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February 28, 1992
LD-92-033

Docket No. 52-002

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555

Subject: Human Factors Engineering - Revised RAI Responses

Reference: C-E Letter LD-91-016 dated April 12, 1991.

Dear Sirs:

As agreed at the December 4, 1991, meeting with NRC staff, enclosure I to this letter provides revised responses to the RAIs originally submitted in the reference letter.

Should you have any questions on the enclosed material, please contact me or Mr. Stan Ritterbusch of my staff at (203) 285-5206.

Very truly yours,

COMBUSTION ENGINEERING, INC.

S. E. Ritterbusch for

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gdl/lw

Enclosures: As Stated

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Enclosure 1 to
LD-92-033

REVISED RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION
I&C AND HUMAN FACTORS RAIs

Number: 620.1

Question: Provide a detailed human factors program plan which includes (1) a scope of work, (2) the organization of the human factors group and their reporting structure, (3) a description of the human engineering and system analysis studies to be performed, (4) the standards and guidelines that will be generated as a result of human factors efforts, (5) a schedule of major human engineering milestones and technical reviews with anticipated levels of human engineering support, and an outline of the human factors test and evaluation plan.

Response: C-E's original response to RAI 620.1 is being supplemented by the submittal of a Human Factors Program Plan. This plan was submitted by C-E letter LD-92-028, dated February 21, 1992. The contents of this plan are as per discussions between C-E and the NRC's Human Factors Branch at the November 17, 1991 working level meeting.

Number: 620.2

Question: Describe the human engineering studies that led to the selection of the flat panel programmable displays used on the control boards. Describe how they meet the operator and instrumentation requirements identified in the task analysis, as well as the maintainability, and reliability requirement established for control room instrumentation. Also address how they contribute to the goal of redundancy and diversity. Include relevant findings from task analyses and product evaluations.

Response: Many factors contributed to the selection of flat panel displays for use on the MCR control panels. This included both human engineering and instrumentation performance factors. Flat panel display technology was selected for discrete indicators and alarms based on the following required characteristics:

<u>Diversity</u> from CRTs to provide common mode failure protection of the MMI,

<u>Seismic Qualification</u> to meet requirements for Regulatory Guide 1.97 Category 1 parameter display,

<u>Selectability</u> of displayed information to support continued plant operation at power upon the failure of the DPS resulting in loss of all CRT information, sensor deviation diagnostics, alarm details and control selections.

<u>Reliability</u> and <u>Maintainability</u>, including short MTTRs (typically 1 hour or less assuming the replacement part is in hand) and long MTBFs (30,000+ hours and increasing).

<u>Dynamic Graphic Displays</u> for trends, automatic scaling, bar charts, etc.

Interface useability that is satisfactory to meet Nuplex 80+ human factors methodology and acceptance criteria.

Standardization because one programmable device serves needs of Nuplex 80+ applications for indicators/recorders, alarms and controllers.

Other positive characteristics include low sensitivity to electric and magnetic fields and low voltage.

The human engineering focus of the flat panel evaluation was on the acceptability of the interface in the proposed Nuplex 80+ applications. A preliminary evaluation initially determined if flat panel devices could acceptably provide the features required (i.e., touch selection, flash, bar charts and digital display). Later the devices were evaluated in specific Nuplex 80+ applications during the suitability verification analysis. Additional information on the selection of flat panel technology is provided in Section 3.6 of the Human Factors Program Plan for System 80+.

The function task analysis results indicated that for many tasks a single value of a parameter is required, not multiple channels of data that may be provided by plant instrumentation. Discrete indicators using flat panel displays meet this need specifically by providing a single validated parameter value instead of multiple channels. The selectability of individual channels meets needs for other tasks and equipment failure situations. Similarly, spatially dedicated displays of high priority alarms required dynamic tiles (i.e., could be either Priority 1 or 2) with the ability to display multiple messages for alarm conditions grouped in a tile. The flat panel devices met these operational needs. Controllers were designed similar to conventional plant controllers using flat panel displays. Task analysis results indicated that selection of inputs, selection of setpoints, output control and mode selection were required to meet operational needs. The human factors usability of the flat panel display interfaces was assured by using the standard interfaces defined in the Information Systems Description (SD-791-01) and adhering to the Human Factors Standards and Guidelines.

Flat panel electroluminscent displays are easily removable from Nuplex 80+ panels by disconnection of quick disconnect cables and removal of four bolts. Replacement of a device takes less than one-half hour. The published expected MTBF of these devices is 30,000+ hours resulting in an availability of 99.998%. Actual in-service experience is exceeding this number and revised published numbers exceeding 40,000 hours can be expected.

Flat panel displays provide indications and alarms on diverse technology that are redundant to information provided on Data Processing System CRTs. This directly supports the Nuplex 80+ approach to address potential common mode failures with diversity. Additionally, flat panel displays for DIAS N and P provide redundant display of Category I PAMI parameters required by Regulatory Guide 1.97, with all of the required characteristics of Category I variables.

A flat panel product evaluation was conducted comparing Liquid Crystal Displays (LCD), Electro-Luminescent Displays (ELDs) and Plasma Displays. The conclusion of the product evaluation was to select ELDs for Nuplex 80+ applications based on ruggedness and display quality.

Number: 620.3

Question: (1) Describe the technical and administrative methods used by C-E's human factors specialists to track the evolution of the design and to influence the design process.

(2) Describe the documentation control system that is in place to ensure that the evolution of the man-machine interface elements of the design have been documented and provide an auditable documentation trail. How are the results of studies, design decisions and trade-offs documented?

Response: (1) The I&CE department has a comment-resolution tracking system that is used to assure future implementation of open items identified during the design process. This system was used by human factors specialists as well as by all members of the Nuplex 80+ design team. For short term tracking, human factors specialists' comments and recommendations have been documented in reports and then integrated into the subsequent revision to design documents. A CESSAR-DC open items list also provided tracking for specific items to be incorporated into CESSAR-DC revisions. All open items are currently closed out as Amendment I has been submitted.

(2) The design was tracked as it evolved through internal memoranda and Nuplex 80+ documentation. The internal memoranda were the primary means for documenting design decisions and trade-offs. C-E has previously committed to develop a design document that consolidates the design evolution memoranda with emphasis placed on the bases for design decisions. Results of studies are documented in either Nuplex 80+ documents or milestone reports for the DOE Advanced I&C Program. The Human Factors Program Plan for System 80+ describes the elements of the design process, the rationale for key decisions and the documents that the results are found in. The System 80+ design activities are subject to a System 80+ Quality Assurance Plan

(18386-QO-001) which controls document distribution, sign-offs and reviews in accordance with C-E QA procedures.

Number: 620.4

Question: How many human factors specialists are currently dedicated, on a full-time basis, to the System 80+ design? Into how many hours of face-to-face contact time does this translate with the NSSS and BOP engineering and design staffs per weeks?

Response: Currently there are four human factors specialists dedicated to the Nuplex 80+ design. These specialists are an integral part of the Nuplex 80+ design team and would approximately account for 160 hours per week of human factors effort for Nuplex 80+. The number of human factor specialists on the design team has ranged from one (initially) to four (currently), depending on the work being performed at any given time in the design process. Section 1.2.1.1 of the Human Factors Program Plan for System 80+ provides additional details on the level of human factors efforts for Nuplex 80+.

Depending on the activities being performed, the direct contact with other design team members ranged from 0% to 100% of the human factors specialist's time with an average of approximately 25%. Human factors specialists were involved in hardware selection and software engineering as well as the man-machine interface design. Activities such as design review meetings and the suitability analysis required a particularly high level of face-to-face contact.

Number: 620.6

Question: Describe the standardized training materials (e.g., content, format, and development process) being provided to the purchasers of the C-E System 80+ for those aspects within the CESSAR design scope.

Number: 620.7

Question: Describe the guidance that will be provided to purchasers of the C-E System 80+ to ensure consistent adaptation of the standardized training materials to site-specific training materials.

Number: 620.8

Question: Given the advanced technology of the C-E System 80+ what are the specific skills, knowledge, abilities, and aptitudes, based on the task analysis, that will be provided to purchasers to assist in the development of site-specific personnel selection criteria?

The information provided in Section 13.5 indicates that information concerning the site-specific operator plant procedures is within the referencing applicant's scope and shall be provided in the site-specific SAR. Since this is not consistent with the staff's position on standardization, the following should be addressed.

Number: 620.9

Question: Describe the standardized normal, abnormal, and emergency operating procedures C-E will provide to the purchasers of the C-E System 80+.

Number: 620.10

Question: Describe the standardized procedural development guidelines to be provided to referencing applicants for those normal, abnormal, and emergency operating procedures (e.g., writer's guide, verification, and validation guide, procedural maintenance guide). Describe the interface information that will be provided to ensure that site-specific procedures will be consistent with the standardized procedures.

Response: Response to Questions 620.6-620.10

The C-E approach to training and procedures was provided in a letter to the NRC (LD-92-002), dated February 18, 1992.

As stated in CESSAR-DC, Sections 13.2 and 13.5, the procedures and training for a particular plant are within the scope of the site-specific SAR. C-E intends to comply with the staff's "training and procedures" position by providing standardized training and operating procedures guidance. This guidance would then be input to the site-specific training program and operating procedures. This approach is necessary as a result of site-specific component selection (meeting standard functional requirements) and utility-owner responsibility for plant operation. Of course, a particular utility/owner may contract with C-E to provide detailed training and procedures. As a result of the February 7, 1991 meeting with the staff, C-E understands that standardized, detailed training and procedures are still requested. C-E is initiating a program including architect-engineers and utilities to address the issue of training and procedures for standardized designs such as System 80+. This program will cover the complete time span from NRC design review through plant construction and startup. It is expected that the first meeting for this program will occur in the April-May 1991 time frame.

Number: 620.11

Question: Does System 80+ use advanced and intelligent operator aids based on expert systems or other artificial intelligence (AI) technologies? If so, describe the following:

a. The extent and dependence on intelligent operator aids necessary to achieve the single operator design goal.

b. The specific operator aids that are planned and technology on which they are based.

c. The methods of knowledge engineering that will be used.

d. The approach to be taken to develop operator confidence in the systems to assure that they will be appropriately utilized.

e. The methods to be used for the verification and validation of the performance of intelligent operator aids.

Response: The Nuplex 80+ ACC uses no expert systems or AI technology in any of its system designs, including the advanced operator aid designs. C-E would like not to preclude the use of expert or AI systems at some time in the design, since they may offer improved information processing and MMI performance. If they are used, approaches to develop operator confidence, perform verification and validation and assure appropriate use will be developed. If incorporated, advanced operator aids will supplement, not replace, the current features of the design on which the staff is basing their safety evaluation. Analysis will be provided to assure that supplemental features do not conflict with licensed aspects of the design.

(Note that the term "operator aids" in System 80+ does not refer to performance or job aids in the generic human factors sense. For System 80+, operator aids are a presentation of supplementary (level 4 alarm priority) type alerting information.)

(a) There are advanced operator aids in the Nuplex 80+ design that are not based on AI technology. None of these is specifically required or was specifically designed to support the single operator design goal; however, as integral parts of the MMI, they do contribute toward this goal.

(b) The advanced operator aids provided in Nuplex 80+ are primarily integrated functions within the Data Processing System (DPS). They are available on any CRT in the Nuplex 80+ design. These aids are listed below with indication of where they are described in CESSAR-DC and a brief description of their benefits to operation.

1. Core Operating Limit Supervisory System (COLSS), Section 7.7.1.8.1

   COLSS continually calculates core related parameters and compares them to appropriate Limiting Conditions for Operation (LCO). COLSS alarms indicate any LCOs that are exceeded, initiating operator action required by technical specifications. The major benefit is automation of complex calculations providing improved monitoring and no operator burden required to perform it.

2. Critical Function Monitoring, Sections 7.7.1.10 and 18.7.1.8.2

   The major benefit of critical function monitoring is to continuously alert the operator to conditions which are having an impact on the ability to keep the plant in a safe condition or producing power. For critical safety functions, critical functions monitoring automatically and continuously performs the monitoring actions required by the emergency operating procedures.

3. Success Path Monitoring, Sections 7.7.1.10 and 18.7.1.8.2

The benefit of success path monitoring to operations is provision of a concise indication of a success path's availability to maintain, or performance in maintaining, a critical function. This benefit has been demonstrated through validations at the Halden Reactor Project, as described in the Human Factors Program Plan and Volume 10 of the Reference Design Documentation.

4 ESF Computer Aided Test (COMAT), Section 7.7.1.8.2

COMAT's major benefit to operations is the monitoring of pretest line-ups, recording test results and monitoring post test line-ups. This is particularly important in preventing components from remaining in test alignments which could prevent proper functioning of ESF systems.

(c) No artificial intelligence is used in the Nuplex 80+ advanced operator aids.

(d) Operators will receive training in all aspects of plant operation as part of the owner/operator training program, including the advanced operator aids. Experience with operating systems in existing plants (e.g., COLSS) and validation of prototype systems (e.g., SPM) provides assurance that operator's confidence in these systems will be high.

(e) The verification and validation of operator aids in Nuplex 80+ will be conducted as an integrated part of the verification and validation activities described in the Human Factors Program Plan. Note that the majority of the operator aids have previously been validated as independent systems.

Number: 620.12

Question: How will C-E demonstrate that the System 80+ design objectives of improving operator performance, reducing maintenance time, and improving reliability are met?

Response: The phraseology used in CESSAR-DC, such as "<u>improving</u> operator performance, <u>reducing</u> maintenance time and <u>improving</u> reliability," requires clarification. These are objectives for the Nuplex 80+ design; however, they are not pertinent to licensing of the design. These phrases will be deleted from CESSAR-DC. The basis for licensing is to demonstrate acceptable operator performance, acceptable maintenance considerations and acceptable reliability. Generally stated, it will be demonstrated that Nuplex 80+ acceptably meets the task needs of the end users (whether operators or maintainers).

There are key reasons discussed with the NRC staff for removing such subjective wording from CESSAR-DC. Attempting to demonstrate improvements, as referred to in the design goals, would be extremely difficult or impossible. First, there is no baseline data available from existing designs for such comparisons. Gathering the data would serve little use toward achieving certification. For example, it would be difficult to measure a dependent variable or conduct objective studies to determine if the goals were met. Second, these goals can be only assessed qualitatively; there are no testable criteria for measuring them quantitatively.

The acceptability of the Nuplex 80+ design will be demonstrated through the use of Design Acceptance Criteria related to the design itself and the verification and validation of the design.

Number: 620.14

Question: What is the projected reliability of the controls and displays in the control room?

Response: The reliability of all Nuplex 80+ control and display systems is documented based on representative hardware (final hardware selections are not made for certification). Typical of Nuplex 80+ system reliability is the availability of control room information from the DPS which has been calculated to be 99.98% with an MTTR of 4 hours. The DPS availability analysis report documenting this calculation has been made available to the NRC in the C-E Rockville, MD office. It is important to note that in the Nuplex 80+ design, information is presented through two separate system interfaces (DIAS and DPS) so the availability of information and reliability of the ensemble in providing it is higher than individual system availabilities.

Control systems (Process-CCS, ESF-CCS and PCS) have redundant controls available in the MCR via dedicated controls and system operators' modules, thus the availability of a given control function is significantly greater than in present control rooms

Additional availability analyses will be performed on other Nuplex 80+ systems in a similar manner to the DPS.

Number: 620.17

Question: How was the adequacy of the information supplied to the operator to perform the tasks determined for the following:

a. Type of data
b. Amount of data
c. Usability of data
d. Compatibility with other forms of information/data supplied in the plant at local control stations, on specific pieces of equipment, etc.

Response: a)b) The adequacy of information required was determined using the data generated in the task analysis. The characteristics of that data are identified in CESSAR-DC Section 18.5 and in more detail in CEN-307. Specific characteristics for the information and controls of the System 80+ design were identified in the System 80+ task analysis. The Nuplex 80+ design was developed using this data and the other sources of input identified in the response to Question 620.16. This included significant input on controls requirements and the functional decomposition from DCRDR task analysis efforts for existing C-E plants because of their plant's similarity to the System 80+ design. The design was independently verified to have sufficient data with proper characteristics in the Availability Verification. This analysis is described in the response to Question 620.30.

c) Determination of the useability of data provided on MMI devices was the key result of the suitability verification as described in the response to Question 620.30. One evaluation was performed in selecting flat panel display technology. This evaluation is described in the response to RAI 620.2 and in Section 3.6 of the Human Factors Program Plan for System 80+.

d) Compatibility of the various forms of information throughout the plant is assured by commitment to use the same Nuplex 80+ conventions plant-wide. This is possible since System 80+ is a complete plant design. Two Nuplex 80+ documents assure consistent and compatible MMI throughout the design; the Nuplex 80+ Information Systems Description and the HFE Standards and Guidelines. The C-E document review system assures that all disciplines including human factors are aware of potential interfaces. Therefore, the design of interfaces at local control stations or specific pieces of equipment will use Nuplex 80+ conventions and be reviewed and approved by Nuplex 80+ design team members.

Number: 620.18

Question: Who is on the initial design team and who is on the review team? Are they the same people or are the teams composed of different people?

Response: The initial design team was composed of human factors specialists, nuclear systems engineers, senior reactor operators, I&C engineers, computer specialists and project managers. Table 18.2-1 of CESSAR-DC indicates the number of full-time and part-time members of the design team that were in each discipline. It is noted that the team included members from Duke Power Company (now Duke Engineering Services, Inc.) who provided both a constructor's and plant operator's perspective on advanced control complex design.

The design review team was composed of representatives from reactor engineering, fluid systems and component engineering, startup services, nuclear licensing, instrumentation and control engineering, human factors services and plant operation and construction. This composition is provided in Table 18.2-3 of CESSAR-DC. The review team was composed of individuals independent from the design team, except for two individuals who were included to respond to questions on the design and design process. This overlap also provided communication between the teams and to facilitate resolution of comments. Not only were review team members independent of the design team, but they were also from different organizations within C-E other than the Instrumentation and Controls Engineering department where the design team was located.

The review team for Nuplex 80+ verification and validation activities consists of people that are independent of the design team, including administratively reporting to separate management. In addition to the formal design review team the design has been reviewed by many individuals and organizations during more than 100 mock-up demonstrations during the last two years. This has included utilities, regulatory agencies, national labs and many foreign organizations. Though their comments are not part of the formal review, comments are considered for changes to the design.

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Number: 620.[illegible]

Question: Human engineering is not included under Design Process Activities. Under Primary Responsibilities a human factors specialist is also not included. Please explain the scope, responsibility, and reporting structure of the human engineering function in the System 80+ program.

Response: The intent of this table was to show a high level list of activities performed during the design of the Nuplex 80+ advanced control complex and to indicate in which activities each discipline, including human factors, had a primary role. Thus, human factors is shown not as a design process activity itself but rather an integral part of many of the activities performed. The Human Factors Program Plan for System 80+ details the scope, responsibility and reporting structure of human engineering function in the System 80+ program.

The scope of the human engineering function includes all those activities listed in Table 18.2-2 with primary responsibility being with a human factors specialist. Human factors specialists also had lesser involvement in other areas such as development of the design bases. The human factors responsibilities included performing the task analysis, defining MMI conventions and methodologies and reviewing resulting interface designs, developing control room environmental criteria, assessing the MCR configuration and performing verification (availability and suitability) and validation activities.

Human factors members of the design team report technically to the supervisor of Advanced Instrument Design of the Instrumentation and Controls Department. Human Factors members of the review team reported to the supervisor of Human Factors and Cognitive Engineering in the Operational Services Department. This was discussed with illustrations in the response to Question 620.1.

Number: 620.20

Question: Identify the human engineering principles established for Nuplex 80. What analyses were used to identify the areas requiring improvement. What "specific improvements" were added?

Response: The human engineering principles that Nuplex 80 was based on are very similar to those of Nuplex 80+. The design was based on a functional task analysis. Human factors specialists and operators were heavily involved in all phases of the design, availability and suitability verification analyses were performed and a dynamic mock-up was used to evaluate and refine the design.

A significant source used to identify areas requiring improvement in Nuplex 80 was customer feedback. Nuplex 80 was sold to TVA and New York State Gas and Electric for System 80 plants. As is indicated in CESSAR-DC, a significant amount of design work was done for TVA. The design was also bid to Tai Power in the early 1980's. A number of the areas addressed in the Nuplex 80+ were identified by customers during the design and bid processes.

A description of the principles established for Nuplex 80+ may be found in the Design Bases Document in the Reference Design Documentation. A description of analyses and performance measures (past and future) can be found in the HF Program Plan.

During the Nuplex 80+ design process areas in the Nuplex 80 design requiring improvement were identified and considered through design review meetings. These meetings included operators, human factors specialists, instrumentation and controls engineers and project management. Each improvement area was considered for regulatory requirements, customer desires and technical considerations, such as advances in technology. Specific areas requiring improvement were identified and addressed as indicated in Section 18.6.1 of CESSAR-DC. These include removing hardwired backups for indications and alarms and integrating spatially dedicated indications and alarms into the primary interface with no backups. This allows the operator to use his normal interface during stressful situations such as losing CRT display capability. A dedicated console for a control room supervisor was added since utilities desired a supervisor to perform a monitoring and direction role and no workstation to support this role was available in Nuplex 80. To meet plant availability goals, Nuplex 80+ is designed for continued operation upon complete failure of the DPS instead of requiring shutdown as with Nuplex 80. Nuplex 80+ incorporates alarm handling improvements, such as mode dependency, to address industry concerns with alarm systems. Incorporation of the big board IPSO into the design provides a plant functional and system overview not available in Nuplex 80. Integration of the SPDS function into the normal man-machine interface through critical functions monitoring makes it part of the everyday interface and, thus, familiar during accident situations. Application of advanced control system improvements which were developed for conventional plants (e.g. automatic low power feedwater control) and were not available for Nuplex 80 also improve plant availability. Integration of divisional equipment into common panels rather than separation by panel sections as in Nuplex 80, allows multiple success path coordination by one operator and improved task performance.

Number: 620.21

Question: How was the potential for human error identified, reduced, and documented in "Reduce the potential for human error that could affect safety or availability?"

Response: The phraseology used in CESSAR-DC, "Reduce the potential for human error that could affect safety or availability," requires clarification. This is a design goal for Nuplex 80+ but, is not pertinent to the licensing of the design. This phrase will be deleted from CESSAR-DC in a future submittal. The basis for licensing will be to demonstrate acceptable operator performance. Inherent in that determination will be an acceptable potential for human error. Human error probability will not be analyzed as a unique dependent variable.

The following paragraphs identify the approach to addressing significant human error potential as a design goal, not a licensing requirement.

Specific problem areas where there was a relatively high potential for human error were identified during the early phases of the DOE Advanced I&C program. This was accomplished by reviewing LERs, Regulatory Guides, I&E bulletins, NUREGs, EPRI reports and other industry reports (e.g., Halden reports). For example, Regulatory Guide 1.97 recommends that the same instruments should be used for accident monitoring as are used for normal operations to enable operators to use familiar instruments during accidents. This led in part to the no backup approach of Nuplex 80+. Other specific areas for improvement were identified in Chapter 10 of the EPRI ALWR-URD. Documentation of the areas requiring improvement was provided through milestone reports in the Control System Performance and Reliability task and the Alarm and Display Methodology task of the Advanced I&C program.

Solutions were formed for the problems identified and incorporated into the design. For example, one area identified as resulting in a high potential for operator error at conventional plants was low power feedwater control. Numerous reactor trips have resulted from manual control during this condition. Digital feedwater systems providing automatic control at low power have been installed at existing plants and have reduced the potential for error in this condition significantly. The same digital control system design is incorporated into the Nuplex 80+ ACC.

C-E has no plans to attempt to quantify the reduction in human error potential. C-E will only verify that new problems have not been introduced by the solutions to existing problems. The Nuplex 80+ verification and validation analyses are the final tests that those features incorporated to solve problem areas do perform without introduction of new errors. The suitability of the interface was evaluated in the verification analysis. Validation of the features in relation to plant operation using the complete control room design will occur later in the design process using the dynamic mock-up. The software based designs used in Nuplex 80+ are more suited to incorporating changes identified during V&V because of the relative ease in making changes in software rather than hardware.

Number: 620.22

Question: How was the reduction of operator information processing identified, reduced, and documented in "Reduce the operator's information processing while meeting all of his information needs."

Response: The phraseology used in CESSAR-DC, "Reduce the operator's information processing while meeting all of his information needs," requires clarification. This is a high level design goal for Nuplex 80+. It is not quantifiable and no baseline data exists for comparison. Thus, it should not be part of licensing the design and will be deleted from CESSAR-DC. The basis for licensing will be acceptable operator performance, as demonstrated through verification and validation using Design Acceptance criteria. Integral in that evaluation will be the operator's ability to get required information from the plant data available.

The approach to addressing stimulus overload is addressed qualitatively in the remainder of this response.

Stimulus overload has been identified as a concern with conventional nuclear plant control rooms. The quantity of data generated from the plant is enormous and little data processing is performed in conventional plants before presenting it to the operator. This led to presentation of more information than a person can reasonably comprehend, particularly during plant upset conditions when many parameters may be changing. The 1979 TMI-2 accident provides a good example of key information being lost in the sea of data provided. This fact has been documented in numerous industry reports (e.g., EPRI NP-3448 for alarm overload). The reality of information overload was confirmed by operators on the Nuplex 80+ design team.

Based on the stimulus overload problem identified above, the Nuplex 80+ goal to reduce the amount of data operators must process, while still meeting their information needs, was formulated through design review meetings and discussions with operators. It was identified that additional information resulting from I&C design and licensing requirements (e.g., 16 instrument channels of the same parameter) was partly responsible for data that added to the operators task loading. Alarm systems presenting more alarms than can be comprehended during upsets, including non-applicable alarms, were also a contributor. The Nuplex 80+ approach is to integrate information to meet the operators needs (as identified in the functional task analyses) while reducing the amount of data to be sifted through to obtain that information.

The amount of processing required of the operator was reduced by validating process signals to provide one correct "process representation value," instead of indicating all parameter channels. That value is used on all spatially dedicated displays and all video displays, including IPSO. Individual sensor values are available on specific Level 3 diagnostic CRT displays. The "process representation value" is also used in all application programs, including control system algorithms and alarm algorithms. The result is that all systems, and the operator, make their decisions based on the most accurate information available. Other processing which was provided to reduce that required by operators includes alarm grouping and mode dependency, critical function and success path monitoring, and the IPSO display which provides a continuous plant overview.

Number: 620.23

Question: How will C-E demonstrate that improvements in the reliability of the man-machine interface have been achieved, as noted in the statement, "Improve the reliability of the man-machine interface through redundancy, segmentation, and diversity"? Does the term man-machine interface refer to the reliability of the hardware or a reduction in human error?

Response: The statement in CESSAR-DC does not refer to human error. The reliability referred to in this statement is the functional reliability of the entire man-machine interface as a whole; i.e., the probability that a given piece of information or a control is available if needed. A goal of the Nuplex 80+ design is to provide a high functional reliability through redundancy and segmentation <u>within</u> systems and diversity <u>between</u> systems. This approach provides highly reliable hardware systems (redundancy), limits the effect of failures in a system (segmentation) and protects against common mode hardware or software failures. For example, redundant processors and data communication exist within DIAS and CCS segments and redundant computers are used for the DPS design. This results in single failures having no effect on the performance of the system related to the availability of information or a control. In addition, both the DIAS and DPS present high priority alarms and indications to assure information access even with multiple failures.

The DIAS and CCS are based on segments related to panel sections and plant functions, respectively. Segmentation limits the impact of multiple failures (e.g., failure of both segment processors)to relatively small, manageable areas. Nuplex 80+ uses diversity to improve reliability by protecting against common mode failures. For example, the DIAS and DPS monitoring systems employ diverse types of processors (super mini-computers vs. micro-computers) and different interface devices (CRTs vs. electroluminscent displays). The result is a reliable system that can continue to operate with failures.

The hardware reliability of individual systems has been or is being calculated, but no quantitative evaluation of the functional reliability is planned. It is not intended to demonstrate that a reduction in human error can or will be measured.

Number: 620.26

Question: How does the Nuplex 80+ configuration minimize required access to the controlling workspace? A desk/barrier does not appear to reduce the requirement for maintenance personnel access to control room equipment and face-to-face communications with the operating staff.

Response: The reduction of personnel access requirements to the controlling workspace is a design goal of Nuplex 80+. It is not a demonstrable improvement, since no baseline data exists for comparison and no objective, quantification of a reduction can be measured. In addition, optimization (i.e., minimize) of this aspect of the design is highly subjective and not suitable for use as a licensing basis. It is more appropriate to state that the Nuplex 80+ Advanced Control Complex includes a number of features designed to address the concern of required access to and traffic in the controlling workspace during both normal and emergency operations. These features are discussed below.

To access information Nuclear Equipment Operators (NEOs) can use CRTs in the Auxiliary Reactor Operator (ARO)/NEO support office or the TSC without entering the controlling workspace. For maintenance, testing and other routine interfaces between operators and NEOs (or other plant staff) the design allows the interface to occur at the CRS desk, outside the controlling workspace or in control room offices. By having interactions with plant staff occur in these locations, no disruption of normal operations activities in the control workspace is caused. Having local maintenance and test panels on the Component Control System (CCS) and the fact that all tests and calibration not requiring licensed operators are performed outside the main control room, further reduces traffic. No cumbersome testing equipment is required to be brought into the MCR. NEOs primarily need to enter the main control room for discussion. Organizational controls which limit the access to the MCR or controlling workspace are the responsibility of the owner/operator.

Nuplex 80+ panel design features further reduce interference which could be caused by maintenance activities. Panels are designed for quick equipment removal. Typically, removal of four screws and detachment of quick disconnect connectors will allow removal of I.D devices. Thus, all discrete indicators, alarm tiles and controllers are easily and quickly removable. Switches are modular and easily replaced. Items whose maintenance would not interfere with operators (e.g., power supplies) are in the less accessible, rear portions of the panel.

Data Processing System CRT interfaces are provided in all three MCR offices as well as in the TSC. For both normal and emergency operations the availability of all CRT monitoring displays in the SS and CRS offices will reduce control room access requirements. Access to plant status information to support management and operations discussions is available without entry into the controlling workspace. The direct viewing window from the TSC will minimize control room access needs of emergency response personnel during emergencies by enhancing communication between TSC personnel and the operating staff. It also allows visitors or plant staff to view the main control room without entry during normal conditions. DPS CRTs, with all the same displays as in the control room, are located in the TSC to meet the information needs of emergency response personnel.

Number: 620.27

Question: Describe the duties and responsibilities of the control room supervisor and describe the tasks expected to be performed at the CRS console in the control room. Which tasks will be performed in the supervisor's office? Who will be the primary operators of the CRTs on the control room supervisor's console and what displays are they expected to use or access?

Response. The control room supervisor (CRS) may perform a wide range of duties related to administration of the operations crew and plant evolutions, monitoring of plant status, and interfacing with maintenance and technical personnel. The basic responsibility of the CRS in the Nuplex 80+ ACC is to oversee and direct, and does not differ notably from his duties at current LWRs. The exact nature of his duties and responsibilities will be determined by the individual owner/operator and its operating philosophy. The CRS may be in his office having meetings, conducting administrative tasks, or communicating with other groups when his presence is not required in the controlling workspace. All of the CRS's activities can be performed in his offices, except where face-to-face communication with operators at the panel is required. Further details on the CRS console and control room offices are provided in CESSAR-DC Sections 18.6.5.3 and 18.6.5.4, respectively.

The CRS, shift supervisor and shift technical advisor will all use the CRS console in the control room. All DPS CRT display page selections are available to these individuals on two CRTs at the CRS console. Their use of them depends greatly on plant condition and the operations in progress. Control room operators will not use this console, as it is primarily a monitoring station with no controls. However, any and all Nuplex 80+ CRT displays can be accessed from the CRS console. If it is determined during the design process that additional CRT displays are required specifically for a CRS's use, they will be added to the display hierarchy.

Number: 620.28

Question: Explain how the control room design addresses the issues of habitability and the storage requirements for working documentation, procedures, supplies and personal effects. Describe the process used to establish the requirements for areas that support the control room such as the Technical Support Center, shift supervisor's office, etc.

Response: The Nuplex 80+ control room is designed to meet the habitability guidance in Appendix A of 10CFR50, Supplement 1 of NUREG-0737, and other pertinent regulatory documents applicable to fire, smoke and airborne radiation conditions. The Control Room Emergency Zone shall be maintained at a positive pressure, in comparison with surrounding rooms, to minimize the possibility of leakage of airborne radioactivity, smoke, or chlorine gas into the control room. The Control Room Area Ventilation System (CRAVS) is designed to maintain the positive pressure in the control room area as well as detect and provide isolation from airborne radiation, smoke and chlorine gas. The Emergency Supplies Room, consisting of at least 200 square feet of floor space, will provide ample storage locations for self-contained breathing apparatus or bottled air, depending on owner/operator preference. Shielding of the control room assures that radiation levels in the control room are well below the limits specified in Standard Review Plan (SRP) 6.4.

The process used to establish the habitability requirements for areas that support the control room was to balance the requirements of SRP 6.4 with SRP 9.4.1. SRP 6.4 requires that the Control Room Emergency Zone include the control and document storage area, computer room, shift supervisor's office, washroom and kitchen area. SRP 9.4.1 requires that the CRAVS provide a controlled environment for the comfort and safety of control room personnel and to assure the operability of control room components during normal operation, anticipated operational transients, and design basis accident conditions. Acquiring filtration units that satisfy filter requirements and allow for the pressurization required in the SRP has been very difficult. Therefore, the Control Room Emergency Zone has been reduced to include only those spaces that are absolutely necessary to perform the minimum for accident mitigation situations. The areas included in the Control Room Emergency zone include only the control room, Reactor Operator's Office, Control Room Supervisor's Office, Emergency Supplies Room, Integration Process Status Overview Room and the Document Room. The areas that remain part of the Control Room Emergency Zone still fall under the guidance provided in SRP 6.4. The areas that are not longer part of the Control Room Emergency Zone are now subject to the same habitability requirements as the remainder workspaces in the plant.

Storage areas in the control room are in line with previous plant designs. An evaluation of currently operating plants indicates that control room information (procedure/drawings/books) are normally stored in cabinets, bookshelves and hanging files. The evaluation indicated that procedures require approximately 175 linear feet of shelf space, books require an additional 40 linear feet, and drawings require 16 linear feet. The Nuplex 80+ control room shall provide this much space, at a minimum, for documents, drawings and books needed in the control room. The document room in the control room contains over 200 square feet of floor space. Additional document storage is located in the control room offices. Storage inside the controlling workspace is provided on the back side of the Control Room Supervisor's desk and on the two Reactor Operators desks. Personal effects for the Shift and Control Room Supervisors will be stored inside their control room offices. Reactor Operators will have ample space for personal effects in the Reactor Operators' offices.

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Number: 620.29

Question: How was "sufficient instrumentation" identified for the Remote Shutdown Panel? Describe the human engineering efforts or studies which contributed to the design of the Remote Shutdown Panel and the "convenience controls" distributed at equipment locations.

Response: The RSP receives the same design process as the MCR panels. Sufficient instrumentation for the RSP was identified based on a function task analysis, as with the main control panels. The description of the human factors engineering task analysis for safe shutdown is described in Section 18.8.1 of CESSAR-DC. In addition, C-E's extensive experience in designing remote shutdown panels for Palo Verde 1, 2 an 3 and other plants was considered. Sections 7.4 and 7.5 of CESSAR-DC give full listings of what was determined to be sufficient instrumentation for the RSP using existing System 80 plants as a baseline. This list was reviewed by all engineering disciplines within C-E to assure all system designer requirements, as well as operational requirements, were met.

Essentially the same design process was followed for the RSP as for the main control room panel designs. The RSP design is based on the standard Nuplex 80+ indication and control methodologies (CESSAR-DC, Section 18.7.1) and HF design criteria (Section 18.7.2). Special needs which differentiate the RSP from MCR panels are described in Section 18.8.1.2-4. The RSP design features similar diversity as the MCR in terms of having diverse means of obtaining information as well as diverse methods for control. This diversity precludes a common mode failure from resulting in loss of either sufficient information availability or control capability at the RSP. Nuplex 80+ diversity is discussed in the response to Question 420.23.

As indicated in Section 18.8 of CESSAR-DC, cold shutdown is achievable from the RSP without the need for local equipment controls. However, local convenience controls are maintained to the same degree as in existing plants. Appropriate human factors criteria are applied to the design of local controls.

Number: 620.30

Question: Describe the human engineering test and evaluation methodologies that have been, or will be, used. How does the human engineering test and evaluation program fold into the System 80+ verification and validation program?

Response: The human factors test and evaluation methodologies can be divided into three phases: those occurring before the start of the Nuplex 80+ design, those occurring during the design certification process and those that will occur after certification. All of these test and evaluation methodologies are described in the Human Factors Program Plan for System 80+. A brief synopsis of the human factors tests and evaluations is provided in the remainder of this RAI response.

Prior to the initiation of the Nuplex 80+ design effort much of the advanced technology used in the Nuplex 80+ man-machine interface had been tested. Critical Function Monitoring System (CFMS) designs are operating in numerous plants as an SPDS and have been evaluated as part of the DCRDR process. In addition to CFMS plant operating experience, a human factors validation program was performed by the OECD Halden Reactor Project on the CFMS design. The extension of the critical function approach to success path monitoring (SPM) was also validated at Halden. This validation demonstrated improved performance for operators using SPM compared to control operators without it. Similarly, after development of IPSO, but before installation at the Borselle plant, the design was evaluated by Halden with favorable results. Halden reports exist for all of these evaluations and the most significant ones are included as part of the Nuplex 80+ reference design documents located at the C-E Rockville, MD office.

Another significant group of evaluations conducted prior to the Nuplex 80+ program occurred as part of the Nuplex 80 ACC development program. This included configuration studies for which the Nuplex 80+ master control console is based and many studies related to CRT display of information and the benefits of hardwired annunciators. The Nuplex 80 studies included a significant amount of interaction with plant operators and use of a complete control room dynamic mock-up. The pre-Nuplex 80+ evaluations, tests and experience are shown on Figure 18.4-5 of CESSAR-DC.

During the Nuplex 80+ design process for certification, test and evaluations have included the functional task analysis and corresponding workload analysis, and the verification analysis. The functional task analysis and workload analysis are documented fully in the Functional Task Analysis Report, NPX80-IC-DP-790-02, of the Nuplex 80+ reference design documents (also see Question 620.24). The availability analysis of the verification process assured availability of required instrumentation and controls with appropriate characteristics. The methodology and results of the analysis are described in the verification analysis report NPX80-IC-TE-790-01 in the reference design documentation. The suitability analysis evaluated the usability of each of the MMI devices and, on a panel basis, the ensemble as a whole using the RCS panel and IPSO prototypes. This is also documented in the verification analysis report. Other tests and evaluations were related to product evaluations (e.g., flat panel displays) and specific man-machine interface conventions. The analyses and evaluations performed during certification are shown in Figure 18.4.1 of CESSAR-DC.

As part of first-of-a-kind engineering a full main control room mock-up will be completed with dynamic MMI components at selected panel sections. This complete, partially dynamic mock-up facility will be used to conduct a HFE validation program using operators and representative operating procedures. This is described in Section 18.9 of CESSAR-DC. Before Nuplex 80+ is delivered to a plant, a factory integration test of all systems, including a complete set of hardware, will be performed. This will include additional human factors validation activities. The Nuplex 80+ design process, including evaluations and tests, is shown in Figure 620.30-1.

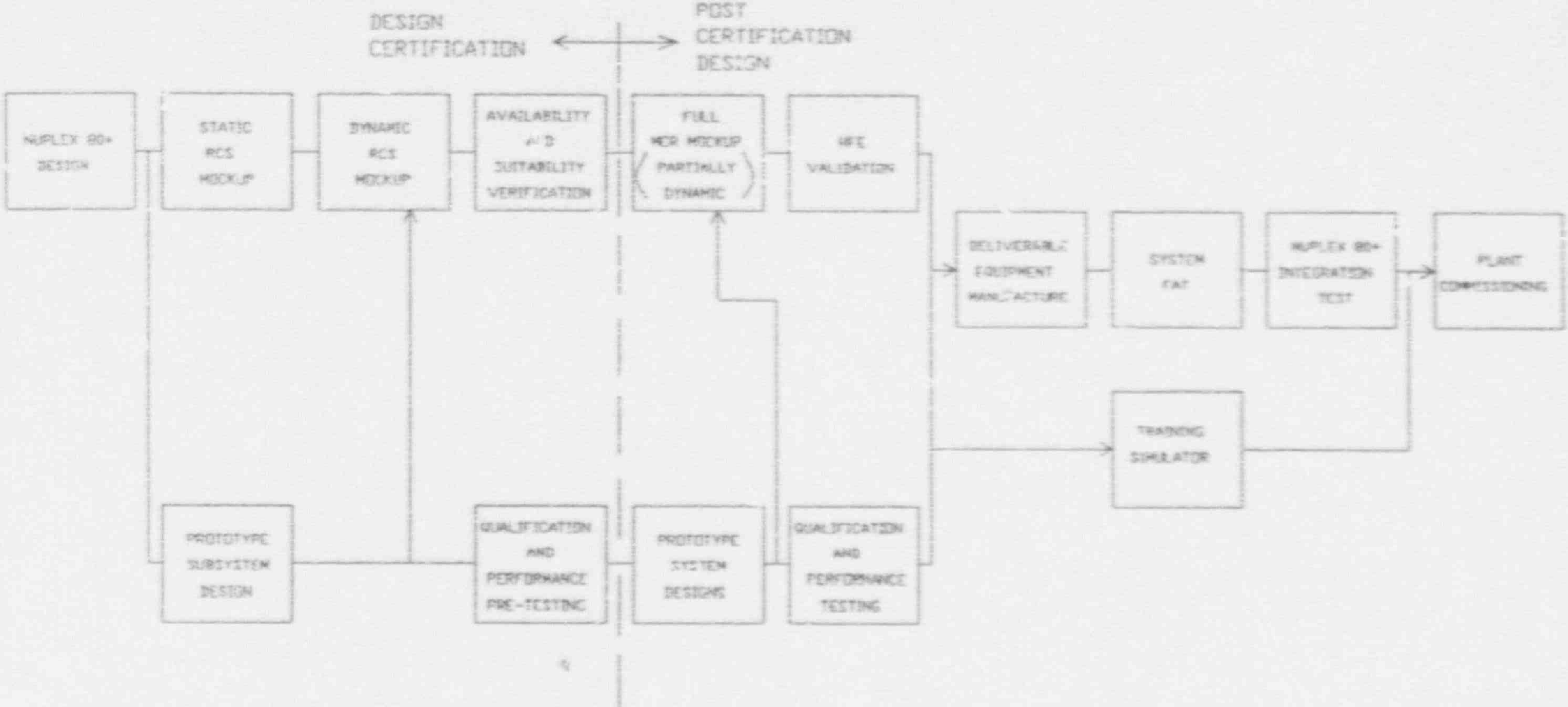
This approach to Nuplex 80+ verification and validation activities was selected because of the evolutionary nature of the Nuplex 80+ design. For conventional power plants, a static mock-up of the main control panels, combined with detailed factory testing of equipment has been used for validation of nuclear plant instrumentation and controls.

For an advanced control complex design, more detailed integration of the static mock-up and dynamic factory acceptance testing is desired. The dynamic mock-up approach is acceptable for the support of Nuplex 80+ verification and validation activities because the design of key man-machine interfaces have not changed radically from conventional designs. All time critical parameters and alarms are provided on discrete indicators and alarm tiles which closely resemble conventional meters and alarms. Primarily a different computer-based hardware implementation is used. Important component controls are essentially identical to those used on System 80 designs. Based on C-E evaluations and review by many independent engineers and operators, these small changes to indications and controls are not expected to induce any new potential for operator error.

The integration of CRTs and soft controllers into the interface can effectively be evaluated on selected dynamic panel sections with little benefit obtained by implementing them dynamically in the entire control room. All Nuplex 80+ MMI devices, including touch screens, are used in existing nuclear power plants. Nuplex 80+ panel layouts follow conventional designs (i.e., by system from heat source to heat sink, with auxiliary panels also arranged by system). The design is based on existing procedures and crew operating methods with no intent to change. Thus, a full scope simulator is not used for verification and validation of the Nuplex 80+ main control room, as it might be if the design was radically different from conventional designs.

The human factors verification and validation activities are part of the overall Nuplex 80+ verification and validation program plan. The remainder of the test and evaluation program as described above is not part of the Nuplex 80+ V&V program.

FIGURE 620.30-1
NUPLEX 80+ DESIGN PROCESS



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Number: 620.31

Question: The System 80+ control room design currently includes several types of control and display instrumentation. Some of it is new to control room applications, some is not. This paragraph states, "The man-machine interface is based on accepted human engineering methods, principles and criteria such as those presented in NUREG-0700." Identify the principal human engineering source documents used in the development of the man-machine interfaces, such as:

a. Identify which elements of the man chine interface were developed based on existing human engineering documentation. Identify the documentation.

b. Identify which elements of the man-machine interface required the development of additional human engineering guidance. Identify the guidance.

c. Describe the means C-E will use to ensure (1) that the man-machine interface aspects of the new technology will be compatible with that of the established technologies, (2) that the new man-machine interfaces will meet the requirements of the tasks, as defined by the human engineering studies, and (3) that the differences as well as the similarities among the man-machine interface devices enhance operator and maintainer performance.

Response: The Nuplex 80+ Human Factors Standards and Guidelines is the principal document which assures that the MMI is based on accepted human engineering principles and criteria. This document provides the design choices for Nuplex 80+ (i.e., standards) and not just guidance (i.e., available selections) A HF Standards and Guidelines Basis document defines the source (document or rationale) for each standard or guideline. Table 620.31-1 lists the source documents used to assemble the HF Standards and Guidelines.

a. Most of the Nuplex 80+ man-machine interface elements were developed based on existing principles and criteria. This was possible because elements were either similar to conventional control room technology or an evolution from conventional technology. Man-machine elements for which criteria exist include IPSO, flat panel displays used for alarm tiles, discrete indicators and controls, CRTs and switches. The source documents used for criteria for these interfaces are provided in Table 620.31-1.

b. The only element of the man-machine interface which required additional human engineering guidance was the use of touch screen interfaces for the CRTs, flat panel displays and controls. The existing guidance used to design touch access were for target size, target separation, response time, input duration, input sequence, and feedback. Two other criteria were developed for implementation of Nuplex 80+ touch screen interfaces:

   1. Actuation occurs upon removal of touch from the screen not engagement. This allows the operator the ability to correct any incorrect selections that may have occurred before actuation.

   2. Touch targets are identifiable from other display elements. Systematic target conventions and spatial dedication of the targets allow the operator to clearly identify which targets are selectable and which are not.

c. 1. The Nuplex 80+ design uses consistent and compatible interfaces and conventions throughout the interface. Technologies for implementing the interface were selected to support compatibility. A good example of Nuplex 80+ interface compatibility is provided by CRT displays and other MMI devices in the MCR. Red and green color conventions are used identically on conventional switches and dynamic CRT displays. Similarly, a standard set of graphic symbology is used between CRTs, switches and controller displays. The yellow alarm color is used on CRTs to ensure compatible with the monochromatic ELDs used for spatially dedicated alarms.

The suitability analysis of the Nuplex 80+ verification process evaluated the compatibility of the different technologies used in the man-machine interface. As identified in Part b, there was only one application of new technology in the Nuplex 80+ MMI with the other devices being used previously in control room applications. Compatibility will be validated during the Nuplex 80+ validation activities, as described in the response to Question 620.30.

2. The availability analysis of the Nuplex 80+ verification analysis specifically evaluated whether task performance requirements were met by the interface devices. Documentation is provided in the reference design documentation in NPX80-IC-TE790-01.

3. Nuplex 80+ is designed to provide an acceptable interface for operators and maintainers. To facilitate this the design uses to its advantage the similarities and differences in the MMI technologies employed. For example, similarities in technologies allow consistent coding conventions to be employed across all interface devices. Specifically, alarms presented on DIAS alarm tiles and through the CRTs use the same flash rates and shape codes for priority. However, the differences in these technologies is also used. For example, spatially dedicated displays use the monochromatic ELDs to present key information simply without color codes. Color graphics CRTs are used to present very detailed information with more extensive coding allowed by color. The technologies used

in the interface are all employed in existing nuclear plant control rooms, though Nuplex 80+ extends the use of these technologies. Similar combinations of different technologies have been made in other industries, including fossil power plants.

The suitability analysis has evaluated the acceptability of the interface, including the similarities and differences between technologies. Because of the standardized interface approach across panels and the use of only two display technologies (CRTs and ELDs), in place of many display technologies in conventional control rooms, maintainer and operator performance will be significantly improved. In order to minimize the detrimental effects of standardized designs such as making interpretation of control and display relationships difficult, Nuplex 80+ uses a hierarchical labeling scheme, lines of demarcation, functional or system mimic groupings and system-related panel orientation. This supports familiarly with a component's operation (e.g., a switch or ELD device) while putting it on the context of system operation.

Table 620.31-1

Sources of Human Factors Criteria Used for Nuplex 80+

1. MIL-STD-1472D, "Department of Defense Human Engineering Design Criteria," 1989

2. DOD-HDBK-761A, "DOD Management Information Systems Guidelines," 1987

3. ESD-TR86-278, "User-System Interface Software Guidelines," Smith and Mosier, 1986

4. ANSI/HFS-100, "ANSI VDT Workstation Standard," 1988

5. "User-Computer Interface in Process Control: A Human Factors Engineering Handbook," Gilmore, et al, 1989

6. NASA-STD-3000, "NASA Man-Systems Integration Standards," 1989

7. NASA-USE-100, Ver. 2.1, "NASA Space Station Freedom Program Human Computer Interface," 1989

8. EPRI NP-3659, "Human Factors Guide for Nuclear Power Plant Control Room Development, 1984

9. EPRI NP-4350, "Human Factors Engineering Design Guidelines for Maintainability," 1985

10. NUREG/CR-3517, "Recommendations to NRC on Human Engineering Guidelines for Nuclear Power Plant Maintainability," 1986

11. NUREG-0700, "Guidelines for Control Room Design Reviews," 1981

Number: 620.32

Question: In the context of being presented as a design basis for Nuplex 80+ this paragraph states, "The number of physical display devices and the quantity of data presented to the operator is reduced compared to control rooms for existing plants."

Provide the human engineering studies C-E has done to determine the benefits and drawbacks of reducing the number of display devices and quantity of data presented to the operator. Include specifically the studies which determined the optimal levels of reduction of display devices and data. Include the results of human engineering studies which were used to support the quantity of data presented to the operator, any consolidation of instrumentation, and any changes in the modes of displaying data to the operator in the Nuplex 80+ control room.

Response: The statement made in CESSAR-DC regarding reducing the number of physical displays requires clarification. This statement was a design goal for Nuplex 80+ and was not intended to be a licensing basis for the design. The basis for licensing Nuplex 80+) is to provide adequate information such that acceptable operator performance is achieved. Acceptable operator performance will be demonstrated through verification and validation activities (as discussed in the Human Factors Program Plan for System 80+) using Design Acceptance Criteria. The approach to information reduction as a design goal was qualitative in nature, and is discussed qualitatively in the following paragraphs.

The intent of this design basis statement was to partially address the stimulus overload concern. This issue was discussed in the response to Question 620.22 as it relates to increasing the operator's information processing burden. By reducing the number of physical displays in an appropriate manner, the information required for task performance is presented to the operator without all the clutter added by presenting all available data. The need to reduce stimulus overload and, hence, the number physical devices and amount of data provided to operators, has been documented in various industry sources. This includes the EPRI ALWR-URD, industry reports (e.g., NUREG-3448 for alarms), and papers (many identifying this concern as a result of TMI).

Qualitative analyses were performed to evaluate the benefits and drawbacks of reducing the number of physical display devices. An assessment was made based on using the combination of serially presented information (via CRTs) and spatially dedicated information (on flat panel discrete indicators and alarm tiles) to determine an acceptable combination. All data is accessible at any panel through the CRT's serial presentation of information. Thus, the focus of the assessment was on how much spatially dedicated data should be presented in a parallel manner. The result of the assessment led to spatial dedication of Priority 1 and 2 alarms and key parameters on discrete indicators and IPSO. Key parameters for discrete indicators were defined as frequently monitored parameters, parameters most indicative of critical safety function and success path status, Regulatory Guide 1.97 Category 1 parameters and parameters required for investment protection or continued operation without the DPS. The design was then evaluated through the availability and suitability analyses of the verification to assure that an acceptable amount of spatially dedicated data was presented. No quantitative studies were performed to determine optimal levels of reduction, since optimal can only be determined if all possible transients and events are known.

The modes of displaying data in the Nuplex 80+ control room do not change. The interface has been designed to function the same for normal power operations, startup/shutdown or emergencies. This approach specifically includes the use of critical functions for both power and safety and the integration of PAMI displays into a functional panel location via the qualified discrete indicators and CRTs.

Number: 620.34

Question: What studies did C-E perform to determine the amount and type of "operator information overload?" Provide the quantitative and qualitative results of the investigations.

Describe the baseline control room in which the studies were performed and the parameters that were measured or assessed. Were the studies replicated on the C-E System 80+ control room design? What thresholds were established for acceptable and unacceptable levels of operator cognitive loading? How does the System 80+ control room design specifically address each of the parameters assessed by the studies?

Response: The phraseology "operator information overload" was not intended as a measurable criteria for demonstration as part of the licensing basis, but only as a Nuplex 80+ design goal. As discussed in the response to RAI 620.32, the basis for licensing is to provide adequate information such that acceptable operator performance is achieved. This is demonstrated through verification and validation. Providing the operator with the required information in the form needed for task performance, instead of all available plant data, will help facilitate the operator performance demonstration. "Operator information overload" will not be looked at as a separate, measurable criteria. Other RAI responses dealing with this issue include 620.13, 620.22 and 620.32.

Qualitative analyses identified the amounts and types of information overload in conventional nuclear plant control rooms. Primary areas identified were information overload from the alarm system after a reactor trip and overload of information from multi-channel indicators of the same process parameter.

The System 80+ control room addresses operator cognitive overload by validating process signals prior to display or alarm, grouping alarms into a relatively small number of alarm tiles, and eliminating Priority 3 alarms and operator aids (e g., permissives which were previously alarms in many existing control rooms) from spatially dedicated displays. Additional reduction in information overload is provided by reducing the number of alarm actuations during transient events. This is provided in Nuplex 80+ by validating signals before generating alarms and mode and equipment status dependent logic. The design also provides operator aids such as critical function monitoring (to support normal operation and emergency procedure response), success path monitoring (to aid in identifying and restoring success path problems) and IPSO (which provides a plant overview for operators). Each of these advanced features performs a function automatically and continuously that otherwise would have to be performed by operators. For example, IPSO takes several thousand plant parameters and reduces them to a few easily understood process representation symbols.

Quantitative studies were performed comparing the numbers of alarm tiles and indicators for conventional control rooms and Nuplex 80+ Results from the studies have shown a 60% reduction in alarm tiles and an 80% reduction in the number of spatially dedicated displays for Nuplex 80+ compared to conventional units. Cognitive loading levels were analyzed as part of the task analysis for specific events, as discussed in the response to Question 620.24. This analysis is documented in Section 18.5 and the task analysis report in the reference design documents. Acceptable levels of loading were based on determining cumulative processing times for tasks performed during an event and identifying situations of operator overload based on cognitive loading.

Number: 620.35A

Question: This paragraph states, "The effectiveness of modern man-machine interface devices will be demonstrated through the use of prototypes and HFE evaluations." Does this refer to demonstrating the software and hardware attributes of the instrumentation? Or does it refer to human factors and human performance evaluations of (1) the device (as a stand-alone instrument) and (2) in the context of the System 80+ control room environment. When in the design process are the HFE evaluations scheduled to occur? Describe in detail the HFE evaluations that will be performed. Provide a basis for the criteria that will be used to determine a device's effectiveness (as a stand-alone instrument) from the human performance perspective. Also provide the assessment methodology that will be used to determine the suitability of a device for incorporation into the System 80+ control room design.

Response: This statement refers to both demonstrating hardware and software attributes and the suitability of the interface from a human factors perspective. The Nuplex 80+ design process has already and will continue to do hardware attribute evaluations using prototypes. This has included seismic evaluations of equipment to demonstrate the ability to qualify equipment for safety-related applications (see RAI 620.2) and hardware configuration studies on prototypes to assure adequate throughput. Software studies have prototyped software implementations using ladder logic programming in programmable logic controllers and software required for data processing features such as success path monitoring, alarm processing and signal validation.

The man-machine interface devices have also been evaluated from a human performance perspective as part of the verification analysis documented in the reference design documentation and discussed in the response to Question 620.30. The suitability analysis evaluated both the man-machine interface devices as stand-alone devices and in the context of the ensemble of Nuplex 80+ interface devices.

HFE evaluations are scheduled throughout the Nuplex 80+ design process. The design process and scheduling of HFE evaluations are discussed in the Human Factors Program Plan for System 80+, as is the type of HFE evaluations performed. The criteria used to evaluate the man-machine interfaces were developed from the list of references provided in the Human Factors Standards and Guidelines document and in the response to Question 620.31. Individual bases for specific criteria can be found in these references and are documented in the HF Standards and Guidelines Basis document. Similarly, the assessment methodology for the suitability analysis is provided in the verification analysis report in the reference design documents (NPX80-IC-TE-790-01). The eventual determination of a device's suitability was determined not only from the human factors acceptability, determined in the suitability analysis, but also by other tests and prototype evaluations such as the seismic analysis. A good example of this process is provided in the response to Question 620.2 for determining the acceptability of flat panel displays. The response to RAI 620.13 provides like information related to the alarm system.

Further verification and validation activities will continue to demonstrate that additional detailed designs conform to the certified design.

Number: 620.35B

Question: This paragraph states, "Under degraded conditions, operators will continue to have access to all required information. Equipment failures impacting automated data process and presentation features are accommodated by increased operator surveillance."

What constitutes a degraded condition? Is it the loss of one computer driven display, one electrical bus (potentially affecting many instruments) or all digitally driven equipment?

How does increased surveillance on the part of the operator compensate for the loss of technical data? Are the data and the synthesized information normally available through the computer database available from other sources? Where will the alternate sources of information be located?

From the human performance perspective, how will "increased surveillance" compensate for loss of the computer? Will operators be required to perform calculations, adjustments, or operations (manual, cognitive, decision-making, etc.) that would normally be done by the computer? Describe the impact on operator and crew performance in the control room, at the Technical Support Center and at the Emergency Operations Facility.

Response: A degraded condition referred to in this paragraph is constituted by credible equipment failures, including failure of processors, data communications or a display device itself. The worst case degradations assumed are total loss of DIAS-N or DIAS-P or DPS failure. These worst case conditions encompass loss of an electrical bus. Loss of all digitally driven equipment is not a credible failure and is therefore not considered in the design. This position is acceptable because digital electrical equipment is protected against EMI and the diverse designs used in man-machine interface systems preclude other undefined common mode failures, including software failures, from rendering both diverse designs simultaneously inoperable.

Figure 7.5-1 of CESSAR-DC illustrates the architecture of the Nuplex 80+ monitoring systems. The following credible failures were considered as degraded conditions: failure of the entire DPS system and, thus, all CRT displays, failure of DIAS-P channel or failure of DIAS-N. Each of these cases will be discussed individually.

The worst case degraded condition from an information access perspective is complete failure of the DPS. This is a highly unlikely event, since the DPS is a redundant system with a calculated and demonstrated availability of greater than 99.98% with an MTTR of less than 4 hours. To address this failure, the DIAS has been designed to provide operators with all information required to continue operation for 24 hours. Increased surveillance is not required to compensate for loss of technical data but rather to accomplish technical specification monitoring and to support information access that is normally enhanced by the DPS and panel CRTs. All functions of the DPS can be performed manually, with additional staff, without the DPS. For example, the Core Operating Limit Supervisory System (COLSS) DPS function which provides core surveillance will have to be performed by an operator. This increased operator surveillance will compensate for not having computer processing to accomplish the function. All required data for this function is available to the operator on DIAS or other displays from the control and protection systems.

Synthesized information from critical function monitoring (CFM) and success path monitoring will also not be available upon complete DPS failure. Since these functions have been designed to support procedures, not replace them in Nuplex 80+, these functions can be performed manually by additional operating staff. For example, the CFM function of performing safety function status checks, normally done by the DPS automatically, can be performed by an STA. This is currently the practice at conventional plants. The alternate source of data will be the DIAS displays, which are located on each panel as part of the primary man-machine interface. Additional information will be provided by operator's modules (CCS and PPS) and switch indicators for component status which are also part of the primary integrated interface.

The impact of DPS failure on the TSC and EOF will be the same as for existing plants. No CRT data would be available in either location and, hence, plant status would not be available via CRT. This situation would be partially compensated for in the Nuplex 80+ TSC design by visibility into the MCR. The viewing window includes a view of IPSO which will continue to be driven by DIAS to provide an overview of plant status. The viewing window also enhances communication with control room operators.

The other credible failures relate to loss of DIAS Channels P or N (see Figure 7.5-1). DIAS P is an independent channel segment of the system which provides one redundant method of monitoring all Regulatory Guide 1.97 Category 1 parameters, including ICCM parameters. Its primary MMI is two flat panel displays of these parameters on the safety monitoring panel. If this channel is lost (though it too has redundant communication and processing), Regulatory Guide 1.97 parameters are still available to operators. Parameter indications are on DIAS N displays dispersed at appropriate functional panel locations throughout the MCR and through any CRT at any panel. This degraded condition will have no functional impact on operations in either the MCR or TSC; however, a technical specification LCO is anticipated to limit the time DIAS-P can be unavailable, since both DIAS-N and P are required to meet the required level of redundancy for qualified systems.

Failure of the DIAS N channel is the other credible degraded condition, though all DIAS N segments have redundant processors and communication. DIAS N failure would render inoperable all spatially dedicated indicators and alarms on the panels. No information would be lost, because all information processing, including signal validation, would still be available through the DPS. Operators would use the DPS for alarm acknowledgement and plant status monitoring as is normally the case, but without the support of spatially dedicated information. IPSO would be unaffected. Little additional surveillance would be required and impact on the operating crew would be significantly less than in the failure of DPS case. This degraded condition has no impact on operations in the TSC.

Operability of accident monitoring instrumentation is covered by a technical specification limiting condition for operation in System 80+. This failure of either DIAS-N or DIAS-P will result in a technical specification action statement to restore the segment within seven days because both DIAS-N and DIAS-P are required to meet the level of redundancy required for qualified systems. Because of the length of the time for action this will not significantly impact daily operations.

Other degraded conditions, such as loss of individual display devices (e.g., CRT or ELDs), loss of any electrical buss, loss of a control device or failure of individual processors (DIAS segments or DPS) are all bounded in terms of impact on the operating crew by the above cases.

In summary, for the worst case degraded condition, failure of the DPS, increased surveillance will be required to monitor continued compliance with technical specifications. All required data is available on other MCR devices. Some additional calculations and decision-making operations will be required by operators which is expected to be handled by additional crew members in the controlling workspace. These would be related primarily to advanced operator aids (as discussed in the response to RAI 620.11) and DPS application programs (see CESSAR-DC Section 7.7.1). Examples of additional tasks required are manual core limit monitoring (COLSS unavailable), critical power production function monitoring, manual Reg. Guide 1.47 Bypass and Inoperable Status monitoring and Secondary Calorimetric calculations. As the task analysis is completed for System 80+ (see the HF Program Plan for System 80+), all additional tasks and calculations required for operation without the DPS will be identified and documented. No impact on controls, e.g., additional adjustments or manual operations, is expected. The primary impact on crew performance will be additional coordination requirements because of the additional surveillance and potential for manual information processing such as critical function monitoring. Coordination will be the responsibility of the CRS.

Operation under degraded conditions, including complete failure of the DPS (i.e., no CRT information), will be evaluated as part of the validation of Nuplex 80+. Design acceptance criteria will be established for these degraded conditions as part of the certification process.

Number: 620.37

Question: This paragraph states that, "Critical functions established for both safety and power production serve as a primary basis for information and alarm presentation." What is the definition of the term "critical function?" How were "critical functions" identified? Was a critical task analysis performed on critical operator and maintainer tasks in the control room and to what level of detail were the critical task analyses performed? If a critical task analysis was not performed, explain why. How were the contributions of the human engineering task analysis and the critical task analysis integrated into the development of information and alarm presentations?

Response: A critical function is one of a minimum set of functions required to be controlled to keep the plant either in a safe, stable condition (critical safety functions) or producing power (critical power production functions). The critical functions approach to monitoring the safety of a plant is required by NUREG-0696 and NUREG-0737, Supplement 1. These documents identified a minimum set of critical safety functions. C-E, in development of the critical function monitoring system as an SPDS, has identified additional critical functions for safety. Power production functions were identified as part of the Nuplex 80+ design process. Some of the initial concepts relating to power production functions were developed in the EPRI Disturbance Analysis and Surveillance System Program (EPRI NP-1684 and EPRI NP-3595). The critical function approach for Nuplex 80+ is described in NPX80-IC-SU790-02 which is found in the Nuplex 80+ reference design documents.

Critical task analysis, as defined in NUREG-0700, Section 3, and MIL-46855B consists of a task analysis performed specifically for those tasks which must be executed in an extremely rapid, time dependent manner. Because of the evolutionary nature System 80+, the plant will function with the typical slow response of nuclear plants. Therefore, no operator actions are required in a time-critical manner (see the discussion of design philosophy "Accuracy vs. Speed" in Section 1.2 of the Human Factors Program Plan for details). Hence, no "critical task analysis" has been or will be performed for System 80+. In lieu of this, Emergency Procedure Guidelines specifying all tasks needed for safe emergency operation have been used in Function Task Analysis and will be used in validation work at the integration test facility.

Number: 620.38

Question: This paragraph says, "Operating staff targets for Nuplex 80+ were established to accommodate a variety of staffing assignments during both normal and emergency operations." How many extra people are expected to be in the control room and the Technical Support Center during an emergency? Provide the analysis that identifies and describes the duties, responsibilities, and capabilities of the additional personnel and the space, equipment, and information they will require. Describe how the current configurations of the control room and Technical Support center meet the requirements and support the duties to be performed.

Response: The control room staffing levels necessary for safe operations will never exceed three operators for any design basis event. This is for the maximum workload post-trip evolution identified in the System 80+ Functional Task Analysis. Nuplex 80+ is designed to accommodate crew size of up to six which would include supervisory personnel. Additional staff beyond this is not required. Other personnel who may be in the control room and are provided for as active observers include an NRC representative, one plant owner management personnel and one communications specialist (per EPRI ALWR URD). They are provided information in the control room offices and are expected to interface without interfering with operations in the controlling workspace with the control room supervisor who is easily accessible. The specific duties, responsibilities and capabilities of the additional personnel entering the MCR during emergencies are the responsibility of the plant owner/operator.

The Technical Support Center (TSC) is part of the Nuplex 80+ advanced control complex which contains monitoring-only interface with the controlling workspace, through the ability to view IPSO and to call up displays on a Data Processing System (DPS) CRT. No control tasks are performed at the TSC and the TSC staff are not directly involved in safety monitoring. Hence, the staffing levels, information needs, etc., are not scheduled for a formal analysis. TSC staffing and monitoring will be evaluated as part of the normal MMI design process.

The number of people expected in the TSC is highly variable, but NRC regulations require that it be designed for 25 people (NUREG-0737). The Nuplex 80+ TSC is designed with adequate space, information through the DPS CRTs, personnel access and communication to meet the regulatory requirements. The Nuplex 80+ TSC is described in CESSAR-DC, Section 13.3.3.1. No additional design requirements beyond the ALWR-URD have been imposed on the TSC.