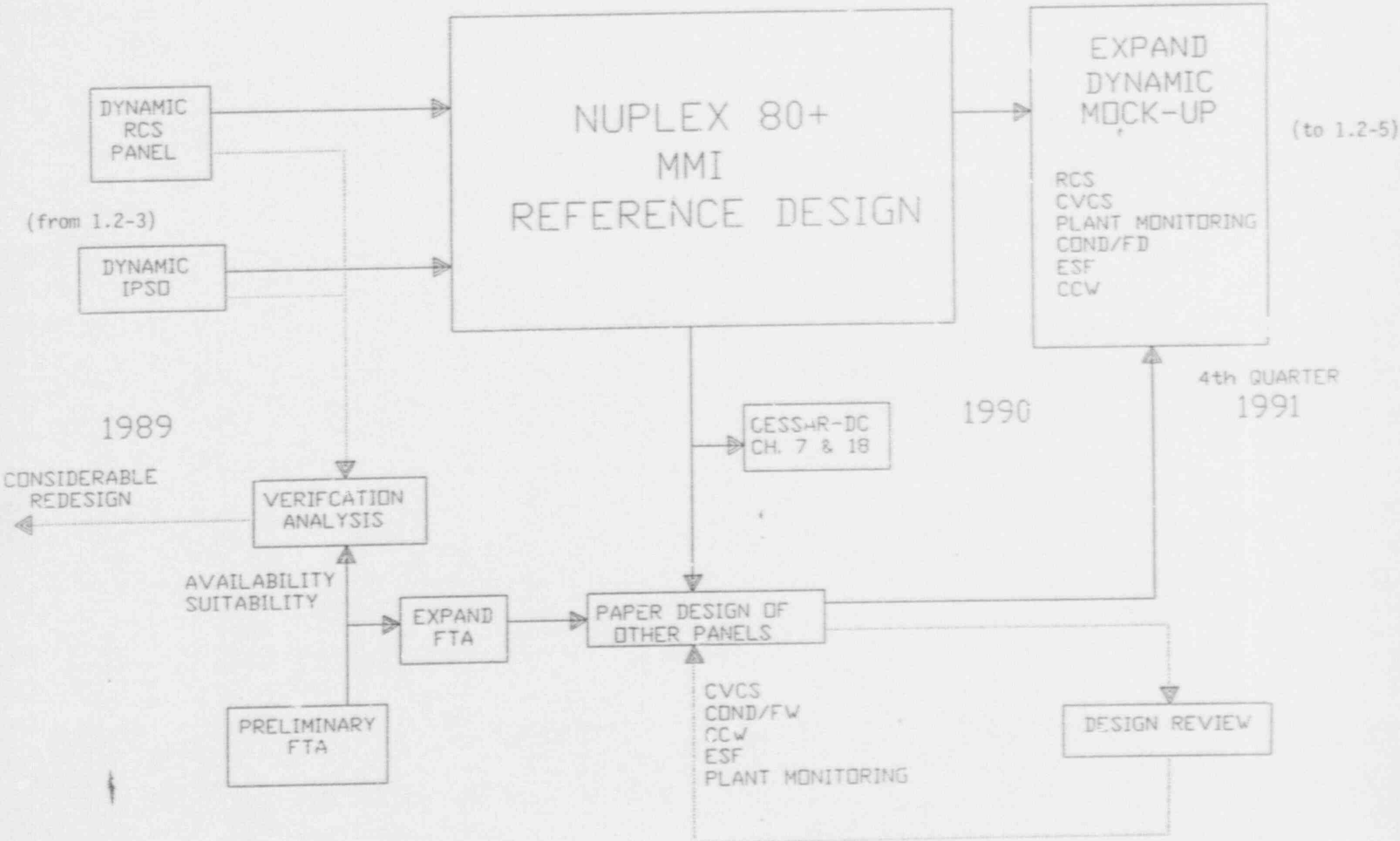


Figure 1.2- 4

NPXMMI4.SKC

NUPLEX 80+ MMI DESIGN PROCESS

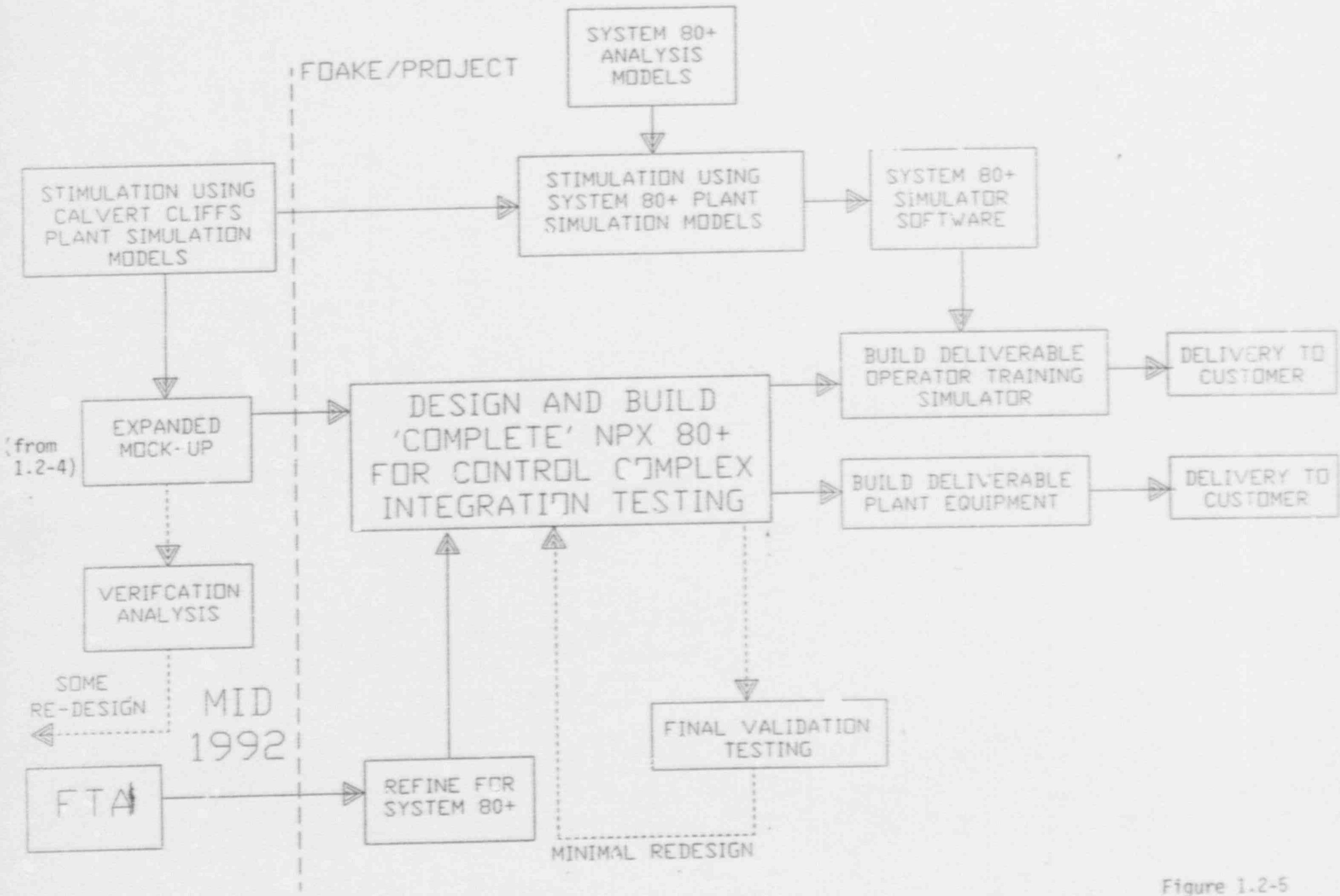


Figure 1.2-5

NPXMMI5.SKD

The Nuplex 80+ design approach can be seen to be consistent with human factors methodology described in references such as IEEE-1023 in that:

- the design is an iterative process using HF specialists, operators, plant systems engineers, and maintenance experts

- prototypes & mock-ups, DRMs, and other technical evaluations are used to develop a standard MMI design

- the design team develops System 80+ information and control characteristics to satisfy the operators' need to perform EPGs (safety functions) and other operating tasks

- the analyses' results are provided to the designers for incorporation into their work and the total design of one panel and the IPSO display

- additional panel sections are being designed using a similar methodology, with ongoing verification work

- the entire product will be validated at the integrated test facility

The C-E design approach utilizes the concept of an engineer or small design team developing a design to meet a specific design basis and to solve existing control room problems. Elaborate studies and analyses were not seen as a practical approach to revising and upgrading the information and control interface for known process systems in an evolutionary design. Rather, the new design focused on solving known problems as well as emergent ones that are identified during the design process. Design flows not only from human factors analyses but also from individual problem solving efforts, design reviews and experience with previous C-E plants.

1.2.1.3-Human Factors Efforts by Subcontractors

Some balance of plant work relating to the man-machine interface for System 80+ is being performed by Duke Engineering and Services (DE&S) as a subcontractor. C-E retains final design authority, review, and responsibility for work which has been or may be performed by DE&S or any other subcontractors. This work, to date, has included some of the preliminary BOP-related panel layouts and much of the physical plant configuration work that impinges on maintenance and access (human factors) considerations. The DE&S organization includes individuals with plant operations, maintenance and test experience, many of which have been temporarily loaned from the Duke Power Company. Their input to the design is particularly valuable.

At all milestone stages in the design, work produced by DE&S

comes to C-E for further review. At these stages in the design, C-E's human factors specialists provide further review to the work produced by DE&S. C-E also provides human factors engineering guidance to DE&S by providing human-factors related guideline documents and Nuplex 80+ design practice documents. This is to assure that DE&S's products not only provide a good human factors interface in and of themselves but also that they are consistent with the remainder of the MMI.

Future System 80+ design work may be performed by other subcontractors. Should this prove the case, the same methods of review, guidance, and control will be used to assure a continued standardized and acceptable man-machine interface.

1.2.2-Philosophy of Design

The philosophy which has been followed in the development of the System 80+ man-machine interface begins with the evolutionary nature of System 80+. Inherent in this philosophy is the criterion of acceptability. The design goal for the Nuplex 80+ advanced control complex human factors effort has been to assure that the MMI is acceptable based on an established set of performance goals. Criteria for MMI acceptability include conformance to existing human factors guidance, correction of significant human error concerns that are identified during verification, and demonstration of the operators' ability to perform required safety functions in a timely, accurate and reliable manner in all cases. In general, the design exceeds this goal.

Since there is no unitary, objective measure of performance quality, nor baseline data against which the notion of 'optimal' can be measured, CE does not claim optimal or near optimal MMI performance. Similarly, C-E does not claim demonstrable improvement in the MMI (vs. conventional plants) by a quantitative measure, though in most cases a qualitative improvement is obvious. The design process and acceptability criteria are all directed to the practical achievement of the design goals listed in subsequent sections of this plan.

The two main philosophies of 1) evolutionary design and 2) acceptability are supplemented by several subsidiary ones. These are summarized below:

Accuracy over Speed: The design of the Nuplex control room is such that operators can perform all necessary actions to control the plant under all conditions and can do so without violating reasonable operational time constraints. In general, The Nuplex 80+ design has emphasized the need for accurate performance and the ability of the design to withstand operator errors without catastrophic consequences. Because of the nature of the nuclear power plant, a rapid operator response time is rarely, if ever, required for

safety. Rapid responses are instead allocated to automation. Therefore, the design emphasizes accuracy of performance over speed. Because no speed-critical tasks exist for the System 80+ plant, no "critical task analysis" was performed.

Evaluation of Design Product by Users: The design team has placed an emphasis on assuring the operator's and other user's intimate involvement in the design process.

Information over Data: Nuplex 80+ presents needed information, not merely data, to users. The design philosophy is to provide sufficient information for operations, in a suitable format for operations tasks, rather than requiring the user to sort or process raw data.

Criteria and Validation: The design of the man-machine interface is based on accepted industry practice and human factors criteria. Initially, criteria from these documents were used directly in the design but as work progressed, conflicting guidance, ranges of guidance, and alternate methods of implementation were distilled into C-E's own Human Factors and Guidelines Document. C-E has avoided designing before guidance is developed, and subsequently rationalizing the results.

No Backup: It is part of the design philosophy not to provide hardwired indicators and controls as a 'backup' certifiable MMI.

Certification of Process: Suitable detail is being provided and documented on the design of the RCS panel and system for an evaluation and certification of the generic design process to be made. Once the validity of this approach is accepted, design acceptance criteria will be developed so that the rest of the MMI design can be evaluated based on this method. The design provides an integrated MMI design which can be seen and accepted rather than the more subjective approach of certifying only method and having no sample product available until later.

1.2.3-Roadmap of Human Factors Documentation

Along with CESSAR/DC, a 13-volume set of reference design documentation, henceforth referred to as the RDD, has been provided. Portions of the RDD which concern the human factors program and process include the system descriptions for the RCS and CVCS panels, the generic Panel Layout Standard, the Control Complex Information Systems system description, the Critical Functions Monitoring description, and the new Alarm Processing Description. C-E will be adding new revisions and documents to the RDD in the near-term.

During the course of this program plan, reference will be made

to these documents along with other C-E documents which have been made available to the NRC such as the Human Factors Standards and Guidelines, the Function and Task Analysis Report, and the Verification Analysis Report. In addition, future documents slated for production, including the V&V plan, Validation report, and others as noted in this plan, will be referred to. The HFPP does not attempt to include or summarize the content of these documents, but their existence or scheduled production should be noted as part of the documentation of the C-E human factors program.

1.2.4-Position on Regulations

The Nuplex 80+ and all other areas of System 80+ Man-Machine Interface shall comply with NUREG-0700 where it is applicable to advanced MMI design. In the absence of NRC guidance on advanced MMI design, the project has developed its own internal guidelines as a distillation of the best accepted industry documents as described in Section 1.2.2. Other NRC regulatory documents which pertain to human factors engineering (such as Reg. Guide 1.97) have also been followed. In addition, efforts have been made to meet generic industry guidance such as EPRI NP-3659 and the EPRI ALWR Utility Requirements Document.

The design meets the current human factors design requirements of the Standard Review Plan, NUREG-0800. The exact position on various references is described outside of this program plan.

2-<u>Human Factors Analyses</u>

The design team has performed and plans to perform a number of formal analyses and less-structured evaluations as part of the System 80+ MMI design process. These begin with systems analysis and move on to task analyses and the three other analysis and evaluation activities which normally flow from TA, namely staffing and configuration evaluation, information and panel design evaluation, and verification & validation. Subsequent to the discussion of these activities, a description of other analyses and evaluations contributing to Nuplex 80+ design is presented. These are alarm analyses and the Halden Reactor studies.

2.1-SYSTEMS ANALYSIS

A formal systems analysis, such as described in MIL-H-46855B, was not performed for the System 80+ Plant. The analysis was not necessary because the systems for the plant are essentially the same as those for previously-licensed C-E units. The nature of systems and operating procedures for these units is well-established and documented. Therefore, a systems analysis would not be beneficial or necessary for System 80+. Analyses from other projects that were applicable to System 80+ (such as SONGS 2 &3) were referenced but System 80+ takes credit for design experience as its primary justification for not needing a formal systems analysis since System 80+ represents few changes that affect the anticipated operations based on the previous design.

The results of previous systems operation knowledge have been incorporated into the Nuplex 80+ design in the following areas:

1-Allocation and layout of systems in the controlling workspace has been based in part on the number, function and relationships identified between System 80+ systems.

2-Crew sizes and staffing needs have been evaluated with consideration of the activities required for system operation.

2.2-FUNCTION AND TASK ANALYSIS

The Function and Task Analysis is the first of four human factors analyses and evaluations which have been done for the System 80+ RCS and which are planned for the other portions of the design which will appear in the advanced control complex. The subsequent three, which will be discussed in following sections, are: staffing and configuration evaluation, information presentation and panel design evaluation, and validation.

A formal function and task analysis (FTA) has been performed for the System 80+ RCS. This analysis and the subsequent report have

previously been made available to the NRC in the RDD, volumes 7 & 8. The plan is to perform similar analyses for all other systems with indications and controls on the main control panel sections during the design process. The RCS FTA represents the methodology which the project team will use, with refinements based on the completed FTA work as noted in Section 6.5 of this report.

2.2.1-Function Allocation

Function allocation, the assignment of functions to either man or machine (or a combination), has been done for System 80+ by evaluating the function allocation in the baseline System 80 design. The functions which must be performed by the overall plant systems to achieve their objectives are the same as for System 80. Changes to function allocation for System 80+ developed over the course of design of many currently operating power plants. These changes were reviewed and evaluated as part of the System 80+ design process in response to problem areas identified based on operations histories and interviews with operators. These areas included:

Automatic Load Dispatching

Automatic Margin Preservation

(both done via the Megawatt Demand Setter)

Evaluation and revision to the high level allocation of function is complete. While it is possible that further problem areas will be identified during the design process, at which time additional changes would be evaluated, the possibility is viewed as unlikely.

2.2.2-Functional Task Analysis

A top-down functional task analysis was performed to identify System 80+ information and control characteristic requirements and to allow evaluation of the function allocation. The results of this analysis may be found in CESSAR/DC Section 18.5 and in the Nuplex 80+ Function and Task Analysis Report in the RDD. In general, three areas were given design support by the analysis. They are the aforementioned function allocation, general panel layout, and RCS panel design.

Functional requirements and controls for System 80+ were based on existing System 80 power plants. Monitoring tasks were primarily evaluated in the FTA because the monitoring portions of the MMI have the most significant changes, as compared to current plants. The System 80+ control requirements and MMI for controls is essentially the same as for System 80 plants, therefore, the System 80+ FTA relies heavily on the acceptability of the DCRDR process conducted previously for System 80 control rooms. The

System 80 instrument list and panel components provided the starting point of the System 80+ FTA.

The analysis considered the four basic operator roles and broke operator functions down into subfunctions, operations, tasks, task information, and control characteristics, as described in the FTA report. Information and control requirements were then gleaned.

2.3-STAFFING AND CONFIGURATION EVALUATION

2.3.1-Staffing

The staffing and configuration evaluation, as described in CESSAR-DC, Section 18.6 is complete for the entire Nuplex 80+ control complex. The control panel profiles and arrangements were defined based on the results of the FTA and on HF criteria from the industry, as described in Section 18.6 of CESSAR/DC.

Prior to developing and evaluating the Nuplex 80+ control room configuration, potential and likely staffing levels for Nuplex 80+ were evaluated. First, a set of operational requirements was established, based on the EPRI ALWR URD, experience with existing C-E units, and licensing considerations such as Reg. Guide 1.97. Based on these, Nuplex 80+ was configured to provide for a variety of operating crew sizes from one to six. The technical bases for these crews is presented below:

One-person crew: An EPRI requirement. Reactor Trip was looked at as the limiting event for crew size (i.e., task loading was highest at this point of operations). Task Analysis found that one operator, at the master control console (MCC) could handle not only standard Hot Standby to Power operations but also immediate post trip actions. Therefore, Nuplex 80+ supports this crew size during normal power operations. Note that the additional crew members are in the main control room but only one operator is in the controlling workspace (i.e., at the panels).

Three-Person Crew: For post-trip and for start-up evolutions, the 3-person crew size was based on an evaluation of C-E generic operating guidelines, on operating experience at existing C-E units, and on task analysis.

Six-person crew: An EPRI requirement based on staffing practices of all utilities with C-E plants in operation or on order, six is the maximum crew size. This is not a necessary crew size but Nuplex 80+ could support such a crew (which

would include an STA and Control Room Supervisor). Adequate workspace is provided.

Acceptability of these crew sizes can be justified but not confirmed now. However, these crew sizes will be validated in the integration test facility for Nuplex 80+ as part of the human factors program/design process.

2.3.2-Configuration

The Nuplex 80+ control room configuration was developed through an evolutionary process, beginning with System 80 control room configuration. This configuration was modified based on post-TMI monitoring requirements, the EPRI ALWR URD, plant design changes for System 80+, and industry and NRC human factors criteria and methods. Several candidate arrangements were evaluated based on operational and staffing requirements as described in CESSAR/DC Section 18.6. Essentially, problems with existing configurations were taken into consideration first. Design goals, such as the addition of a CRS workstation and redundant controls, addition of an overview mechanism for determining plant status, et. al. were considered next. The current Nuplex 80+ configuration is a result of factoring this evaluation into the design process described in Section 1 of this plan.

2.4-INFORMATION PRESENTATION AND PANEL DESIGN EVALUATION

The information presentation and panel design evaluation, as documented in CESSAR-DC, the RCS and CVCS panel design reports, the Control Complex Information Systems design description (RDD vols. 5&6)and the HF Standards and Guidelines, has been completed for a reference design for the RCS and is being implemented on other panel designs for Nuplex 80+. This evaluation developed standard information and control methodologies and implemented them in panel design, based on the results of FTA. This evaluation practice will undergo additional iterations as it continues to be applied throughout the Nuplex 80+ design.

With the Nuplex 80+ man-machine interface design philosophy as a starting point, methods were developed through evaluation of alarm, display, and control techniques. Refer to the Figures in Section 1.2 for an illustration of this process. This led, simultaneously, to establishing panel design criteria, and allocating information requirements to alarm, display, and control methodology. At this stage, information and control requirements from the FTA were a major input, leading to the development of information processing algorithms (algorithmic rules that relate plant data to information displays). The criteria and algorithms led, along with configuration panel arrangement, to the design of the Nuplex 80+ control panels.

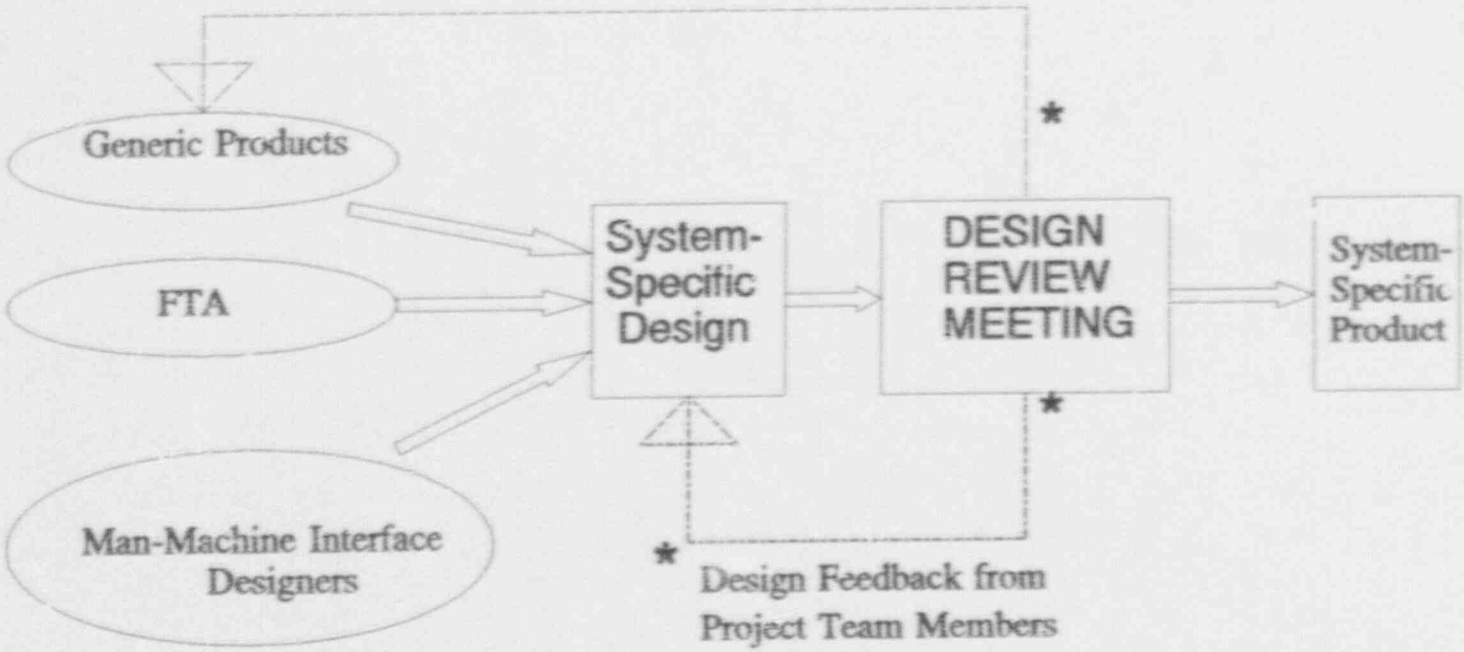
Generic products resulting from this evaluation were:

1-raw data processing algorithm.

2-panel design criteria

3-generic design documents such as Human Factors Standards & Guidelines, the Critical Functions Monitoring and Information Systems descriptions, and the Alarm Processing description

These products are re-evaluated on an as-needed basis during the detailed layout of other control panels, and are re-verified if changes are made. However, no formal analysis is planned at this time. Rather than a formal analysis, engineers and designers define methodologies with a rationale which must then submit to the DRM process described in detail in Section 1.2.1.2 of this plan. Figure 2.4-1 illustrates the process.



Generic to Specific Design Process
Figure 2.4-1

2.5-VERIFICATION AND VALIDATION

The design team has performed verification for the RCS panel design as documented in the Verification Report (in the Reference Design Documentation). It is planned to pursue the same verification methodologies and provide similar levels of documentation for other control panel designs. This topic shall be discussed further in the 'Test and Evaluation' section (Sec. 5) of this plan. The purpose of V&V of the Nuplex MMI is to demonstrate adequate operator task performance capabilities and the capacity to perform necessary functions in the control room. Verification will be based on the task analysis data as performed for RCS and planned for other panels (see Section 2.1). Suitability and adequacy of control room inventory will also be addressed in verification. Note that C-E performs both an availability verification based on FTA results and a suitability verification to establish the acceptability of the interface.

Verification consists of all of the steps necessary to review and evaluate the design adequacy of all of the parts of the design. Validation consists of a review of the overall product or unit at the integration test facility. The validation effort will be based on a multi-phase approach, to ensure integration to support operational functions. These phases will include:

1-demonstration of adequate operator comprehension and access to indicator and control information

2-adequacy of crew size for tasks

3-ability of crew to perform all required functions

This initial validation work will be performed after the availability of a full-scope, partially dynamic mock-up of Nuplex 80+. This work has been done for the RCS system. A similar method is planned for the rest of the Nuplex 80+ control complex, with the work performed in steps as more and more of the design is completed. For instance, MCC one-person operation will be validated before the Auxiliary and Safety Consoles are completed.

Final validation will be performed on the integration test facility. This will be a fully dynamic facility with simulation available. Validation will be demonstrated as final proof of MMI design acceptability.

2.6-ALARM ANALYSES AND EVALUATIONS

A number of power industry studies of plant alarm and annunciation systems were used as contributing material in the

development of the Nuplex 80+ alarm system. Based on these, and the existing System 80 alarm systems, an evaluation of potential alarm system MMI features was performed for the Department of Energy, as part of the Advanced Instrumentation and Control Milestone B work. During the course of this work, various NRC and nuclear industry guidelines on alarm systems were reviewed. Below is a listing of some of these studies and the data they provided to the initial Nuplex 80+ alarm scheme:

EPRI-NP-3448: Provided list of problems with current schemes and data on prioritization definitions.

NUREG/CR-2776: Provided alternatives for advanced alarm display systems.

NUREG CR-2147: Provided recommendations for solving 'classic' annunciator and alarm system problems.

NUREG-0700: Provided guidance on CRT displays, desirable alarm features, MMI characteristics (such as color, response time, etc.), and prioritization.

NUREG/CR-3217: Provided details on short-term improvements which were possible for existing System 80 plants.

NUREG/CR-3987: Provided guidelines and information used by C-E for an evaluation of computer-based alarm schemes.

NUREG/CR-4463: Provided guidance and prospective methodology for a test plan for evaluating annunciator systems.

EPRI Alarm Seminar (MPR Associates, 1988): Provided bases for incorporating spatially dedicated alarms into the design.

Based on these studies, the team began Nuplex 80+ alarm system design and proceeded according to the design process described and illustrated in the other sections of this program plan.

It is important to understand that in the Nuplex 80+ alarm scheme, the alarm system is not actually necessary for accident mitigation, safe shutdown, or the successful performance of the operators' safety and accident mitigation roles in other design basis operating scenarios. Hence, it is a non-safety system and provides what is essentially a monitoring support function. Consistent with this philosophy, the emergency procedure guidelines require no action to be taken in response to alarms and as a result, the alarm system is excluded from the FTA process.

2.7-HALDEN REACTOR STUDIES

In 1986-8, a number of studies were performed at the Halden reactor and its simulation facilities, located in Norway. These

studies and evaluations provided important input to the design of the Integrated Process Status Overview (IPSO, i.e., the big screen 6' x 8' display above the MCC), the Critical Functions Monitoring (CFM) feature, and the Success Path Monitoring function (SPM). What follows is a brief description of these studies and how they influenced the development of the Nuplex 80+ MMI design.

2.7.1-CFM

In 1987, a study was performed at the Halden reactor facility to validate the concept of Critical Functions Monitoring on a PWR simulator. Full details on the study may be found in Volume 10 of the RDD. Simulator tests were run and it was concluded that the CFM function, which provides on-line assessment of the status of critical functions, is a valuable tool to reduce operator error, especially in conjunction with success path monitoring. This led to a decision to implement a similar CFM feature in the System 80+ design, Additional overviews of the Halden work may be found in subsequent Subsections 2.7.2 and 2.7.3 of this report.

2.7.2-SPM

The Success Path Monitoring feature for System 80+ is intended to be an advanced computer-based operator support function which provides an on-line assessment of the status of both availability and performance of success paths that mitigate challenges to critical functions. A prototype version of the system was developed and tested at the Halden reactor PWR simulator. The man-machine interface was evaluated by having experienced operators cope with a series of realistic simulated transients.

Operator performance was evaluated to judge the efficacy of different information presentation systems. Operators' response times and accuracy were measured and comments were recorded. The results indicated the advantages of SPM in allowing the operator to better detect and correct success path problems before they impinged on critical functions. Based on the results of these studies, a similar SPM feature was included in the System 80+ design.

2.7.3-IPSO

As part of an evaluation of whether to provide operators with an overview of plant status, and a determination of the best display method for this information, C-E participated in a study at the Halden reactor PWR simulator in 1986-7. IPSO was evaluated for the adequacy of its MMI in a series of studies which included experienced operators and simulations of three different phases of operation (selected to represent different task loading situations).

Subjects evaluated IPSO's use during normal and abnormal operations, as well as aspects of its MMI such as content and format. Further study investigated the use of IPSO as a focal point for decision making. Results of the studies supported the

usefulness of a large-screen plant overview display. Based on these results, the design team elected to include a large screen display in the Nuplex 80+ control complex design and made modifications to the content and format of the display to improve the man-machine interface based on user comments.

2.8-SUMMARY

Reference design work from previously licensed and operating System 80 plants has been used as the basis for determining:
-function allocation
-information and control requirements
-generic operating sequences
-controls used for the man-machine interface

Generic industry references and applicable NRC documents provided further input to the project design philosophy and HF guidelines. Industry alarm studies and Halden reactor studies contributed to the design of the IPSO, CFM, SPM, and the Nuplex 80+ alarm system. Operating experience from Duke and System 80 plants has influenced control complex layout, information and control requirements, and task sequences which were developed. Functional task analysis has provided direct input to panel layouts by elucidating relationships between controls, indicators, and the functions the panels must perform. As such, it has also served as an input to staffing and configuration evaluation, information presentation, and panel design analysis. Conceptual design bases have been founded on both FTA results and a priori judgements based on design reviews, knowledge of hardware, aforementioned operating experience, and input from a multi-disciplinary design team.

3-Human Engineering of MMI and Equipment

Human Factors of detailed equipment design has been and continues to be a major part of the design team's human engineering efforts. Control room interfaces that make up the man-machine interface include the IPSO, alarms, discrete indicators, process controllers, data processing system CRTs, and component controls. Equipment to provide these interfaces include one big screen display and a combination of CRT screens, electro-luminescent touch screens (flat panel displays, henceforth referred to as ELDs), and pushbutton controls (henceforth referred to as switches). What follows is a description of the evolution of the interface from functional design goals, with a description of design rationale. The design goals are not intended to be testable criteria with clear dependent variables but were intended instead to be objectives for the system designers and human factors engineers as the Nuplex 80+ design developed. Why particular pieces of hardware were chosen is also briefly explained.

3.1-INTEGRATED PROCESS STATUS OVERVIEW (IPSO) DISPLAY

The IPSO, which currently uses a six foot by eight foot rear projection display, is designed to give an understanding of critical functions status, as well as success path availability and performance. It evolved from a generally expressed concern that the presentation of information on separate, small-format devices could prevent the operators from getting the overall "feel" of plant performance, and that CRT displays could cause a 'tunnel' effect of narrowing operator focus. IPSO provides the overview to any operator in the controlling workspace in a single glance. In addition, it is visible from the Shift Supervisor's office and the Technical Support Center so that those not directly controlling the plant but still possessing a need for high-level plant status data, can obtain the information quickly without interrupting controlling workspace activities.

The IPSO display also exists as a display page available on any CRT screen in the control room and at remote facilities such as the Emergency Operations Facility. Thus, although the big board display is located behind the Main Control Complex (MCC) workstation, IPSO is also available to maintenance and supervisory staff, visitors, and engineering personnel. In the control room it is particularly valuable to operators who are coming on shift or who wish to rapidly reacquire the 'big picture' after attending to a detailed task or paperwork.

Design goals for IPSO included:

-Reduce quantity of information to an easily understood and recognized amount

-Provide a single location for quick assessment of key information indicative of critical power plant production and safety functions status as well as major success paths

-Compensate for a reduction in dedicated displays by allowing a 'feel' of plant conditions, thereby promoting a critical functions rather than a systems orientation

-Compensate for reduced staffing by providing an overview while doing detailed diagnostic tasks

-Be viewable to not only control room operators but also Control Room and Shift Supervisors and staff in the emergency facilities

Key Design Decisions and Rationale for IPSO included:

-Large Screen: The Halden evaluations showed that a large screen display was preferable for monitoring and obtaining information quickly.

-Level of Detail: The Halden studies also showed that highly processed information, not raw data, was preferred by users.

-Spatial and Serial: Design reviews showed that spatial and serial information were best left on the panels.

-Mounting, Projection, and Format: see paragraphs below;

IPSO uses the same criteria for display design and format as the CRT display pages. See CESSAR/DC Section 18.7.1.1 for details and Section 18.7.1.2.2 for IPSO design criteria pertaining to what type of information was chosen for display.

The IPSO MMI was empirically evaluated through visits to hardware vendors, trying out different mounting methods and projection techniques, and application of human factors references to determine light intensity, ambient conditions, display size, and similar factors. Rear screen technology was found to interfere least with other control room tasks. A slightly tilted screen and black bezel were found to enhance viewability at all viewing locations.

Hardware evolutions for IPSO have included the evaluation of a variety of smaller screens, projection technologies, mounting angles and heights, ambient light levels, wall colors, and adjacent wall and frame colors. These evolutions occurred through design review meetings, hardware trials, and empirical judgements.

3.2-DPS CRT DISPLAYS

Every panel in the Nuplex 80+ control room has at least one CRT display (some have two). In addition, CRT displays are

provided in the Technical Support Center, Remote Shutdown Panel, CRS console, the Operator's office, the Shift Supervisor and CRS office, and the Emergency Operations Facility. Screens are currently envisioned to be 19 or 20 inch diagonal full color monitors which employ touch-screen technology for the operator interface.

CRT pages represent the best method of presenting the Data Processing System's plant information, which is available to the operator in a structured hierarchy. There are three levels of displays plus the IPSO overview. Among the functional design goals for the DPS CRT displays were:

-Assure that all information required for following operating procedures is available to the operator with no more than three levels of depth

-Assure consistent man-machine interface with other control room hardware and internally among display pages through the use of an information systems description document and human factors standards and guidelines

-Functionally consolidate information traditionally scattered across recorders, meters, status lamps, etc. in one location.

-Provide Level One displays with the most useful general monitoring information

-Provide Level Two displays with information that is most useful for controlling plant components and systems

-Provide Level Three displays with information most useful for diagnostic activities

-Provide alarm mapping and access categorization to support alarm acknowledgement and understanding through the CRTs.

Details on paging, menus, etc. may be found in Section 18.7.1.3 of CESSAR/DC.

Touch screens were chosen for the CRTs and ELD displays in order to focus operator attention and save the excess panel space which keyboards or trac balls would have required. Additionally, touch screens make use of the human inclination to point directly without these input devices. Touch screens allow the menu itself to be used for accessing and manipulating the system, which cuts down on page clutter and allows more useful integration of menus and touch areas into the display format. A full listing of this type of design decisions and rationale for DPS displays is below:

-The organization of this displays was selected to provide the big

picture and a clear, uncomplicated hierarchy of detail

-Displays must be able to provide both analog and digital data presentation simultaneously

-SPDS function needed to be integrated into the rest of the DPS displays

-DPS displays needed to be available throughout the Nuplex 80+ MMI (hence CRTs on every panel)

-Based on empirical evaluation and suitability verification, a menu change was made to provide two-touch access to any screen

-Integration was provided with the alarm system to allow alarm acknowledgement from CRTs

The design bases for the CRT screens may be found in the information systems document. The hardware itself was selected to meet criteria in NUREG-0700 as well as NRC requirements for seismic category II. The actual useability of the CRT displays and the hardware, i.e., its adherence to good human engineering principles, will be checked as part of the aforementioned V&V process.

3.3-ALARMS

Details on the characteristics of the alarm system for Nuplex may be found in CESSAR/DC Section 18.7.1.5. These design goals and rationale, as well as system evolution are discussed below without an attempt to fully describe all features associated with alarm and annunciation in Nuplex 80+.

Design bases for the alarm system were described in Section 2.6. Design goals for the alarm system included:

-Reduce the number of generated alarms to minimize information overload

-Display alarms with distinct visual cuing based on priority of response and significance of the alarm for operation, in order to focus operator attention

-Use display techniques which aid the operator in quickly correlating the impact of the alarm on plant safety and performance

-Ensure recognition of all alarms while preventing task overload

-Provide rapid, direct access to supporting information to facilitate operator response

-Enhance operator confidence in alarms by providing redundant,

diverse, and intelligent processing of alarm inputs

-Employ good human factors engineering to enhance organization, and to assure useability of all alarm system features

Design features and rationale employed to meet these design goals included:

-Providing mode dependency to reduce overload and eliminate nuisance alarms

-Providing alarm significance mapping: alarms are mapped to appropriate displays (e.g.-CRTs, IPSO, Alarm Tiles) based on the significance of the tasks and/or equipment involved

-Grouping alarms with specific messages for plant conditions

-Maintaining spatial dedication for the most important alarms in order to enhance useability and reduce search and processing time

-Providing only momentary audible indication of cleared and new alarms to prevent klaxon disturbance

-Individual acknowledgement of changes in alarm status was required to alert operators to changes in status

-Setpoints for critical function alarms were tied to emergency operating procedures to integrate the MMI with EPGs

3.3.1-Alarm Tiles

Some alarms are presented on CRT displays and/or the IPSO screen, based on the significance mapping feature. All alarms which appear on the dedicated alarm tile displays are based on alarm prioritization, a three-level scheme developed per NUREG-0700 and EPRI NP-3448. Originally, alarms defined as priority one or two were selected for display on the spatially dedicated alarm tiles but verification of design has led to a more functional approach to this aspect of MMI development.

Alarm inputs are now selected for display on the alarm tiles based on their relation to significant operator action conditions. Alarms which can result in this type of operator action, even if the prioritization system classifies them as priority three, will be displayed on the alarm tiles. The alarm presentation scheme and significant operator action conditions are discussed in the alarm processing document.

A description of the hardware rationale for the alarm system may be found in Section 3.6

3.4-DISCRETE INDICATORS

Discrete indicators, along with the alarm displays, form the man-machine interface of the Discrete Indication and Alarm System (DIAS). They differ from process controllers in that they do not provide the ability to control plant parameters from their screens. Control on DIAS displays is limited to the ability to page between related data on the discrete indicators and the ability to page through levels of alarms on the alarm screens.

The discrete indicators are an evolutionary successor to analog and digital meters and strip chart recorders. Design goals for the discrete indicators' MMI were:

-Provide a validated list display of all Reg. Guide 1.97 Category I variables

-Provide information to allow continued operation without the DPS;
 a) tech. spec. monitoring with < 24 hr. surveillance
 b) info. needed to assess personnel hazards & equipment damage
 c) Reg. Guide 1.97 Category 1 and 2 parameters not already on single parameter displays

-Provide key parameters used to assess success path performance and status of critical power and safety functions

-Provide access to individual sensor channels used in process representation values to allow continued operation without the DPS available

-Provide continuous display of all SPM and CFM monitored plant data

-Reduce the quantity of data which the operator must process in order to minimize information overload

-Provide simple access to support data (Tech. Spec. and Reg. Guide 1.97 information for example)

-Safety-related pedigree to allow use of same spatially dedicated displays for normal and post accident monitoring, to ensure familiarity

-Enhance operator confidence in display by providing redundancy, diversity (from DPS CRT displays), and intelligence in processing and reliability in hardware

-Provide automatic range changes as appropriate to plant situation

The following design decisions and rationale were employed to assure that the design goals were met:

-Spatially dedicated displays were chosen to reduce time to access information, improve familiarity of the MMI, and to enhance useability

-Analog and digital information (e.g.-trends and numeric data) were presented together when appropriate to allow the replacement of recorders, analog meters and digital meters

-Access to multiple channels of data was provided to allow the reduction in the number of meters and reduce information overload. This also facilitated non-DPS operations for 24-hour Tech. Spec. considerations

-Hardware was selected and the system designed so that operators could use the same indicators for PAMI as normally

-Indicators were chosen and displays formatted to meet MMI portions of Reg. Guide 1.97

-Validated signals were used to improve operator confidence in information display reliability

-No controls or buttons were required external to the displays, to simplify the MMI and save space

In hardware considerations, the discrete information was considered for mainly CRT presentation in C-E's earlier Nuplex 80 (as opposed to 80+) design. However, results of discussions with operators, design reviews and the functional task analysis process convinced the designers of NUPLEX 80+ of the operational advantages of spatially dedicated displays. For a discussion of hardware used for discrete indication, see Section 3.6.

3.5-PROCESS CONTROLLERS

Process controllers, located in the benchboard section of the control consoles, provide the operator with the ability to automatically or manually control plant process loops, such as closed loop controllers. As such, they represent an evolution from the traditional hardwired Manual/Auto (M/A) station found in conventional control rooms. In fact, a design goal of process controllers was to have the ELD provide an operator interface which was familiar based on the operating conventions of traditional hardware.

Functional goals for process controllers were determined based on operating experience and an examination of workload, suitability, etc. which resulted from the RCS functional task analysis and subsequent verification. They included:

-Process controllers must provide the ability to control all control loops for a process parameter

-Process controllers must provide the full range of functions currently provided by M/A stations (setpoint control, mode control,

display of range and channel, display of current parameter value, etc.).

-Digital display of value

-Touch areas allowing swift access to other control loops of the parameter

-Format, method of operation and human factors conventions consistent with the rest of the man-machine interface

The following rationale and decisions were included in the design of the process controllers, in order to mesh with the design goals:

-Controls were separated from discrete indicators and DPS displays to assure operator control actions would be deliberate

-A familiar MMI was chosen that mimics function and operation of conventional M/A stations

-Integration of component controls related to the process control, on one controller (e.g.-pressurizer heater and spray controls are subsystems combined to form the pressure control loop)

-Master and subcontrollers for a process are integrated on one module to facilitate operation

-Controllers were located near appropriate indicators to enhance useability

A discussion of the hardware used for process controllers may be found in Section 3.6.

3.6-HARDWARE FOR ALARMS, DISCRETE INDICATORS, AND PROCESS CONTROLLERS: ELECTRO-LUMINESCENT DISPLAYS

There are three basic types of ELD displays used in the main control complex: alarm displays, process controllers, and discrete indicators. A brief discussion of common features and why this technology has evolved for these portions of the Nuplex 80+ MMI is presented here.

ELD technology was chosen to meet functional design goals of display clarity and reliability as well as the ability to purchase off-the-shelf qualified displays from a number of sources. These displays are not color, but do provide high contrast. They employ the same man-machine interface conventions as the rest of the control room hardware. The use of color as only a back-up or secondary coding method for information on the CRT displays assures a one-to-one mapping of data coding and format techniques between

the ELDs and the CRT displays.

The ELD technology evolved from traditional analog indicators and alarm systems in an attempt to consolidate volume while improving the man-machine interface. Earlier consideration of plasma displays was superseded by ELDs because of their better visibility and contrast, superior hardware, and more reasonable cost. Much of the design basis was concerned with maintaining a familiar man-machine interface while incorporating newer technology to eliminate information overload, unwieldy panel sizes, etc. The key to the selection of this hardware type was that it allowed C-E to maintain the advantages of spatial dedication in the design while still greatly reducing the overall volume of indicators and controls in the controlling workspace.

3.7-COMPONENT CONTROL

Momentary type switches, used for component control, comprise the last major man-machine interface component type for Nuplex 80+. These controls look and feel to the operators as they would in a conventional power plant, even including the traditional use of red-green for process industries. In size, resistance, luminance, and other man-machine interface features, they adhere to the human factors standards of NUREG-0700, MIL standard 1472, EPRI NP-3659 and similar industry guidance.

Behind the panel switch device, these controls are not conventional. They employ multiplexing with fiber optics back to control systems, thus eliminating cabling under the floor and in the panels themselves. This is an improvement to the man-machine interface in that it simplifies maintenance, a design goal (see Section 4.1). Types of components controlled from these switches include valves, pumps, breakers, dampers, fans, heaters, and sprays. In addition, a similar hardware type (but separately labelled and color-coded) pushbutton may be found on every panel section for lamp test.

Design criteria used to identify components that should be controlled from momentary switches included:

-The component is in the main flowpath of a success path

-The component bears no relation to any process controller

A consistent MMI is maintained for color coding, wording and symbology, with the rest of the Nuplex 80+ MMI.

After review of reference design (i.e.-the baseline System 80 design and its evolution through Nuplex 80) and the regulatory requirements for control, the design team interviewed experienced PWR operators and navy operators. Functional task analysis and a

review of the control requirements and list of tasks and subtasks convinced the designers to employ an evolutionary approach with some momentary switches, for critical operating paths based on task sequences reflected from the Emergency Procedure Guidelines. Newer technology was used to improve some aspects of the man-machine interface while maintaining a technology of proven reliability and acceptability.

Main resulting design features were:

-Maintaining the conventional MMI aspects to enhance operator acceptance

-Provide spatial dedication to co-ordinate the MMI with alarms, discrete indicators, and process controllers

4-Maintenance, Training and Procedures

Maintenance considerations have been a continuous influence on the design of the System 80+ man-machine interface. In this section, the MMI design philosophy for maintenance will be explained. The areas of training and procedure development will also be briefly mentioned, although the design team does not consider these areas to be part of the design certification human factors program.

4.1-MAINTENANCE

Designers considered maintenance human factors in the design of Nuplex 80+ through the application of industry guidance (e.g.-DOE HF Design Guidelines for Maintainability-DE 85 016790), MIL standards, from operating experience, and from input given by experienced operators. Based on these evaluations and the team's design review process, the maintenance goals for hardware were developed. The repository for the human factors goals for maintenance is the Human Factors Standards and Guidelines document, and the companion Bases document which lists all of the source references for each guideline. It is out of the scope of the program plan to list all maintenance goals and rationale pertaining to human factors. However, representative examples are provided below, at a generic level, to aid in evaluating the human factors program:

-Equipment shall be off-the-shelf, preferably from more than one vendor, to reduce replacement time and interruption of operations

-All equipment replacement at control panels shall be 'front-access', to cut maintenance time.

-All information and controls in Nuplex 80+ are presented on at least two panels so that maintenance activities on a single panel will never prevent access to information or controls needed by operators

4.2-TRAINING AND PROCEDURE DEVELOPMENT

Maintenance and operating procedures will be developed as the System 80+ design progresses but these activities fall outside of the scope of the design certification human factors program. However, procedures will be validated at some future point during operator training and simulation. Further, the Nuclear Services human factors group provides writer's guides and other technical support to in-house professional procedure writers.

Like procedure development, training of operators, maintainers, and other personnel is not part of the design certification HF program. The System 80+ man-machine interface is designed such that operations and maintenance are facilitated by

the use of good design practice.

Training and procedure development are handled by in-house specialists in these areas. Training is dealt with on a generic System 80+ basis. In other words, training will be based on the entire design and the nature of the tasks involved, not merely on human factors. Likewise, many non-HF considerations are taken into account by procedure writers. The involvement of the human factors program plan with these areas may be briefly summarized as:

-The MMI is designed to facilitate maintenance activities while disrupting operations as little as possible

-Once emergency procedure guidelines are developed by procedure writers, they will be used in the validation of the Nuplex 80+ MMI

-The Nuplex MMI, especially the critical functions alarms, are designed to support the refinement of generic System 80 procedures into System 80+ procedures

5-Test and Evaluation

The design team employs a test and evaluation program for human engineering aspects of the design which is integrated into the overall design and evaluation process (see Figures 1.2-1 through 1.2-5). Such activities have been described in previous sections, most notably the V & V portion of Section 2 and Figure 2.4-1. In this section, the design reviews, verification, and human factors participation in other disciplines shall be described, along with evaluation objectives. A representative milestone schedule is provided. However, since levels of funding vary over time, the exact schedule is still to be determined at this point. Hence this schedule provides more of an indication of where in the design process these test and evaluation activities are located than actual calendar dates.

5.1-DESIGN REVIEWS

One of the design team's principal tools for evaluation of design, from human factors, other engineering discipline, and operations points of view, is the design review meeting. MMI aspects of the design review include verifying useability and consistency of the interface, implementation of design goals and bases, and whether or not the design can be implemented successfully.

As described earlier (in Section 1.2.1.2), experts from all of these disciplines work on an integrated design team. Individuals are given assignments for portions of the design. These individuals, upon completing a draft of work for their project, are required to conduct a design review meeting at which the rest of the design team, and all other interested parties may critique, correct, and advise. Minutes and action items from all design review meetings are documented.

These meeting provide early and specific feedback to designers and allow the product to be reviewed well in advance of any finalization. Exact frequency of these meetings is determined by progress on the design. It is important to emphasize that no system is designed without design reviews.

5.2-VERIFICATION

As described in Section 2.4, verification has been performed for the RCS panel and is planned for the other panels in the control complex. Based on the information and control requirements, and the results of functional task analysis, verification addresses the availability aspects of the MMI. Based on NUREG-0700, the HF Standards and Guidelines, verification addresses the suitability of the man-machine interface. The sum of the two are the acceptability criteria for the verification process. As such, it represents a systematic empirical test and

evaluation of the design. The design team employs verification evaluations as defined in NUREG-0700 where:

-Suitability is the acceptability of the interface methodology to support generic user tasks. Verification of human engineering suitability is performed to identify human interface problems that may affect task performance but which are not evident when the MMI is evaluated without regards to the tasks

-Availability demonstrates that all necessary and sufficient indicators and controls to perform tasks are available and that they are in a format and configuration which supports the tasks

Verification has been performed on the RCS panel design for both of these aspects. See the Verification report in the RDD for details. The actual panel design is necessary for availability verification while only prototypes were necessary to check suitability since the generic characteristics of the man-machine interface do not change from panel to panel. Verification is an ongoing process in the Nuplex 80+ design. Some has been performed, more is scheduled as work progresses.

Validation, which is the final step in the design process, is described in Section 6.

5.3-FURTHER TEST AND EVALUATION

Section 2 of this plan described the human factors analyses and evaluations which have been performed thus far in the design of the Nuplex 80+ advanced control complex. Section 6 lists those activities which are yet to be performed. The design team is pursuing these activities systematically, from a human factors viewpoint. Verification is being pursued on a system by system and panel by panel basis as design progresses, as are remaining areas of Function and Task Analysis. Systems Analysis and Function Allocation are regarded as complete, along with those areas of the task analysis described as complete in Section 2.2

Table 5.1 provides approximate dates as part of the plan for upcoming test and evaluation. It also lists those evaluations which have been completed.

Test and Evaluation Schedule
Table 5.1

Completed Evaluations

Halden Evaluations:
IPSO CFM SPM
Industry Alarm Evaluations
Staffing and Configuration Evaluation
Systems Analysis

Completed Portions of Ongoing Evaluations

FTA:
function allocation; identification of I&C requirements; identification of tasks

Verification:
RCS suitability and availability; overall MMI suitability

Schedule of Future Evaluations and Tests

Evaluation	Approximate Date
Further Verification	
MCC (except turbine)	1992
SC (ESF)	1992
AC	
SC	1993-199?
CRS Console	in First-of-a-Kind
RSP	Engineering
MCC (turbine)	
BOP	after commercial sale
Validation at Integration Test Facility	
Further Panel by Panel TA	ongoing from 1992 as design can support it
Full Scale Mock-up and Prototyping	ongoing process from 1991
Revised HF Standards & Guidelines (and Bases)	late 1992
Develop HF Design Acceptance Criteria	1992-1993
Static Mock-up Evaluations	beginning 1992

6-Future Human Factors Activities

In addition to the ongoing interdisciplinary design process described in the earlier sections of this plan, a number of specific human factors activities and analyses are planned as the design of the System 80+ MMI progresses. A list of these activities and the approximate schedule for them may be found in Figure 5.1. This section contains a brief explanation of these activities to enhance understanding of what is planned. Refer again to the figures in Section 1.2 for an understanding of the integrated design process. This process is similar to that outlined in IEEE-1023 and a comparison between Figures 1.2-1 through 1.2-5 and the design process figure of the IEEE document provides a useful insight into the relationship between the generic (IEEE) design process and that pursued for System 80+.

6.1-FINAL HUMAN FACTORS STANDARDS, GUIDELINES, AND BASES

A complete version of the Nuplex 80+ Standards, Guidelines and Bases has been prepared for the Heavy Water Reactor Facility. Slight modification is underway to convert these into applicable System 80+ guidance. The Standards and Guidelines provide all designers on the team with a controlled compendium of human engineering information to assure a standardized man-machine interface across the project. The bases are a listing of the source materials from which the guidance was culled.

6.2-FULL SCALE MOCK-UP ACTIVITIES

The use of mock-ups of control panel arrangements, a key step in human factors design efforts, is an ongoing process for the Nuplex 80+ design. Currently, a full scale main control complex static panel arrangement exists. Actual layouts on these panels are not yet done, though efforts are ongoing. This static mock-up will provide a location for future analyses and a basis for design reviews pertaining to board layouts.

A dynamic Nuplex 80+ mock-up currently exists for the MCC and one SC panel. This mockup contains functioning CRTs plus some DIAS displays, switches, and process controllers. Some controls on this mock-up are static representations and the layouts are not final. This mock-up serves as an evolving demonstration and design tool for the man-machine interface. Future work will include much evaluation and testing of the hardware and layouts plus continuing work to upgrade the static portions to a more dynamic version.

6.3-PROTOTYPING AND PROGRAMMABLE FEATURES

As the work on the dynamic mockup progresses, the current ELD, CRT, and Switch hardware, as well as the IPSO undergo continuous prototyping upgrade work. New display features are tried to evaluate equipment and operator performance, and the usability

aspects will continue to be tested. The Nuplex 80+ Information Systems Description Document, prepared by human factors specialists on the design team, is used by prototype designers to implement the human engineering aspects of display screens. The future will hold further iterations and improvements to incorporate the results of relevant analyses into the integrated design.

6.4-VERIFICATION ACTIVITIES

Described as part of the test and evaluation plan, it is important to further note that verification activities are an ongoing process. Independent suitability reviews of individual panels are planned as the panel layouts are developed. This work will comprise the bulk of future verification analyses. See Section 5.2 for additional information on verification. Some design goals of this future verification work include:

-Comparing information and control requirements to actual inventory

-Identifying missing or superfluous controls and indicators

Basically, this activity will be the panel by panel verification of availability and suitability as described in Section 5.2.

6.5-FURTHER TASK ANALYSIS

A continuation of the task analysis process, using the same methods as those described in the FTA report for Nuplex 80+ (in the RDD). Each panel section of the control complex will undergo a task analysis prior to final panel layout, in a similar methodology to earlier FTA.

One important difference is based on the experience with the earlier FTA work. A large amount of effort was expended at that time to produce detailed sorts of information. For instance, Gross Functions, Task Listings, and Task Elements were all sorted by events. Elaborate process time calculations were performed and detailed parameter usage by parameter was sorted. It was found that overprocessing of the data added little or nothing to the man-machine interface design and that documenting these sorts added many hundreds of pages of unneeded documentation to the RDD. Therefore, future FTA activities will modify the amount of sorts performed and the level of documentation archived. The exact level of sort and documentation which will be employed has not yet been determined but the basic FTA methodology will remain unchanged.

Design goals of this activity are the same as those described in Section 2.2.

6.6-STATIC MOCK-UP EVALUATIONS

A phase of future HF evaluation activities which was not envisioned in the original design is the evaluation of the man-machine interface at a full-scale static mock-up of the Nuplex 80+ controlling workspace. The static mock-up is being developed for Nuplex based on human factors rationale as described in EPRI-NP-2411 (final chapter). As such it provides a venue for human factors analyses and evaluations and an ability to rapidly an inexpensively prototype candidate arrangements of the man-machine interface. Activities which are planned for the static mock-up include:

-traffic and motion evaluations

-evaluation of the anthropometry of the MMI

-verification of useable control panel layouts based on task sequences (operator walkthroughs)

-evaluation of candidate control panel arrangements

The availability of the static mock-up in a much earlier stage of the design than the integration test facility will assure that these evaluations can be performed before a stage in the process when it is extremely difficult to make design changes. Further, since full panel layouts are not needed to evaluate traffic and motion or anthropometry, some portions of the static mock-up evaluations can begin prior to detailed panel layout work.

6.7-VALIDATION ACTIVITIES

The final human factors test activity planned for the Nuplex 80+ design is the control room validation. This analysis features procedure-based run-throughs, after procedure guidelines have been made into draft operating procedures for an actual power plant. The validation will be done in real time with a full-scale integration test facility.

Among the purposes of the validation, from a human factors viewpoint, are the validation of crew sizes and the final check of the overall man-machine interface of Nuplex 80+.

Shortly after the validation activities, the design will be complete.

6.8-DESIGN ACCEPTANCE CRITERIA

A key remaining HF activity in the System 80+ design is the development of Design Acceptance Criteria for the Man-Machine Interface. These criteria will be the basis for determining that the MMI has been adequately designed up to that point. The development of the same type of criteria (clear, objective,

testable) as in non-HF areas of the design is an important design goal. Based on NRC guidance, development of these criteria will begin in the first half of 1992 and reach early agreement on design acceptance criteria which will evaluate the man-machine interface's adequacy.

7-Conclusion

This program plan has provided an overview of human factors engineering activities for the Nuplex 80+ Advanced Control Complex and the overall System 80+ standard plant design. Past, current, and future activities have been described and references provided to project documents which provide further details.

An effort has been made to describe the entire human engineering program, identify it's elements, and explain how they are managed. Thus, it provides a partial basis for review of progress as well as that of product. The program plan provides information to show how and when C-E has satisfied or will satisfy all human factors performance, design and program requirements specified by the regulatory agency.

It has not been possible to plan to a detailed, month-by-month schedule due to the commercial aspects of the design (i.e., to a great extent future schedule will depend on funding, both internal and external). However, wherever possible, the approximate timeline and the sequence or order which activities will follow regardless of the exact calendar date for the work has been shown.

New co-operation with Asian and European ABB entities and project participants will likely expand the available experience and expertise resources available in the future. For instance prototyping assistance is being provided at this time from ABB-Atom in Sweden.

In summary, human factors is part of an integrated and wide-ranging design effort, but not the only driving force in the design. Nevertheless, human factors experts on the design team assure than an adequate man-machine interface has been and will be maintained throughout the design.