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Ann Riley & Associates
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1625 I Street, N.W., Suite 921
Washington, D.C. 20006
(202) 293-3950

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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BRIEFING ON HUMAN FACTORS PROGRAM AND NRC VIEWS OF NAS RECOMMENDATIONS

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PUBLIC MEETING

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Nuclear Regulatory Commission
One White Flint North
Rockville, Maryland

TUESDAY, MAY 31, 1988

The Commission met in open session, pursuant to notice, at 2:00 p.m., the Honorable LANDO W. ZECH, Chairman of the Commission, presiding.

COMMISSIONERS PRESENT:

LANDO W. ZECH, Chairman of the Commission
THOMAS M. ROBERTS, Member of the Commission
KENNETH CARR, Member of the Commission
KENNETH ROGERS, Member of the Commission

STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

S. CHILK

G. ROE

W. PARLER

F. COFFMAN

V. STELLO

B. REGAN

H. BECKJORD

AUDIENCE SPEAKERS:

D. ROSS

PROCEEDINGS

[2:00 p.m.]

CHAIRMAN ZECH: Good afternoon, ladies and gentlemen. The NRC determined upon reviewing the causes of the Three Mile Island accident that human performance and human factors were important contributors to the accident.

Since that time, the NRC has invested significant resources in understanding and implementing requirements for improved human factors in commercial nuclear power plants.

Control room designs have been reviewed and improved. Emergency operating procedures have been evaluated and improved. Training has been enhanced.

Control room staffing requirements have been upgraded and many more things have taken place in the field of human factors.

Still human error contributes to about half of all licensee event reports. Operators, while dedicated, well trained, and competent, continue, at least on some occasions, to have trouble with procedures.

Control rooms still have some unnecessary annunciator lights on during operations. This places a burden on the operators to account first of all for the reason that the light is on and then to understand and know where the alternate indicators are that would compensate for that light that is operating abnormally.

The operators are, in any case, the first and the last line of defense in the defense in-depth philosophy. We must do what we can to create the environment where operators can and will take the appropriate action when it's needed, both in routine operation and in off-normal situations.

Today we will hear from the Office of Regulatory Research and the Office of Nuclear Reactor Regulation about the human factors activities at the Nuclear Regulatory Commission.

I understand we have slides that have been available at the entrance to the room. Do any of my fellow Commissioners have any opening remarks to make?

If not, Mr. Stello, you may proceed.

MR. STELLO: Thank you, Mr. Chairman. I'll turn the meeting over here very shortly to Harry Beckjord who has some opening comments and we'll get on with the briefing.

I thought at the outset it's important to recognize that while this afternoon you'll hear a great deal from Research and some from NRR, two offices not here, AEOD and NMSS.

I wouldn't want, because they're not up here at the table, to suggest that those activities are limited to these two offices. They certainly are not.

We have been finding that a significant amount of the data that's analyzed in AEOD show significant human involvement in the LERs that are being analyzed, about 60 percent of them,

we found are in one way or another a contribution of either failure, inadequate training or procedures, or whatever.

I was impressed when the Academy briefed the Commission that they emphasized it's time to get behind those data, understand what the problems are, and see what we can do about it, and we have begun.

There is much to be done. I think we have, though, made considerable progress in this area and are committed to do a great deal more.

We have in the Office of NMSS, who is not here, a program that is just getting under way. As you recall, that Office has done not very much in the area, and they have hired a specialist to help them form their program because we, too, have found in the materials and licenses they are responsible for, the areas where significant improvement again can be made by application of human factors principals.

The staff is committed to undertake this broad program. The paper that we have sent to the Commission tries to give at least a broad-brush treatment of the entire Agency response, to lessons of TMI that says that we hadn't paid adequate attention to the human side of the equation.

We are now, and we're even going to do more in the future as you'll hear this afternoon. With that brief introduction, I'd like to turn to Mr. Beckjord who has some opening comments and then we'll go through the briefing.

CHAIRMAN ZECH: Before we begin, let me just ask the staff again that during the National Academy of Science briefing on May 19th, we asked at that time the staff be prepared to comment on their recommendations.

I hope you're prepared to do that today and we'd appreciate hearing your comments on those recommendations.

MR. STELLO: We are and we will provide those comments.

CHAIRMAN ZECH: Thank you very much. You may proceed, Mr. Beckjord.

MR. BECKJORD: Thank you, Mr. Chairman. I just had two comments before Dr. Coffman carries on with the presentations.

The first was on the May 19th report that you heard. This report took a broad view of the role of human factors in the safe operation and management of nuclear plants and it addressed its report to the NRC and the nuclear industry as a whole.

It also recommended that the NRC undertake a number of the research projects that it has proposed. In the May 23rd paper, which you're going to hear the briefing on this afternoon, we have pointed out the projects which we think it's appropriate for the NRC to undertake.

I just wanted to say that in total there were 44 recommendations. These were covered in the May 23rd document,

but we won't have time to go through all of them in detail this afternoon at this presentation. But Mr. Coffman will describe or respond with a number of specific examples.

Secondly, I wanted to say that the Electric Power Research Institute and the Institute of Nuclear Power Operations have sent written comments on the recommendations of the National Research Council Committee on Human Factors.

The Research Office plans to meet with EPRI, with INPO, and also with NUMARC in June to review both the Committee report and also the Research Office human factors plan.

And I expect to discuss with them at that meeting the possibilities for cooperative and coordinated efforts in human factors research.

CHAIRMAN ZECH: All right. Thank you very much. You may proceed.

[Slide.]

MR. COFFMAN: As Vic Stello mentioned, human factors regulatory research is being performed as part of the Agency's overall human factors activities.

So first this afternoon I'll introduce the remaining two presentations as far as the Agency's overall human factors activities and then I'll cover the RES presentation.

[Slide.]

MR. COFFMAN: The second viewgraph you will see some of AEOD's and NMSS's, a summary of their activities. AEOD's

reviews of operating experience include monitoring of licensee event reports and performance indicators and activation of the incident investigation and diagnostic evaluation teams and managing the Technical Training Center.

NMSS is in the process of prioritizing its human factors needs. Some example priority areas are medical misadministrations and radiography safety.

[Slide.]

MR. COFFMAN: On the next viewgraph you see NRR and RES listed. NRR has several activities underway, both at Headquarters and in the regions, and Jack Roe will present NRR's activities immediately following the RES presentation.

RES does research both to support regulatory decisions and to anticipate human factors developments that are potentially safety significant.

[Slide.]

MR. COFFMAN: On the next viewgraph, which is number four, you will see that the Agency's resources associated with human factors activity for fiscal years '88 and '89. The resources are shown both in units of million dollars and FTE.

The bulk of the NRR personnel associated with human factors activities are in the regions. They are involved with operator examinations, licensing and requalification.

Between about 55 percent and 60 percent of the total number of Agency personnel working on human factors are

involved in operator examinations, licensing and requalification.

The Office of Research funding on human factors consists of a little more than 40 percent of the Agency's total funding on human factors.

[Slide.]

MR. COFFMAN: On the next viewgraph, which is number five, my purpose in the RES presentation today is briefly to review the historical highlights to indicate the coordination with user offices and to summarize both the program plan and the resources being used to service the human factors regulatory research plan.

And as was mentioned when Dr. Neville Moray, Chairman of the NAS Panel, summarized the NAS report on May 19th, we have responded with enclosure two to the Commission paper to SECY 88-141, and it provides an item by item description of our use of the NAS Panel's recommendations.

I do not plan to repeat all the details here although I will summarize the NAS Panel's recommendations and our use of them.

[Slide.]

MR. COFFMAN: On the next viewgraph, by way of historical highlights, human factors in commercial nuclear power receive noticeable emphasis first in 1976, when the reactor safety study, WASH-1400, systematically estimated the

degree to which humans could impact safe operation.

And in 1979, the TMI action items included such things as the detailed control room design reviews, emergency operating procedures, and the safety parameter display systems.

From 1981 to 1985, the research program in human factors completed most of its tasks. The remaining tasks were incorporated into ongoing programs.

A couple of considerations have led to the revitalizing of human factors research as specific needs became evident, and the Chairman has already mentioned some of these.

Although there are safety benefits that have already accrued from human factors work within the Agency, there remains this large fraction of reportable events that continue to be attributed to human error.

In addition, operator errors of omission as assessed by PRAs were not only shown to be significant, but the measures themselves of operator errors are difficult.

[Slide.]

MR. COFFMAN: The next viewgraph is intended to itemize our coordination. One of our major assignments since the 1987 reorganization was to revitalize human factors regulatory research.

To revitalize this research, we have coordinated, restructured and re-focused the currently needed research tasks.

In addition, we're also thinking how to package for use the research products. That is, how to make the research products friendly to the users.

We requested and reviewed user needs from the other offices. We considered ongoing research, we considered past accomplishments, and we considered all the NAS Panel's recommendations by way of defining the currently needed research projects.

Part of that process, similar needs were integrated into one project and there was intense coordination among the user offices.

We will continue that intense coordination, both informally through frequent interactions and formally through both division level and branch level research review groups.

The human factors regulatory research plan will be updated periodically as projects are completed, as user needs are modified, and as new research needs are defined.

[Slide.]

MR. COFFMAN: Go to the next viewgraph. It's a brief summary of the user needs. NRR in this viewgraph 8-A, NRR's needs include research into the influences of organization and management practices on safe operations.

It includes human reliability assessment measures and root-cause determination. It includes the impacts, both beneficial and detrimental, of advanced technology such as

expert systems and improved fault detection, as was mentioned earlier.

Team performance measures are included, possibly with the use of simulators and procedures and training effectiveness measures are included, including those things for extreme environments.

[Slide.]

MR. COFFMAN: On the next viewgraph, which is 8-B, NMSS's research, as I mentioned, their needs are in the process of being defined and prioritized.

[Slide.]

MR. COFFMAN: The next viewgraph, which is 9-A, AEOD's research needs included an indicator for monitoring cognitive error, managing impact on safe operations, and reliable performance indicators of maintenance program and training program effectiveness.

[Slide.]

MR. COFFMAN: Then on the next viewgraph, 9-B, Research's needs center around the review measures for advanced control rooms, the human factors of accident management, and reliable measures of human error.

[Slide.]

MR. COFFMAN: On the next viewgraph, which is number 10, the objective of the research itself is to improve our understanding of the causes of human error for the purpose of

reducing its incidence, and to provide the technical basis for support of requirements, recommendations, and guidance.

The research involves hardware and humans and their interactions in a total systems approach. The objective of the plan is to identify the major areas of human factors research.

The plan identifies both near-term research to support regulatory decisions, which include such items as generic issues, human factors generic issues, and long-term research to anticipate human factors developments that are potentially safety significant.

We've broken the plan into five research areas, which is shown in viewgraph number 11.

[Slide.]

MR. COFFMAN: Human performance research is to model the factor shaping human performance. Human reliability assessment research is to assess the human error rates using credible data.

Man-machine research is to assure that this interface communicates clearly and compatibly as needed for safe operations.

Procedures research is to assure the reliability of rule-based actions. That is, to minimize procedural errors. Qualifications research is to assure the matching of the innate human capabilities with the system's task requirements.

Training research is to assure the matching of the

required skill levels with the level of training received and to maintain it both for individuals and for teams.

Organization and management research is to measure, model, and monitor the influences of supervisory and organizational practices on safe operation.

Although maintenance is not identified as a separate area, maintenance is addressed throughout these five areas. The details of these five areas and their three dozen contracts are too much to cover now, but they are described in detail in Enclosure 1 to the SECY paper.

But as an example of one of these areas, let me quickly summarize one which is the man-machine interface. Here, the objective is to assure that the interface communicates clearly and compatibly as needed for safe operations.

So the purpose involves assuring that both we have identified those factors that garble the interface and that we determine what improvements can be made.

By way of ongoing projects, we're looking at the need to identify whether it should be a human factors review for local control stations since the detailed control room design reviews cover the central control rooms.

Another ongoing project is to determine if the guidance for human factors of control -- what should be the guidance for human factors review of the control rooms on new

plants.

Another area was mentioned earlier also, the annunciators, human factors generic issue 5.2 where the objective is to identify the need for criteria and the criteria for the review of control room board annunciators.

As far as planned research in this area of man-machine interface, we're looking at the impact of high technology on control room operations.

One question is to identify if mixing old and new controls adversely impacts operator performance. Another area of planned research is computer classification, where the question is should there be different classes of computers with different requirements based upon their functional use and their potential impact on safe operations.

Another planned area is expert systems verification and validation where the question is can we identify the review criteria for verification and validation of expert systems.

A key ingredient to the use of expert systems is being able to quickly determine how the software arrived at its recommendation.

That is, the expert system must be a transparent box and none other than a black box. Another area of planned research is in reliance on SPDS, whether -- or potentially will the operators overly or excessively rely upon the SPDS rather than the Class 1-E control board instruments that have met Reg

Guide 1.97.

In support of a lot of this work in man-machine interface, we are using the Halden Project. The Halden Project is a valuable resource. It uses a four-loop PWR simulator for research and experimentation.

The Project also includes a man-machine laboratory with experience in the developing and testing of advanced instrumentation.

The Project uses reactor operators in the research. Similar facilities are not currently available in the U.S. Through the Halden Project we are able to participate with worldwide experts in the identification and solutions of man-machine interface problems.

We expect to come out of Halden knowledge on the use of expert systems as operator aids, review criteria for advanced instrumentation, information on computer based procedures, simulator data on operator performance for the purpose of human reliability assessment, and guidelines on verification and validation of software.

If I could go the next viewgraph.

[Slide.]

MR. COFFMAN: It addresses resources. Currently there are eight professionals directing human factors research. This staff will be completely adequate when we fill an existing vacancy.

The staff is multi-disciplinary. The current staff is entirely composed of senior professionals including internationally recognized experts in man-machine interface designs, cognition modeling, human reliability assessment, and simulators.

These professionals are qualified to direct particular areas of human factors research both by the formal training and by applied experience.

By formal training, there are three doctorates and ten masters. Every professional has at least one masters degree.

Every discipline involved has at least one masters degree. We are heaviest in psychology with one Ph.D., four masters, and four bachelors.

Although applied experience can replace the classroom, there's no substitute for the experience itself. There is a minimum of 11 years applied experience in any single discipline within the human factors technology.

The total applied experience is two-staff centuries. Over 60 percent of the experience is in human factors and engineering psychology.

When it comes to contracting, we are particularly looking for well-qualified professionals that are experienced both in human factors and in other disciplines.

The fiscal '88 contracts are allocated about 50

percent to national labs, 10 percent to universities, 15 percent to consultants, and 25 percent to international agreements, and we expect that the university and consultant percentages will be increasing.

COMMISSIONER CARR: Could you give me those numbers again, please?

MR. COFFMAN: Yes, sir. It's 50 percent to national laboratories, 15 percent to consultants, 25 percent to international agreements. Did I miss one?

COMMISSIONER CARR: Universities.

MR. COFFMAN: Ten percent to universities.

[Slide.]

MR. COFFMAN: On the 13th viewgraph, you'll see the fiscal '88 and '89 budget for human factors research as it is distributed by percentages. The total is in million dollars.

The past funding for human factors research has averaged about $2.3 million. During most of the NAS studies, the NAS Panel's study, human factors research funding was less than $1 million and was entirely dedicated to human error and human reliability assessment.

The five-year plan would project a stabilized budget at a funding level somewhere between about $7 and $8 million. But the allocation of the funds will vary annually to respond to defined user needs.

I'd like to go to the NAS --

CHAIRMAN ZECH: Wait. Before you go away from that one. If I recall, didn't Dr. Moray say that one of his recommendations was that we didn't spend anything on that first item? Is that what he said?

MR. COFFMAN: Their recommendation was geared toward not spending additional funds on subjective, enhancing subjective estimates for human reliability assessments.

Not expanding the subjective aspect because that's all it appears to be doing.

CHAIRMAN ZECH: Yes. What is in that first item, human performance? Isn't that a fair amount of subjective effort?

MR. COFFMAN: The -- no, I wouldn't call it subjective effort. Within that is some work on cognition modeling which is an attempt to take it out of a process where the analyst looks up a description of a task and tries to match what the estimated error rate for that task is with the task he's got at hand.

Here, in this work, we're looking to model the cognitive process in repeatable ways that can be tested and then folded into reliability assessments.

In addition, there is work on maintenance, simulating maintenance errors and what the influences of changes in maintenance practice has on maintenance.

CHAIRMAN ZECH: So what you're saying is that Dr.

Moray suggested we don't spend anything in this area on the theoretical or the subjective part of it, but we go ahead on the more practical or the more usable type performance that would be in the human factors.

Is that the way you understand it?

MR. COFFMAN: Yes, sir. If I might have the liberty to paraphrase a little.

CHAIRMAN ZECH: Go right ahead.

MR. COFFMAN: In the past, there has been a process used, referred to as the third process, that has been primarily one where experts have gotten together and tried to define groups of tasks and then indicate what the error rate is associated with that task.

And so it becomes one of subjective judgment among experts. In contrast, what we're doing is trying to model the process and model it in a way that it can be measured and the measurements can be repeated.

So we're moving away from subjective estimates of human error rates into --

COMMISSIONER CARR: What kind of data bank are you using?

MR. COFFMAN: The data bank, we're trying to expand the data bank through the use of simulators and we're trying to work with EPRI who has done an extensive amount of research in this area and they have extensive data.

We also have the work going on at Halden where we expect to obtain some information there.

COMMISSIONER CARR: This is not a data-gathering expenditure. It's just using current data that's already available.

MR. COFFMAN: This is a modeling and data combination and some of the data that is there, data takes different forms, the data that is there is one of aggregated subjective judgment.

What we're looking for is modeling and the collecting of objective repeatable observations. We don't think that we're repeating the error that the NAS pointed out. Not the error, but just going back and doing old work on subjective estimates of error rates.

COMMISSIONER ROGERS: Well, if I could interject, my understanding of what the recommendation was was that, rather than try to accumulate more information and more data on frequency of errors and assigning numerical values to frequency of errors, that the research should be directed more to the root cause of the error.

What's the basic origin of the error, and therefore what can one do to begin to change those frequencies, rather than the further collection of average frequencies of error, and using that data for PRAs or whatever.

And my understanding of his recommendation was to not

do that, but, rather, to try to get at the root cause of an error and to find what steps might be taken to help to prevent errors from occurring, rather than to simply characterize the average frequency, the pure frequency of their occurrence when you haven't done anything.

Does that relate somewhat?

MR. COFFMAN: Yes. That's right. And in modeling, I didn't use the word of determining the cause, but in modeling that's exactly what you're doing. You're trying to determine those factors in a measurable way that are the cause of these errors, error rates.

CHAIRMAN ZECH: Well, if I may just add one thought to this, too. My understanding of what he told us was that we had done enough studying of theoretical business in this area and that, perhaps, we ought to get into the more practical area of root causes and the things that are more real to the operators.

At least that was the way I understood him to say, that we shouldn't spend any more money on a rather theoretical, subjective approach, but we should get on with doing something that would be more practical.

Now, did you understand that?

MR. COFFMAN: Yes.

CHAIRMAN ZECH: All right. And that would be root causes that Commissioner Rogers is pointing out, also. In

other words, we want to get our hands dirty in this thing, and get some operators involved in it and find out what we really can do to help them.

And they're the ones that can probably tell us better than anybody else, as far as I'm concerned. Certainly, they should be involved, and I think that was what he was saying.

I'd try to link that up, because it seemed to me that was a rather important observation on the part of somebody who had looked at it as carefully as he had, to recognize we shouldn't be spending a lot of money on the rather ethereal, theoretical, subjective type things that have been fairly well studied.

But we should focus our efforts on something that would be more practical. Or, at least, that's what I felt he said. Do you agree with that?

MR. COFFMAN: Yes. We agree with it in a practical sense, in that this area includes work on event reporting and investigation of events that have occurred.

CHAIRMAN ZECH: And we don't just study it and get a lot of data and put it on the shelf. But we try to apply it and do something for the operators and the maintenance people and others, the human factor, the people who use the results of this effort.

I like that approach that he had, and at least that's what I thought he was saying. I hope that's what our research

program will be doing, too.

MR. COFFMAN: Dr. Moray's panel also, in fact, underscored one of the things that we're doing in this area with the maintenance. It involves going out to the plants and, in fact, involving operators in the development of models.

CHAIRMAN ZECH: Excellent.

[Slide.]

MR. COFFMAN: Let's see. I think I'm on the 13th viewgraph. I guess I'm going over the NAS recommendations.

COMMISSIONER ROGERS: Before you leave the budget, could you say just what the level of effort is at the Holden Project, the NRC's part of it, and how big those studies are that are going on there?

I know they may be spending pounds and we're spending dollars, but roughly what percentage of their effort is supported by NRC and what does that amount to in dollars?

MR. COFFMAN: We support 7 percent of the total Holden Project, and it amounts to, as far as human factors research, it amounts to $560,000 per year for us over a three-year period.

COMMISSIONER CARR: Do we have a say in what the program consists of over there?

MR. COFFMAN: Yes, sir. We have at two levels. At a technical level and at a director level, we have participation in the project, and as a Board member.

CHAIRMAN ZECH: Could you go back to the previous slide for just a minute, please?

I wanted to ask you a question on procedures. I think you had procedures listed there in the middle. What research do we need to do in procedures?

What I'd like to know is how will it help the operators? Not only the operators, but the maintenance, surveillance, and testing people at our power plants.

I'd just be interested in what kind of research you have in mind concerning procedures.

MR. COFFMAN: By way of on-going research and procedures, there is a human factors generic issue, 4.4, where the question is should we upgrade other procedures, other than the emergency operating procedures.

Because, as we look at emergency operating procedures reported events, it seems like the other procedures have a role in some of these reported events. So, one of the on-going efforts we have is to determine --

CHAIRMAN ZECH: You mean like procedures for conducting surveillance or testing and things like that?

MR. COFFMAN: What we had in mind in this was more for normal and abnormal operating procedures. Maintenance is being addressed separately from the one project. But that's not all the projects going on in procedures.

CHAIRMAN ZECH: Well, I guess I'm still trying to

come down to the nuts and bolts, though, at the practical factor, the human factors and make it practical, and say: All right. How would procedures, this research money, how will it really help the operators and those maintenance people, surveillance people, testing people?

How will it really help them perform better, and will it preclude errors in the future? In other words, what kind of procedural research do you intend to do that will be practical?

MR. COFFMAN: Let me give you an answer. It may take me a second here.

We have this work going on in the operating procedures. But, then, in addition, we're looking, as a Chernobyl follow-up item, we're looking at procedural violations.

What causes humans to violate procedures? And that's some on-going research that we plan, and it would include any procedures.

But the way we speak to the operators, one way we speak to operators is through rule-making. And there is a maintenance rule-making underway you're aware of, and our branch is actively participating in that.

So, as far as influencing the instructions or guidance to the operators on maintenance, it would take place through that channel.

CHAIRMAN ZECH: Well, let me just give you an

examples. Perhaps what I'm thinking about, maybe, it would be a little easier way to answer my question, which is that I'm trying to see where we're going to get something practical, hands-on, out of this research effort in the case of procedures.

One thing I have in mind would be, how about the flow charts in the control rooms that are being used in some plants now? They take their procedures and they convert them to flow charts. You know what I mean. It's a logic diagram. They're in use in many places that I've seen.

Now, to me, that helps. It takes this book of emergency operating procedures, that's rather clumsy to use, and puts it in a practical chart you can use. Some of them, I will admit, are overdone a bit, because it gets so you can hardly read them. But they should get them --

And human factors research, I think, could contribute to this. How can you make procedures in another form that are very useful to the operators in a real emergency?

In other words, when you have an emergency situation, the operators are very busy, and they're trying to do things to control the plant. But one of the senior operators in the control room has the responsibility of making sure they do the right thing and follow those procedures.

And he uses the book and calls out procedures, and they call back and respond whether they've shut the pump off or

whatever they might be doing. Whatever the action is that's called for.

But they've taken those books and they've put those procedures on one big flow chart. That makes sense to me, because, in the heat of kind of an emergency situation, it's easier to look and follow that diagram and check things off with a pencil that could indicate you've done that and that, and it gives you kind of a record of what you've done, too.

That's the kind of practical procedural effort that I would think might be helpful in the human factors program, and the research people could, I believe, make a contribution in that area. I give you that as an example that I think would be useful in the procedural area.

Then, my question really is, are you looking into those kinds of things?

MR. COFFMAN: Let me take the aspect of procedures that we are looking into, and that's in accident management. But when it comes to the more normal procedures, I think that's more typically an area that maybe NRR would like to address.

But as far as accidents go, in contrast with maintenance procedures, we are looking at operator aids, not just the format of the procedures, but operator aids and possibly the use of expert systems.

This is planned work. The only thing we have on-going at this point in research is the other procedures.

CHAIRMAN ZECH: Well, we could talk to NRR in a minute. But my only point is that in the research area, if you're spending a pretty good part of the budget -- 18 percent in '89 is a pretty good part, I think, on procedures -- I would hope it would be oriented to what can we do to help the operators and prevent them from making mistakes.

I mean not just control operators, but maintenance people, surveillance people, testing people, and so forth. That procedural effort in research, I believe, should be oriented toward some practical accomplishments in performance of all those operators.

And that's my point. I hope our research program is going there, rather than going off in some theoretical direction that may not really end up with a product for the operators.

MR. COFFMAN: One of the outcomes of the Holden work is -- Yes, sir?

MR. ROSS: I was going to pick up on --

CHAIRMAN ZECH: Well, why don't you identify yourself for the reporter?

MR. ROSS: D. F. Ross, Office of Research. I think we're doing something very practical along these lines at the Holden Project.

We just finished some work where we had a sample of 18 operators that were divided into three groups of six. And

we had operator aids in the way of different forms of computers that would assist these people during real transients that are simulated.

Each group was given a different type of computer-based aid, and this aid would tell him what to do and perhaps what not to do during typical transients, like loss of feed water and so on.

We then evaluate how well the group of six would respond to transients, how many mistakes they would make, how fast they would do something right. And, then, based on that, try to come to some conclusion whether computer-aided systems might be of some quantifiable benefit.

And the results of this experiment, which is just completed, answered, I think, pretty conclusively, yes. They make fewer mistakes if they have the right type of computer graphics, say, with colors. Red is bad. Red is poor. The value is closed. The pump is not running.

I think, as we proceed into accident management, we'll find this type of hands-on data with operators fresh from the reactor next door to be very useful to us when we try to decide should our reactors have these aids and, if so, how should we regulate it, how should we specify our performance requirements, and so on.

CHAIRMAN ZECH: Okay. I agree. That's a good example of procedural research that would be of a practical

value. I appreciate that. Thank you.

All right. Can we proceed?

[Slide.]

MR. COFFMAN: I think we're at 14. NAS employed these experts in behavioral and social sciences and nuclear physics and plant operations to identify areas that have not received adequate attention and to provide guidance for the human factors research.

This 14th viewgraph lists some key words from the NAS panels, broad recommendations to facilitate the management and use of human factors research.

[Slide.]

The next viewgraph, 15, lists the key --

MR. STELLO: Frank, before you leave that, I remember one particular recommendation that we had with respect to availability of simulators to do their research. They said that they had a problem.

We, now, very shortly will have three simulators available to us from Chattanooga, where, if there is a need or commitment, I'm sure now there will be no problem in getting available time to do whatever research they want to do in universities and elsewhere.

So, I don't believe that would be a problem at all in the future.

CHAIRMAN ZECH: Very good.

[Slide.]

MR. COFFMAN: There were some more specific recommendations and these specific recommendations were to be investigated both by the NRC and the rest of the nuclear community.

[Slide.]

MR. COFFMAN: On the 16th viewgraph are how we have outlined our response to our use of the panel's recommendations. Enclosure two as mentioned provides an item by item description of our use, but our focus was in revitalizing human factors regulatory research, so we were considering past accomplishments, what was already reality, ongoing research and all these recommendations.

The majority of the panel's recommendations coincided with user needs. Most of the recommendations coincided with ongoing programs. There were these few, as Dr. Beckjord had mentioned, there were 44 more specific recommendations and there were nine of them where there is no action planned at this time.

We will be revisiting these recommendations as we continue to interact with the regulatory users and the industry groups. Since the panel's recommendations were addressed to the entire nuclear community, we requested that NUMARC, EPRI and INPO review the report for comments and for areas they may wish to research alone or through cooperative research.

If you would like me to cover a couple of examples of the areas that we have no actual plan at this time, I can do that.

CHAIRMAN ZECH: Why don't you do that quickly.

MR. COFFMAN: One of the recommendations suggest we create a national research facility for the study of human factors and our response is essentially that research currently funds the Halden project and we are in addition exploring joint research with EPRI and we are exploring coordinated research with INPO, so we did not feel at this time that it was worth the initiative to establish a national research facility.

Another recommendation was NAS suggested that we identify applications of software psychology literature in the development of nuclear power plant computer programs. The NRC does regulate safety related functions and in special circumstances, we do look at the software. An example would be the SPDS. We feel this is more effectively addressed by EPRI, possibly EPRI, because they are the ones that in fact developed the software.

CHAIRMAN ZECH: Is the staff prepared to give the Commission a summary of the recommendations from the NAS report and your recommended actions?

MR. STELLO: Yes. Table 1 of the report to the Commission goes through it item by item, recommendation by recommendation.

CHAIRMAN ZECH: Are these additional things that we are hearing now? Is it right from the report?

MR. COFFMAN: Right from the report.

CHAIRMAN ZECH: That's fine.

MR. COFFMAN: If you look in that table, I think they are numbered.

COMMISSIONER CARR: For instance, your number three said they would like to have access to facilities such as simulators. In your response, you don't mention simulator access at all and the bottom line says we aren't going to establish a national research facility and there is no mention of providing access to simulators for those people.

CHAIRMAN ZECH: Mr. Stello says -- I think you are going to get simulator support for them.

MR. STELLO: Yes, through AEOD, through Chattanooga Center, we have three simulators down there and to the extent there is a need for any further research.

CHAIRMAN ZECH: That is a little different than what you have told us.

COMMISSIONER CARR: This is not our guys researching. This is providing access to simulators for behavioral science research?

MR. STELLO: That's correct.

COMMISSIONER CARR: It is outside of research.

MR. STELLO: That's correct.

COMMISSIONER CARR: The response doesn't indicate that we are going to do that. I'm glad to hear you are going to do that.

CHAIRMAN ZECH: Also, my point is that there are other things that you have developed since you have written that, that are at variance and perhaps we should be aware of that.

MR. CARR: There is also an indication that peer review is useful, but at some stage. I don't know when you're going to bring that peer review in. You just agree that it's a good idea, but there's not a committment to bring peer review in.

MR. COFFMAN: If I might address first, the simulator. Yes, Recommendation 3 says that simulators should have access to simulators.

MR. CARR: Not us, them.

MR. COFFMAN: Well, yes, that's true.

MR. COFFMAN: We've got access. Their beef was that they don't have it and therefore, they can't help us.

MR. COFFMAN: Okay, I misunderstood. Your second question?

MR. CARR: Was on peer review -- it kind of leaves it; yes, it's a good idea, but we'll bring it in at some stage.

MR. COFFMAN: What we do on peer review is, from the very beginning, we're interacting with the user offices for the

purposes of defining what the user needs are and that is our primary focus.

MR. CARR: I would propose that the users are not peers. We're talking about human factors peers, I assume. I start looking at the research that you're doing and deciding whether that's the right research, rather than the user. I may be wrong if I --

MR. COFFMAN: No, sir. I was just outlining the process, but let me just pick on one aspect of the process, which again the NAS report endorses. In the developing of the cognitive model work and the MAPS work, we did invoke comments by peers, brainstorming by a group under contract for the purpose of establishing the best way to go about conducting the research.

I think if you look at it far enough and try to compare word-for-word, the NAS report and the NRC response, at some point you could find what appear to be disconnects. I think you may be down to the point of style almost. I think the intent is, there may be even in some of these areas that we've listed as no action; we have taken some action. It just may not have gone far enough to call it complete action.

CHAIRMAN ZECH: If there are any differences that you develop during the course of your work that would make your response need a clarification, I hope you'll give it to us. That's what we want to know, because it looks like there may be

a couple areas where you've been able to do something that the report does not indicate that you were able to do, specifically in the area of simulators.

If that's the case, then we would appreciate your updating the Commission on that. All right? May we proceed?

MR. COFFMAN: Just to try and wrap up what I was giving you. It was coming out of the table in the response and I was not adding any new items. I was just addressing those items where we had no action at this time.

CHAIRMAN ZECH: I understand. Let's proceed.

MR. COFFMAN: I think that completes the agenda for the RES presentation, which was to summarize historical highlights; to show the coordination with user offices and to describe the regulatory research plan and then how we use the NAS panel's recommendation.

CHAIRMAN ZECH: All right. Thank you very much.

MR. ROE: Sir, the Nuclear Reactor Regulation human factors program is one that is also multi-disciplinary. It's broad and covers not only the headquarters, but also the regions and various programs, not only in operator licensing, but in our inspection of emergency operating procedures and our inspections associated with the man/machine interface, such as the safety parameter display system, the detailed control room design and review and also the assessment inspection of training programs for the licensed utilities.

In addition, the NRR program supports other offices and the diagnostic efforts of AEOD. Our particular program is also in evolution. It is evolving from licensing reviews to one of operational safety assessments. Today, most of our effort is in the field at the reactor sites.

Bill Regan, who's the Chief of the Human Factors Assessment Branch, will discuss many of our programs. We recently briefed the Commission on operator licensing, so we will not re-address that today. In addition, you've just brought up the aspect of procedures. We really have four objectives for our program, from the research.

The first one is with respect to emergency operating procedures, the secure accident management; we are interested in enhancing those documents, those procedures, those approaches which exist today in the facilities. Bill will talk a little bit about what we found EOP inspections to date.

One of the enhancements we're interested in, is being sure that those flow charts are properly used and assist the operators in carrying out their jobs, instead of are a liability in carrying out their jobs.

The second thing is, we're interested in these types of procedures -- emergency procedures -- that we look to the future. The technologies that are available to date, are coming available tomorrow to assist the operators in performing their jobs. For example, it may be useful to look at the

possibility of having emergency operating procedures, that there's text on one side of a split CRT screen and there's schematics on the other side to really help them do the job.

Third is, that we're interested in looking at taking the logical approach that's been taken in the EOP's, into other types of procedures, such as the abnormal, transient and normal operating procedures, all the way down into the maintenance procedures. There has been a dedicated effort at this particular level that is somewhat lacking in the other levels, so we need to make a review and research in that.

Last, I think it is important that we determine what causes individuals to violate procedures, so that, as Dr. Moray said, we find out what the problem is and we fix that cause. Next, I'd like to briefly discuss one of the programs that we have going on within NRR, before turning over to Bill.

That is our program that is associated with probablistic risk assessment. NRR has a program on the sensitivity of plant risk parameters to human factors. The objective of this particular program, is to identify and to characterize critical human performance actions and errors of major risk significance.

Right now, we are using the Oconee and Limerick PRA's to assist us in this effort. The Oconee analysis is one for pressurized water reactors and it is nearing completion. The Limerick analysis has just been started and is expected to be

completed next year. The results of those will be reviewed on the regulatory program when they become known.

Now, I'm going to turn over the program to Bill who will address those ongoing programs we have in the human factors area, both within headquarters and the regions.

MR. REGAN: Following TMI, the initial focus was on programs that would aid the operator in doing his job and aid in his interface with the plant. Generic Letter 8233, issued in December, 1982, established requirements for emergency response capability and among the areas covered were the detailed control room design review, the safety parameter display system, and emergency operating procedures.

With respect to the CRDR, or control room design review, the requirement was that licensees and applicants for licenses, carry out a detailed review of their control room for the purpose of improving the availability and useability of information and controls to assist the operator in preventing and controlling accidents.

The approach was for the licensee to establish a multi-disciplinary team that would review the control room, review the tasks of the operators in an emergency and identify needed modifications. Following this, they would propose safety significant changes and carry out implementation on a approved schedule.

Progress has been very good, I think, in this area.

Of 110 units that are currently under NRR's cognizance, licensees for 91 of the units have completed their reviews. In over half of these, improvements to the control room have either been implemented or they have been approved and are under implementation. With respect to the remaining units, in these cases, for 19 of them, they must complete the review and the others are still carrying out studies to come up with resolutions of problems that had been identified during the review.

In fiscal 1988, the staff effort in NRR has been reduced somewhat in this area to put more focus on emergency operating procedures, which I'll discuss in a moment. At the same time, we are exploring less resource-intensive ways of bringing final closure to this area.

With respect to the safety parameter display system, that was another requirement and the 737, Supplement 1. The purpose there was to provide a concise display of parameters that were descriptive of plant processes, in order to aid the operators in determining the plant's status and to give them at all times, an overview of plant status without going to the board.

The approach was as follows: because of the interest in having quick implementation of the SPDS, the review was set up as a post-implementation review. The utility would provide a safety analysis report which we would review early on, to

ensure that none of the actions they were taking would constitute a safety issue at the plant. At some time in the future, after implementation, we would audit the installation on a spot-check basis.

We have issued SER's for over half the plants and we have conducted a number of audits. Initially, there was a pilot program of 6 audits which were carried out in 1985 and early '86. These audits showed that the installations were not coming up to expectations. Only two of the six were found to be satisfactory. We expanded the audit program and have now audited about half of the units. Again, that ratio held true.

Only about one third of the installations were found to be fully meeting the requirements. As a result, we're developing a revised approach in which we plan to issue a generic letter which will outline to the utilities in more detail, what the requirements were, what we have found to be a satisfactory approach, what we found in the field -- my term is good practice -- and then ask them to give us information on their installation.

We're not going to every plant. We can get an initial clip as to which ones look to be like problem plants and which ones look to be probably satisfactory.

In the area of emergency operating procedures, NUREG 0737 Supplement 1, directed that new procedures be developed which were function oriented or symptom oriented, rather than

even-based. It also required that they be human factored. It required that the utilities and -- as it turned out, the owners groups did this -- reanalyze transience and prepare guidelines against which the EOP's would be developed.

Finally, to submit to the NRC for review, a procedure generation package, which would consist of the plant's specific technical guidelines, a writer's guide, verification of validation program and a description of the training program which would be utilized to train the operators in the emergency operating procedures.

Again, this was set up as a post-implementation review. We expected and wished the utilities to implement these improved procedures as quickly as possible. We received all the PGP submittals. We've reviewed most of them and have issued SER's on about a third of them. About two years ago, we started some audits to look at the EOP's themselves, rather than just looking at the PGP documentation, against which the EOP's were developed.

We found a number of problems. We found that in many cases, the utilities, while they had a satisfactory PGP, in implementing their EOP's or preparing their EOP's, there was not any direct relationship between the PGP and the resulting EOP's. As a result of these concerns, we issued two information notices, one in 1986 and one in 1987, and decided early this year to follow it up with an accelerated EOP

inspection program.

This was intended to be a pilot program. Sixteen plants were chosen -- 4 from each vendor type. NRR, in cooperation with the regions, set up 4 teams, each one focused on a specific vendor, to do an in-depth inspection of the EOP's at these plants. The program was developed in February. Training took place in March at the simulators in the training center. Teams trained together.

The inspections started towards the end of the March and the initial 16 plant inspection will be completed about mid-July. As you can see, these inspections take from 2-3 weeks each. It's a very intensive program and each of the teams are on the road most of the time.

We have completed 9 inspections so far and while we have found a number of problems with the EOP's -- many of them in the human factors area and in most cases, problems with respect to verification and validation of the EOP's -- we have not found any problems that we would consider really safety significant to the point where you would have question as to whether the plant should continue operating with those procedures.

In that sense, I think the results of the inspection have been rather edifying and favorable.

After we have completed the 16th plant review, we are going to consider where we go from there, whether bulletins or

orders are necessary or whether we want to continue the program. I will speak about a continuation in a moment or whether things are at a point where we can go back to a more normal operation.

There was a Phase 2 which was instituted just a couple of months ago, Phase 2 of the EOP inspection program. This had particular focus on BWR Mark I's because of the current concern about Mark I plants and the attention they have been getting.

Dr. Murley and other senior management in NRR felt that it would be useful to extend this inspection program to these plants. A few of them had been covered in Phase 1 of the EOP program. All the others are being covered in Phase 2.

Inspections of these additional 12 sites started last week with Fitzpatrick and will be running through September, at which time that program will be complete.

By the time we have finished these two phases, we will have looked intensively at the emergency operation procedures of 28 plants, which constitute 40 units. It is a fair cross-section of the industry.

Mr. Chairman, you mentioned earlier the flow chart procedures. I took from what you are saying, and I think it is true, that it constitutes an improvement, an additional aid to the operators in carrying out these procedures under the stress of an accident.

In the past, we have put out guidance for writer's guidance, human factors guidance, so I am preparing textual emergency operating procedures. We are now in the process of developing similar guidance for preparation of flow chart procedures.

The work that we have been doing, we are doing it through Battelle Northwest Laboratories, and it has gained quite a bit of interest on the part of the utilities and a number of the utilities have consulted with the group who are preparing this guidance to gain some assistance. I think this is an effort that is certainly worthwhile and certainly timely.

CHAIRMAN ZECH: You mentioned the flow charts, I've seen a number of them in the control rooms. I always ask the operators, are you sure those flow charts are the same thing that are in your emergency operating procedures. That's pretty important. The emergency operating procedures, the ones we approve, and when they translate them to this chart, it always concerns me a bit. I asked them if they are sure and I ask them, did you participate in the transfer from the emergency operating procedures to the flow chart. Usually I get a pretty strong response that they did participate.

It is awfully important that those flow charts adhere right to our emergency operating procedures, which are the ones we have reviewed and approved. I must say I do get a favorable response from the operators themselves who seem to understand

that the emergency operating procedures are the valid document but the flow chart made up from those documents in a very careful manner can be very useful to them. It also encourages me and gives me some degree of confidence to know that they do participate very carefully in that review. I also take the opportunity at the time to ask them, are you able to have an input on those procedures, are you satisfied they are correct and if you have any concerns about them, do you have an opportunity to raise that to the utility. Again, I get a favorable response on that action, too.

The operators must, if they are going to use the flow charts, they have to know they are in compliance with our requirements, again, I think it is important that they participate in that evolution.

MR. REGAN: They participate directly.

CHAIRMAN ZECH: We should check that so often.

MR. REGAN: Part of the verification validation of procedures is testing them, not only walking them down in the plant but testing them in the simulator to make sure they work.

CHAIRMAN ZECH: Our Regional people and resident inspectors, the Regional inspectors, our own NRR people, when they go out, they should check those flow charts, too. You shouldn't just assume.

MR. REGAN: That has been part of our inspection program and also part of the inspection program has consisted

of interviews with the operators to learn their views concerning the procedures, problems they have and so forth.

CHAIRMAN ZECH: Good.

MR. ROE: Before Bill goes onto another section, there were a couple of comments about the EOP inspections. I think it is noteworthy that this particular inspection is focused on whether the plant can carry out the EOPs. We check them out by having a plant in the simulator run through these emergency actions, then we take the opportunity to walk the procedures through in the facility itself to see if the operators can carry out the steps. If the environment will allow them to carry out or whether there will be too high a temperature, maybe a steam environment or radiation environment, and lastly to see if the equipment that is necessary to carry it out, such as valves, whether they can be actually operated by those operators and whether things such as jumpers that are called for in the procedure are available.

The second point is we have received quite a few kind comments, not only from the Regional inspectors but also from the utilities about the nature of our inspection and how much the people have learned from going out there and actually looking for the performance of these EOPs in the plant itself.

CHAIRMAN ZECH: Let's proceed.

MR. REGAN: The next area I wanted to briefly address is plant personnel training. As you know, the Commission

approved a policy statement on training and accreditation in February, 1985, which endorsed the INPO accreditation program for a two year trial period. The industry committed that during that period, ten programs at 61 sites would be ready for accreditation. That was by December of 1986.

During that period, rulemaking was deferred.

As part of that process, the staff was to independently evaluate the accreditation process through post-accreditation reviews and also observing, going along with the INPO teams during team visits.

The industry has met their commitment. During the past three years, two and a half years, there has been 150 team visits and visiting 677 programs. 575 of those programs have been accredited. The staff has accompanied INPO on 19 of those visits and we have carried out eight post-accreditation reviews.

While we have found some problems which we have passed onto INPO, by and large we found that the program is working and we recommended that the program be continued.

The Commission has approved and we are now in the process of revising the policy statement. That should be ready shortly.

CHAIRMAN ZECH: I might just make one quick comment in that regard. Having been visiting the plants now in the commercial nuclear industry for almost four years, there is a

noticeable improvement in training. Clearly there is a noticeable improvement in training over that period, at least from my perspective. Training is now getting a rather formal review. The utilities I think are doing an excellent job in training, certainly better than they were when I started looking four years ago.

It is a commendable effort, I think, that has taken place and has upgraded, I think, performance and perhaps has contributed, I believe it has contributed to the improved performance we have generally seen. That doesn't mean there is not room for more improvement or even better training. It does mean, at least in my view, my observation, and my previous experience in training over a number of years, at least my assessment has been that training is clearly improved and that is something I think we should take note of.

MR. REGAN: More recently, the NRR staff's attention has been moving toward plant operations, as Mr. Roe indicated earlier, as issues like the control room and SPDS are resolved, we are concerned with issues such as shift scheduling and overtime and we are in the process of preparing a revised policy statement covering these matters. The issue of professionalism which I know is near and dear to the Commission's heart. We are working again on a policy statement on this area.

We are starting to look closely at licensee

management and organizational climate. If our focus had not already been in this area, it would certainly have been brought to that point because of the Peach Bottom event. We are looking very closely at Peach Bottom, both in terms of the operator rehabilitation and the organizational climate and the changes that are being made in management there.

We have done studies on Davis-Besse and also are looking in a preliminary way at Turkey Point in terms of their management and organization.

Our staff has participated with AEOD in diagnostic inspections of McGuire and Dresden where our staff focused on the human factors issues and most particularly on management and organization issues.

That completes my discussion.

MR. STELLO: Mr. Chairman, we are through. I would make one point. On the last page of the papers, where we talked about the training center, maybe we need to make it clearer, make sure the research community at large does understand that we are --

CHAIRMAN ZECH: The last page?

MR. STELLO: The very last page. We will make an effort to do that.

CHAIRMAN ZECH: Fine. Thank you very much.

Questions from my fellow Commissioners? Commissioner Roberts?

COMMISSIONER ROBERTS: No.

CHAIRMAN ZECH: Commissioner Carr?

COMMISSIONER CARR: Yes. I want to make a comment. As a former funder of research programs, I would classify the human factors research program plan as soft. It is not -- we have spent a lot of money and I have a hard time picking out in there the hard tasking so that you are going to be able to defend that plan when the budget crunch comes. It doesn't lend itself to any feel that you are going to get a completed project and I think we need to follow it closely.

For instance, one of the things, a management study on management, organization influence on human error rate, the 2.5.1.2, which says "develop an organization model of the site specific operational units, operators' maintenance text, instrument and control text, that can impact nuclear power plant reliability. Indicate the relationship between these operational units and other site specific units. That is security, corporate units, that is purchasing and non-utility units, that is contractors."

That doesn't sound like it needs to take 20 percent of the budget for projects like that. I would just caution you, when you come in for your money, you better have a pretty firm program.

CHAIRMAN ZECH: Commissioner Rogers?

COMMISSIONER ROGERS: I'm a little unclear about the

management and organization research. It seems to me that is a very tricky area and first, what kind of research really is meaningful there and how much one really can learn just by good management practice that has been developed over the years in other sectors.

I'm a little puzzled as to what one is really going to learn in the way of basic research, get from basic research results in management and organization. It picks up a little bit on Commissioner Carr's concerns. I think he has indicated that he is a little uncomfortable about what is going to come out of it and I would say I share that discomfort, without trying to go into it in great detail.

I am a little perplexed about the man-machine interface areas of research priority, because I distinctly recall the point being made that there was a feeling of the NAS Panel that there really wasn't a need for new research in man-machine interface. There were some other aspects, namely human error identification of root cause. As a distinct research area of itself, I was under the impression that the NAS Panel did not favor considerable new research in the man-machine interface as such. That depends a great deal on how you define that area, I'm aware. Your budget has quite a bit of -- 23 percent of it is in the human-machine interface area.

I just want to be clear that what you are contemplating there is really something new and is not

retreading the human-machine interface area which has been around for a long time, that has a lot of traditional work in it. That's a comment and a question.

The other one is that derives a little bit from that point of view, that one of the points that was made, there is an awful lot of human performance research in the literature that simply hasn't been incorporated over into this field of activity. It exists. There seems to be a lack of awareness of what that research is by the people who are operating nuclear power plants.

I wondered what your thoughts are with respect to bridging that gap and trying to at least provide some way to encourage people to use existing knowledge, perhaps providing it in a form or format that is more readily adaptable to their own particular needs.

I recognize that we don't run plants and we don't tell people exactly how to do it. Perhaps some examples could be developed of ways of starting that flow into the daily operations of nuclear power plants, of the use of information which is well known, well documented, but simply news to people who run nuclear plants.

CHAIRMAN ZECH: Just a couple of comments, a couple of general comments. Human factors in my view is a very important field and I think it is one that we can emphasize more in our regulatory responsibilities. If you look to the

future and think about perhaps some time of new plants and new designs and all, we should use the experience that we have had to date in design, construction and operations, and incorporate in all those fields, working together, an emphasis on human factors.

In other words, a new design I would hope would have some operators' input, some constructors' input, too. As the design gets put together and the construction starts, I would hope the operators also have a chance to be involved in the construction and engineering aspects, at least people with operational backgrounds.

If you don't design it in and construct it in, it has been my experience that putting it in later is very difficult. For the future, I submit that human factors is something to be considered, those of you who are responsible perhaps for reviewing new designs.

The second part of that general comment is what do we do now, we have already got the plants designed and how do we enhance human factors with a plant that is already designed. Perhaps the design is not optimum. The construction is not optimum. What I mean by that very quickly is in some areas, plants that I've seen, it is clear that the design of the control room really could be improved. I think it has been recognized and studied. Even the construction, and let me explain that briefly.

I found some plants designed that make maintenance very difficult. Obviously, operators and maintenance people were not involved in that, or else they would have had a little more room to work.

It is very important up front to consider human factors.

What do we do about the plants that are out there now that perhaps could have been designed better regarding human factors? It is very difficult. I think we should do what we can to recognize that we should try the best we can with the plants that are already designed and operating to make them user friendly. What can we do there? We can help with the procedures. We can help with flow charts, mimicking, labeling, those kinds of things.

It is not really the essence of human factors but it kind of makes up for plants that might have been better human factored in the first place.

The safety parameter display system, SPDS system, I think is an excellent tool, but it is just becoming to be realized as to its value.

I would perhaps think that we might want to consider even asking some of the utilities to participate in a pilot program. It might have some interest. We might be able to go to one of the industry groups and ask them to take this on as a project to see what they could do about the plants that are

already designed, what could we do better with human factors. The effort would be worthwhile in my judgment because as we all recognize, there are a number of -- we have said close to 50 percent of the events that have some form of human error involved, and maybe even a higher percentage.

In any case, the pay back would be large in my view.

Those are a couple of general comments. I have some more specific comments very briefly. The control room, I do think that often without much extra effort -- utilities that I have visited recently are doing quite an excellent job in this regard -- they are trying to make mimicking more user friendly, trying to color code, trying to label. There is an effort to recognize the value of human factors.

In the control rooms, I think we are probably making as good an effort as anywhere. On the other hand, other parts of the plant, sometime at the pump stations or other places in the plant where they need to be operated in case of an emergency but not in normal operations, to put operating instructions at the plant, at the station, make them available, that is one suggestion.

Again, maintenance and accessibility are terribly important in my view. We should be mindful of that and the utilities should be mindful of that as they try to make added improvements to the plants as they exist today.

We should always look at the operator, the

maintenance individual, the chemist, the Rad protection individual, those who are on the shifts, for example, 24 hours a day, will the modifications or will the changes made be user friendly to them, will they be able to do their job better. Will testing and surveillance be improved by what we are doing or will it be more of a problem.

Can we improve communications, for example, in procedures that involve surveillance and testing. I've seen recently at one of the plants a procedure, surveillance in progress where the individual had on a set of phones with communications with the control room and another part of the plant and communicating directly like that before any evolution took place. Most plants do that quite well. On the other hand, perhaps even that system can be made a little more user friendly, communications is an important part of it.

Those are just some specific thoughts. More than anything, I think we should involve the operators. By "operators," I don't mean just the control room operators. I mean the maintenance person, surveillance people, the equipment operators, the chemists, the Rad protection people, those people who are actually going to do the job. We should involve them in evolutions that will lead to changes to their station or their facilities, allow them to participate and become involved.

It not only gives them a feeling of ownership, which

I think we all realize has considerable value, but they have good ideas. Those are the people that are there all the time. They can assist in the area of human factors that could result in improvements to the power plant.

Those are my thoughts. I think the research program is only part of human factors, as we know, and as Mr. Stello pointed out earlier, we know that NRR is involved, NMSS is involved, AEOD is involved, too. The research part is important. We all want to see it solid and strong and not soft. We would like to feel that the research going -- at least I would like to feel that the research is really going to result in perhaps some practical application to improve performance by some of the broad school of operators that we have mentioned.

In other words, we recognize there has to be some what I term basic research that may or may not be a direct application, but should be done because of the possibility of broader application and understanding of human error and so forth. I think also we are interested in the more practical side of research in that we do want to see some kind of an improved performance and we want to see a benefit come to it from human beings who make errors and who we criticize and rightly so for making errors, but we want to help them and prevent them from making those errors. Therefore, we have an obligation I think to do what we can to be constructive in this

way and not just count the errors and add them up and have a bunch of statistics. We want to use those statistics and to recognize that most of these people we have operating the plants are trying very hard to do it right. If they make errors, it is not in my judgment and experience because they want to make errors. It is because they are human. They make mistakes that other humans might make.

If we have people who are trying hard to do it right, I think it behooves us to do what we can to assist them to do it right. That is what human factors and our efforts in this regard should be focused on in my judgment.

Are there any other comments from my fellow Commissioners?

COMMISSIONER ROGERS: Just one point that I didn't get any word on. What is the mechanism for technology transfer from the Halden Project? How do you see that actually getting transferred to the U.S.? Is it different, little different culture, little different approach in Norway. How do you see that being brought into U.S. practice, whatever is learned there?

MR. COFFMAN: The Halden Project issues reports and some of these reports merit translation into research information letters or into information notices. There is a formal written mechanism. In addition, we can participate and our contractors can participate on site during the conduct of

the experiments. Halden would participate with us during the design of experiments. As best we can, we plan to include operators in the design of the experiments and the interpretation of the results.

It is rather focused at this point. It is not broadly across the --

COMMISSIONER ROGERS: That is U.S. operators?

MR. COFFMAN: Yes, sir.

COMMISSIONER ROGERS: All right.

CHAIRMAN ZECH: Let me conclude then by saying very briefly that what we are doing -- this is a very important human factors discussion and we want to follow through on this and be mindful of our responsibilities. We are not doing this for human factors' sake. What we are doing is trying to develop a regulatory product that will enhance safety. That is our role. That is what we are trying to do, develop a regulatory product. I think we should all focus on that, Research, NRR and others. What can we do to develop a regulatory product that will enhance the safety of operations. Safety is our big business, public health and safety will be enhanced if we can do that.

I think our efforts in this regard are very important.

Are there any other comments?

COMMISSIONER CARR: You will notice this plan is

going to be updated periodically. In what period do you plan to update it?

MR. COFFMAN: I think the general thoughts have been -- there is no focused schedule. The general thoughts have been initially it would be annually but then after that, it may settle down where it won't need to be updated that frequently.

COMMISSIONER CARR: Thank you.

MR. STELLO: I think the answer depends on how much the industry does. There is a lot going on in the industry and we will want to go back and refocus on it.

CHAIRMAN ZECH: Let me thank the staff for an excellent presentation. We stand adjourned.

[Whereupon, at 3:40 p.m., the briefing was concluded.]

CERTIFICATE OF TRANSCRIBER

This is to certify that the attached events of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: Briefing on Human Factors in Commercial Nuclear Power Plants and Control Room Designs

PLACE OF MEETING: Washington, D.C.

DATE OF MEETING: Tuesday, May 31, 1988

were transcribed by me. I further certify that said transcription is accurate and complete, to the best of my ability, and that the transcript is a true and accurate record of the foregoing events.

Suzanne Young

Ann Riley & Associates, Ltd.

OUTLINE OF PRESENTATIONS ON HUMAN FACTORS

* INTRODUCTION TO NRC HUMAN FACTORS ACTIVITIES

* RES PRESENTATION

* NRR PRESENTATION

NRC HUMAN FACTORS ACTIVITIES

AEOD: REVIEW OF OPERATING EXPERIENCE

NMSS: MEDICAL MISADMINISTRATIONS,
RADIOGRAPHY SAFETY

NRC HUMAN FACTORS ACTIVITIES (CONT.)

NRR: OPERATOR EXAMINATION AND LICENSING, EOPS, MAINTENANCE/ SURVEILLANCE, MAN-MACHINE INTERFACE, EVENTS ANALYSIS, RISK ASSESSMENT

RES: SUPPORT REGULATORY DECISIONS, ANTICIPATE HUMAN FACTORS DEVELOPMENTS OF POTENTIAL SAFETY SIGNIFICANCE

NRC HUMAN FACTORS RESOURCES

	FY88 $ (FTE)	FY89 $ (FTE)
AEOD	$ .4M (3)	$ .4M (3)
NMSS	$ .2M (2)	$ .3M (4)
NRR(H&R)	$4.8M (85)	$7.8M(113)
RES	$4.2M (6)	$6.1M (8)
NRC	$9.6M (96)	$14.6M(128)

OUTLINE OF THE RES PRESENTATION ON HUMAN FACTORS

* INTRODUCTION TO RES PRESENTATION
* COORDINATION WITH USER OFFICES
* SUMMARY OF HUMAN FACTORS (HF) RESEARCH PROGRAM PLAN
* RESOURCES
* DISCUSSION OF NAS RECOMMENDATIONS

INTRODUCTION TO RES PRESENTATION

* CHRONOLOGY

* NEED FOR HF RESEARCH

COORDINATION WITH USER OFFICES

* REQUEST USER NEEDS
* REVIEW ONGOING AND COMPLETED RESEARCH
* IDENTIFY NEED FOR ADDITIONAL RESEARCH
* INTEGRATE SIMILAR USER NEEDS INTO ONE PROJECT
* COORDINATE PLANNED PROJECTS WITH USERS

SUMMARY OF HUMAN FACTORS RESEARCH NEEDS

* NRR
  - ORGANIZATION AND MANAGEMENT
  - HUMAN RELIABILITY RESEARCH
  - IMPACT OF ADVANCED TECHNOLOGIES
  - OPERATOR/TEAM PERFORMANCE
  - PROCEDURES AND TRAINING
* NMSS
  - PRIORITIZED AGENDA OF HF CONCERNS IN MATERIALS LICENSING

SUMMARY OF HF RESEARCH NEEDS (CONT.)

* AEOD
  - COGNITIVE ERROR
  - MANAGEMENT
  - PROGRAMMATIC PERFORMANCE INDICATORS
* RES
  - MAN-MACHINE INTERFACE FOR ADVANCED CONTROL ROOMS
  - HF ASPECTS OF ACCIDENT MANAGEMENT
  - HUMAN ERROR DATA BANK

HUMAN FACTORS RESEARCH PROGRAM PLAN

* OBJECTIVES
  - IDENTIFY MAJOR AREAS OF HF RESEARCH
  - IMPROVE UNDERSTANDING OF THE CAUSES OF HUMAN ERROR
  - NEAR TERM RESEARCH
  - LONG TERM RESEARCH

RESEARCH AREAS

- HUMAN PERFORMANCE AND HUMAN RELIABILITY ASSESSMENT
- HUMAN-MACHINE INTERFACE
- PROCEDURES
- QUALIFICATIONS AND TRAINING
- ORGANIZATION AND MANAGEMENT

RESOURCES

* RHFB STAFF
  - EIGHT PROFESSIONALS
  - MULTIDISCIPLINARY BACKGROUNDS AND EXPERIENCE
* RESEARCH CONTRACTORS
  - NATIONAL LABORATORIES/UNIVERSITIES/ CONSULTANTS
  - EXPERIENCED HUMAN FACTORS STAFFS
  - MULTIDISCIPLINARY CAPABILITIES

HUMAN FACTORS RESEARCH BUDGET

	FY 1988	FY 1989
HUMAN PERFORMANCE AND HRA	32%	28%
HUMAN-MACHINE INTERFACE	25%	23%
PROCEDURES	16%	18%
QUALIFICATION AND TRAINING	11%	11%
ORGANIZATION AND MGMT.	16%	20%
TOTAL BUDGET (MILLION)	$4.2	$6.1

NAS RECOMMENDATIONS

* PROGRAMMATIC RECOMMENDATIONS
  - COMMITMENT TO HF RESEARCH
  - ADOPT A SYSTEMS ORIENTED APPROACH
  - PEER REVIEW AND ENHANCED ACCESS TO FACILITIES
  - CONTINUITY OF HF RESEARCH PROGRAM
  - **TRANSFER OF KNOWLEDGE**
  - DISSEMINATION OF HF RESEARCH REPORTS

NAS RECOMMENDATIONS (CONT.)

* HF RESEARCH AGENDA
  - HUMAN SYSTEM INTERFACE DESIGN
  - PERSONNEL SUBSYSTEM
  - HUMAN PERFORMANCE
  - MANAGEMENT AND ORGANIZATION
  - REGULATORY ENVIRONMENT

RES HUMAN FACTORS PROGRAM

* RES COMMITMENT TO HUMAN FACTORS
* SYSTEMS ORIENTED APPROACH
* PEER REVIEW
* ACCESS TO SIMULATORS
* STABLE HF RES BUDGET
* **TRANSFER OF KNOWLEDGE**
* HUMAN FACTORS RESEARCH AGENDA

INTRODUCTION TO NRR PRESENTATION

HUMAN FACTORS PROGRAM

- CONTROL ROOM DESIGN REVIEWS
- SAFETY PARAMETER DISPLAY SYSTEM
- EMERGENCY OPERATING PROCEDURES
- PLANT PERSONNEL TRAINING
- OPERATOR EXAMS AND LICENSING
- MANAGEMENT AND ORGANIZATION
- RELIABILITY AND RISK ASSESSMENT

POLICY ISSUE
(Information)

May 23, 1988

SECY-88-141

For: The Commissioners

From: Victor Stello, Jr.
Executive Director for Operations

Subject: HUMAN FACTORS INITIATIVES AND PLANS

Purpose: To provide the Commissioners with a description of the staff's human factors initiatives and plans and with the staff's disposition of the recommendations provided in a National Academy of Sciences (NAS) February 1988 report entitled Human Factors Research and Nuclear Safety.

Background: On January 28, 1987, the staff recommended termination of the agency's Human Factors Program Plan (SECY-87-19, Human Factors Program Plan -- Progress Report for Fiscal Year 1986). The Commission indicated acceptance of that recommendation in a February 27, 1987, memorandum from S. Chilk to V. Stello. At the same time, the Commission requested "... a brief description of agency human factors initiatives in progress or planned and an evaluation of the recommendations of the expected June 1987 NAS study on the need for additional human factors research...."

A March 23, 1987, memorandum from V. Stello to H. Denton and E. S. Beckjord directed the Office of Nuclear Regulatory Research (RES), with the assistance of the Office of Nuclear Reactor Regulation (NRR), to provide an information paper responding to the Commission's request by October 1, 1987. The date for providing the information paper to the Commission was based on the scheduled receipt of NAS recommendations on human factors research by the end of August 1987. On August 17, 1987, the NAS informed the staff that it could not provide its report as scheduled, and the staff notified the Commission of this delay on September 21, 1987 (SECY-87-240, Human Factors Research Planning for FY 1988 and Beyond). The staff committed to provide the information paper responding to the Commission's request approximately two months following receipt of the NAS report. The report was received on February 29, 1988.

Contact:
A. Rubin, RES
49-23546

Discussion: RES, NRR, the Office for Analysis and Evaluation of Operational Data (AEOD), and the Office of Nuclear Material Safety and Safeguards (NMSS) all have ongoing and planned activities in the area of human factors. The following paragraphs provide a brief description of those activities.

The Office of Nuclear Regulatory Research. RES has developed an expanded program for human factors research in response to Commission guidance and to recommendations in a December 1986 NAS report entitled Revitalizing Nuclear Safety Research. The Reliability and Human Factors Branch in the Division of Reactor and Plant Systems was formed to take the lead in this area. To date, efforts by RES have included identification of human factors research needs in coordination with NRC user offices and development of a Human Factors Research Program Plan (HFRPP -- See Enclosure 1). The objective of the HFRPP is to outline the structure and content of a Human Factors Research Program which meets the Commission's 1987 Policy and Planning Guidance commitment "...to explore methods to better understand the causes of human error and to reduce its incidence."

Research areas within the HFRPP include human performance and human reliability, the human-machine interface, procedures, personnel qualification and training, and organization and management. Consistent with the NRC's research philosophy, projects in these research areas include both short and long term tasks. Short term tasks will support timely regulatory decisions and user needs. Long term tasks will allow the NRC to anticipate human factors problems of potential safety significance. The Appendix to Enclosure 1 summarizes ongoing projects and work planned to respond to user requests and NAS recommendations in each research area.

Formal user requests from NRR, AEOD, NMSS as well as within RES have identified a wide scope of human factors research needs. The HFRPP responds to these requests. More detail will be provided in periodic revisions to the plan and its appendix as coordination among the offices continues.

In addition to the user requests, a February 29, 1988, report by the NAS entitled Human Reactors Research and Nuclear Safety provided recommendations for human factors research. This report made two types of recommendations. The first type was designed "...to facilitate the initiation, planning, management, conduct, and use of human factors research." The second type was to identify "...specific research topics to be investigated by the NRC and the rest of the nuclear community." The staff's responses to the NAS recommendations are provided as Enclosure 2. The HFRPP is responsive to most of the NAS recommendations. NAS recommendations which were not acted upon, as discussed in Enclosure 2, will be considered in future revisions to the HFRPP.

The enclosed HFRPP represents the best estimates of the RES staff for human factors research products for the near term (i.e., 1988-1990). It also encompasses recommendations for longer term research to support anticipated needs.

The Office of Nuclear Reactor Regulation. NRR initiated significant programs in the area of human factors following the accident at Three Mile Island. Those programs addressed control room design, safety parameter display systems, emergency operating procedures, training of plant personnel and operator examinations and licensing. The emphasis of NRR's human factors programs has been on licensing issues. As the programs addressing licensing issues near completion, that emphasis is gradually shifting to plant operations and maintenance issues. To support this shift, NRR has become involved in the evaluation of performance and the assessment risk associated with human factors issues. A summary of NRR's human factors programs related to licensing and operations and management issues is provided as Enclosure 3.

The Office for Analysis and Evaluation of Operational Data. Several AEOD programs identify and evaluate human factors concerns related to the safe operation of nuclear power plants. The programs include an ongoing review of operating experience using licensee event reports (LERs) as well as Incident Investigation and Diagnostic Evaluation Team Programs. Information from LERs is also monitored as part of the Performance Indicator Programs. AEOD's Technical Training Center (TTC) supports NRR's human factors activities by training staff members involved in emergency operating procedure reviews and operator licensing. In the future, as time is available, the TTC simulators may be used for human factors research projects supported by RES.

In addition, the AEOD evaluation of nonreactor events includes human factors considerations. Specific studies in this regard have involved medical misadministrations, radiography, and loss of integrity of sealed sources. Current studies include an assessment of both human performance and equipment reliability for large irradiator events.

A summary of AEOD's human factors programs is provided as Enclosure 4.

The Office of Nuclear Material Safety and Safeguards. Up to now, the NRC human factors programs have concentrated on power reactors. However, NMSS is taking steps to develop human factors programs for NMSS licensees.

One of the Study Groups established in support of the Strategic Plan evaluated how human factors should be considered in regulating nuclear materials. The Group concluded that human factors were important to materials safety, and that, because of the large numbers of different types of licenses involved, a study was needed to prioritize human factors needs for each type of licensee. The Group suggested a "matrix approach" to correlate human factors with various types of licensees.

NMSS will pursue development of a human factors program and establish priorities in coordination with RES. NMSS has hired a fulltime human factors specialist who will work closely with management in developing the program. Although it will take time to review the wide variety of materials licensees and human factor issues, some examples of priority areas are: medical misadministrations, radiography safety, and contingency planning.

Victor Stello, Jr.
Executive Director
for Operations

Enclosures:
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ENCLOSURE 1

Enclosure 1

HUMAN FACTORS RESEARCH PROGRAM PLAN

Prepared By

The

Office of Nuclear Regulatory Research

United States Nuclear Regulatory Commission

May 1988

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HUMAN FACTORS RESEARCH PROGRAM PLAN

OFFICE OF NUCLEAR REGULATORY RESEARCH

UNITED STATES NUCLEAR REGULATORY COMMISSION

1.0 INTRODUCTION.

The fundamental mission of the Nuclear Regulatory Commission (NRC) "...is to regulate those who commercially use or produce nuclear material so that the public health and safety, the common defense and security, and the environment are protected."[1] Both the NRC and the industry it regulates recognize that humans can favorably or adversely affect the performance of systems which process or use nuclear materials. This recognition has driven efforts to improve safety by reducing "human error." For example, the Three Mile Island accident led to NRC requirements addressing nuclear power plant staffing and qualifications, emergency operating procedures, control room design, and the safety parameter display system.[2] The nuclear industry developed and implemented plans to resolve concerns in these areas based on the NRC requirements.

1.1 Human Factors. NRC and industry efforts to reduce human error fall within the scope of "human factors." Human factors is a system-oriented, technical discipline that integrates knowledge from a number of other disciplines (e.g., engineering, psychology, physiology, health, and education). Implicit in the discipline's system orientation is a broad

definition of system. This definition includes the hardware, software, and people who function to satisfy system goals (e.g., for a nuclear power plant it would include not only operators but maintainers, managers, emergency response team members, and others). The definition of system used here also includes other functional elements such as procedures and personnel selection and training programs.

Human factors attempts, through a process of evaluation and improvement, to assure that the humans within a system can perform their tasks in a manner that satisfies system goals. The process of human factors evaluation and improvement involves a number of functions. Those functions are:

1. Identification of the performance requirements placed upon humans by the systems of which they are a part

2. Identification of human performance capabilities

3. Evaluation of the influence various factors (i.e., performance shaping factors) have on those capabilities

4. Evaluation of a system's human performance requirements against known human performance capabilities to identify human factors concerns (i.e., situations where human performance requirements may exceed human performance capabilities)

5. Review of the significance of these concerns in relation to system goals (e.g., safety, availability, cost)

6. Development and verification of alternative approaches to resolve human factors concerns considered to be significant

7. Comparison of the impacts of the alternative approaches on the full set of system goals

8. Implementation of a preferred alternative and monitoring to see its impact on achievement of system goals

As implied by Function 8, the process of human factors evaluation and improvement is frequently iterative. For example, the process can be used throughout the life of a nuclear power plant and may be particularly useful when there are changes in plant hardware (e.g., installation of technologically advanced equipment that promises significant improvement in plant performance).

Human factors concerns may be addressed by proposing changes either to reduce human performance requirements (e.g., automate equipment or improve the human-machine interface) or to improve human performance capabilities (e.g., improve personnel selection and training). Reduction of human performance requirements is often the more viable and potentially effective approach; however, improving human performance capability is appropriate for resolution of some human factors concerns. There may often be several viable proposals for resolving a particular human factors concern. In such a case, the alternatives should be compared carefully in terms of such issues as:

1. Effectiveness (immediate and long term)

2. Impact on other parts of the system

3. Ease of implementation

4. Cost (initial and continuing)

Effective resolution of a human factors concern frequently requires coordinated changes in several areas (e.g., improving the human-machine interface may be combined with changes to training and procedures) in order to assure that the full set of system goals is met.

1.2 Need for Human Factors Research. There have already been significant safety benefits from applying human factors principles to the nuclear industry. However, human factors concerns continue to be identified by events documented in Licensee Event Reports. While many of these events are not highly significant from a safety standpoint (e.g., a missed or late surveillance test of equipment), a number of them (e.g., those involving losses of safety system function[3]) do illustrate that human factors concerns have the potential to affect the public health and safety adversely. Continued protection of the public health and safety requires a process, such as that outlined in Section 1.1, to identify, evaluate, and resolve significant human factors concerns.

Other sources also point to the need for continued attention to human factors concerns. For example, a December 1986 report by the National Academy of Sciences (NAS)[4] recommends a "... transfer of advanced technology for improving human reliability to the nuclear industry." Introduction of some advanced technologies may be inevitable because replacements for currently installed instruments and controls are becoming unavailable. The unavailability of replacement parts is leading the industry to difficult decisions about instrument and control replacements or upgrades. Other factors (e.g., regulatory requirements such as the one for the safety parameter display system) may also be expected to result in the introduction of advanced technology into existing plants. Regardless of the reason for introducing more advanced technology, adequate information about how that technology affects human performance requirements and capabilities is needed. That information can be used to confirm success in cases where the reason for introducing more advanced technologies is to resolve human factors concerns. In other cases, that information can be used to provide guidance to assure that introducing advanced technology does not result in new, safety significant human factors concerns.

A February 1988 NAS report[5] makes two types of recommendations related to human factors research and nuclear safety. Recommendations of the first type are designed "... to facilitate the initiation, planning, management, conduct, and use of human factors research."[5] Recommendations of the second type identify "... specific research topics to be investigated by the NRC and the

rest of the nuclear community."[5] In sum, the NAS's recommendations call for a continued strong commitment by the NRC to support a broadly defined human factors research program.

Results of an Electric Power Research Institute (EPRI) project provide further support for continued attention to human factors at nuclear power plants. The EPRI project involved review of a sample of the summary reports submitted to satisfy the NRC's detailed control room design review requirements. Specific results[6] support the NAS's 1986 conclusion about the introduction of more advanced technology into existing plants. They also identify the need for research which confirms the effectiveness of some current approaches to resolving human factors concerns (e.g., panel layout enhancement) and the need for research in anticipation of potential human factors concerns (e.g., criteria for integrating new technology into existing control rooms).

The discussion above suggests that both the NRC and the nuclear industry need to enhance their abilities to identify human factors concerns, to evaluate those concerns for significance, and to resolve concerns which can adversely impact system performance and thereby threaten the public health and safety. Enhancement of current abilities to identify, evaluate, and resolve human factors concerns requires advances in knowledge about human performance capabilities and about the requirements and constraints placed upon those capabilities by systems that use or produce nuclear materials. To that end, the Office of Nuclear Regulatory Research (RES) has developed this Human

Factors Research Program Plan (HFRPP). Recommendations from the reports cited above, as well as requests for human factors research from within the NRC contributed to HFRPP development.

2.0 OVERVIEW OF THE HUMAN FACTORS RESEARCH PROGRAM PLAN

The HFRPP addresses both near and long term human factors research needs. Consistent with the NRC's research philosophy,[7] near term tasks will support timely regulatory decisions by providing independent expertise. Long term tasks will allow the NRC to anticipate problems of potential safety significance by providing new or expanded knowledge. The HFRPP also encompasses work to resolve human factors generic issues and to develop regulatory positions (e.g., rules, regulatory guides, etc.)

2.1 Objective of the Plan. In its Policy and Planning Guidance for 1987, the Commission commits "... to explore methods to better understand the causes of human error and to point to methods to reduce its incidence."[1] The objective of this plan is to outline the structure and content of a human factors research program designed to meet that commitment. The plan identifies the major areas within which NRC sponsored human factors research is expected to be conducted. An appendix to the plan summarizes ongoing and planned research in each of the areas. The plan also addresses issues such as program planning and coordination, task prioritization, plan update, and resource requirements.

2.2 Planning and Coordination. RES's Division of Reactor and Plant Systems (DRPS) is responsible for planning and coordinating the HFRPP. DRPS will prepare detailed plans for meeting human factors research needs identified by NRC Offices. Current or expected users include the Office of Nuclear Reactor Regulation (NRR), the Office for Analysis and Evaluation of Operational Data (AEOD), the Office of Nuclear Material Safety and Safeguards (NMSS), other divisions of RES, and the Regions. Research requests from users will be reviewed and any necessary clarification obtained. Available research products and ongoing research by the NRC and others (e.g., EPRI, the Institute for Nuclear Power Operations (INPO)), will then be reviewed for applicability. Additional research projects will be identified if ongoing research or the results of research already planned or completed can not satisfy the need.

HFRPP activities will be coordinated both inside and outside the NRC. Initial coordination within the NRC resulted in statements of human factors research needs from NRR[8], AEOD[9], NMSS[10], and RES.[11] A draft plan[12] for severe accident management research also identifies human factors research needs. HFRPP activities will be coordinated with those of the Severe Accident Management Research Plan to assure that those needs are met. Ongoing coordination within the NRC will help to assure that modified or new research needs are addressed when identified and that usable research products are developed and transferred to user Offices.

Coordination outside the NRC (e.g., with EPRI, INPO, the Halden Research Project, other international agencies, vendors, utilities, owners groups, national laboratories, professional organizations, consultants, and

colleges/universities) will provide important information about current and future developments. Proposed new systems and system modifications, human performance data, and programmatic issues related to the application of human factors technology to the production and use of nuclear materials will be of particular interest. DRPS will seek to develop coordinated or cooperative human factors research efforts with organizations outside the NRC in accordance with recommendations in the December 1986 and February 1988 NAS reports.[4,5] Prior to initiating most research tasks, a review of the applicability of research from other industries to the nuclear power industry will be performed by appropriate experts who are independent of the organization that may conduct the research.

2.3 Prioritization. Identified human factors research needs will be prioritized to assure that those most crucial to the NRC's mission are satisfied first and that other needs are satisfied in a timely manner. The prioritization process will address such issues as:

1. Does the research have significant potential for reducing risk associated with human performance at facilities which process or use nuclear materials?.

2. Is the proposed research technically feasible?

3. Is the schedule for completing the research timely (i.e., will licensing decisions be made before the research is completed and can be applied)?

4. Is the research directly related to resolving identified human factors generic issues? What is the priority of these issues (e.g., high, medium, or low)?

5. Is there a specific user need for the research?

6. Does the research cover areas that NRC reviews as part of its regulatory responsibilities?

7. What related work is ongoing at NRC or outside the agency?

8. Do the potential benefits justify the costs?

2.4 Update of the Plan. This plan will be revised periodically. DRPS will continue to seek formal statements of user needs, as those needs become apparent. Plan updates will reflect modified or new user needs as well as the resolution of any current needs resulting from research that has been completed.

2.5 Research Areas. The HFRPP encompasses five research areas. They are:

1. Human Performance and Human Reliability Assessment

2. The Human-Machine Interface

3. Procedures

4. Qualifications and Training

5. Organization and Management

Research tasks in these areas will enhance performance of the NRC mission by providing the analytical and experimental bases for guidance, recommendations, or requirements which work to reduce the likelihood of human errors that could adversely affect public health and safety. The broad issues and safety concerns addressed by these research areas are discussed below.

The process of evaluating human factors concerns and recommending improvements to resolve these concerns includes issues which transcend the five research areas described above. For example, a hypothetical human factors concern might be resolved by improving either the human-machine interface or by additional training. In such a case, the question is not what human-machine interface or training improvements can resolve the specific concern. Rather, it is which of the proposed improvements is a better resolution given system goals and constraints. A more typical example might involve resolution of a human factors concern through coordinated improvements in several areas (e.g., human-machine interface, procedures, and training). The question in this case is not how well any single approach works. Rather, it is the appropriate integration of approaches.

2.5.1 Human Performance and Human Reliability Assessment. Human factors concerns are identified by comparing human performance requirements with human performance capabilities. Research in this area will provide needed

information about human capabilities and the impact of various performance shaping factors (e.g., high temperature and humidity) on those capabilities. Research in this area will also, through appropriate comparisons, identify human factors concerns.

Human reliability assessment may be seen as a specialized area of human factors research. The NRC's human reliability assessment effort has two objectives. The first is to develop a data base of human error rates and to support methods for integrating human reliability assessments and segments of reliability evaluations into probabilistic risk assessments. The second is to develop tools which allow use of data generated by human reliability and probabilistic risk assessments to address unresolved and generic safety issues. Human reliability assessment can also support a comparison of alternative approaches to resolving safety significant human performance concerns.

2.5.2 The Human-Machine Interface. The human-machine interface is the link between humans and system hardware and software. Displays and controls are the most obvious elements of the human-machine interface, but other hardware and software are included (e.g., communications equipment). A safety concern may result when elements of the human-machine interface do not support an adequate level of human performance. For example, human error rates for safety-related tasks may be unacceptably high when vital information is difficult to find, difficult to read, difficult to interpret, or misleading.

Research tasks in the human-machine interface area will address a broad range of issues related to whether that interface supports an adequate level of human performance. Examples of important human-machine issues are:

1. Compatibility with human sensory, perceptual, and cognitive capabilities (e.g., vision, audition, and information processing)

2. Compatibility with human physical characteristics (e.g., height, reach, and strength)

3. Compatibility with human physiological characteristics and capabilities (e.g., heat tolerance, oxygen requirements)

Human-machine interface research will support comparison of human performance requirements against human performance capabilities. Research will also serve to confirm the effectiveness of human-machine interface modifications designed to resolve significant human factors safety concerns.

2.5.3 Procedures. Procedures are a means to assure that tasks are performed in a manner that satisfies system requirements. They typically provide information about:

1. Conditions indicating the need to perform a task

2. The sequence of task activities

3. Any constraints (e.g., time limits, warnings, and cautions)

4. Feedback indicating the effect of task performance

5. Conditions indicating the need to branch to other procedures

6. Conditions indicating that the task is complete

Procedures provide an appropriate resolution to some human factors concerns, but inadequate or poorly presented procedures can increase human error rates. Research in this area will serve to identify the need to implement or improve procedures designed to resolve human factors concerns. Research will also serve to confirm the effectiveness of proposed procedures or improvements to procedures.

2.5.4 Qualifications and Training. Human performance is related to the innate abilities and acquired knowledge and skills that are brought to a task. Thus, one approach to resolving human factors concerns is to select personnel based on their qualifications with respect to performance of tasks that are important to system performance. Another approach is to enhance knowledge and skills through training to improve task performance. The rationale for both these approaches is that human performance requirements are more likely to be met by greater human performance capabilities. The approaches are not mutually exclusive and, in fact, are often used together. Research in this

area will serve to identify the need to implement or improve qualifications and training of personnel who are parts of systems which use or produce nuclear materials. Research will also serve to confirm the effectiveness of proposals to implement or modify qualifications and training requirements.

2.5.5 Organization and Management. Human performance can be affected by a number of factors related to organizational design (e.g., staff size and composition, span of control) and management practices and decisions (e.g., shift scheduling, equipment selection). Changes in organization or management can affect either human performance requirements or human performance capabilities. For example, changes in staff size or composition can affect individual workloads (human performance requirements) while changes in shift length can affect such factors as fatigue (human performance capabilities). Research in this area will address the relationship between organization and management and human performance. It will also serve to confirm the effectiveness of proposed changes to organization and management for resolving human factors concerns.

Research on the influence of organization and management on human error rates will also provide tools by which plant safety performance can be monitored. This research will support the development of programmatic performance indicators.

2.6 Other Activities. Conduct of the HFRPP will involve related activities which are not, themselves, classified as research. For example, an NAS report[5] recommends that the NRC develop "... a bibliographic system for NRC-supported human factors reports." Activities of this type will be planned and conducted to the extent that they are necessary to assure the HFRPP's support of the NRC's mission.

3.0 RESOURCE REQUIREMENTS

As part of its responsibility for planning and coordinating the HFRPP, DRPS will prepare recommendations to the Director, RES for the resources needed (i.e., staff and budget).

3.1 Staffing. Management of the overall program and of individual human factors research tasks is the responsibility of the Reliability and Human Factors Branch (RHFB), DRPS. Because of the broad scope of human factors, the RHFB staff includes professionals with training and experience in several technical disciplines (e.g., psychology, engineering, computer systems, industrial organization). Human factors research tasks will be carried out by national laboratories, colleges and universities, and private industry. Qualified sources will have experienced human factors staffs with multi-disciplinary capabilities (e.g., engineering, operations, and psychology).

3.2 Budget. Budget projections for the human factors research program for fiscal years (FYs) 1988-1992 are shown below:

Human Factors and Human Reliability Research Budget ($1,000s)

	FY 1988	FY 1989	FY 1990	FY 1991	FY 1992
Human Performance and Human Reliability Assessment	1,365	1,705			
Human-Machine Interface	1,051	1,394			
Procedures	665	1,124			
Qualifications and Training	488	695			
Organization and Management	661	1,169			
TOTALS	4,230	6,086	7,550	6,650*	6,650*

Details of FY 1990 - 1992 budgets to be determined

* Budget decrease in FY91 and FY 92 is based on the assumption that currently identified human factors generic issues will be completed and no additional ones will be identified and performance indicator work will reduce.

3.3 Schedule. Schedules for research tasks are documented and tracked in the Research Project Management Information System. Schedules for research related to generic issues and the resolution of those issues are documented and tracked in the Generic Issue Management Control System.

4.0 REFERENCES

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4. National Research Council. Revitalizing Nuclear Safety Research. National Academy Press, Washington, DC. December, 1986.

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6. Electric Power Research Institute. NP-5795, Control Room Deficiencies, Remedial Options, and Future Human Factors Research Needs. Electric Power Research Institute, Palo Alto, CA. In press.

7. Memorandum from E. S. Beckjord to RES staff. Subject: "Nuclear Regulatory Research Philosophy," dated May 4, 1987.

8. Memorandum from T. E. Murley to E. S. Beckjord. Subject: "Human Factors Research Program," dated November 9, 1987.

9. Memorandum from E. L. Jordan to B. W. Sheron. Subject: "Human Factors Research and AEOD Needs," dated September 4, 1987.

10. Memorandum from H. L. Thompson to E. S. Beckjord. Subject: "Human Factors Research Program," dated March 23, 1988.

11. Memorandum from B. M. Morris to B. W. Sheron. Subject: "Request for Research Needs in the Area of Human Factors and Human Reliability," dated November 9, 1987.

12. Office of Nuclear Regulatory Research, Division of Reactor and Plant Safety, Reliability and Human Factors Branch. Draft Severe Accident Management Research Plan, dated November 3, 1987.

HUMAN FACTORS RESEARCH PROGRAM PLAN

APPENDIX

SUMMARY OF HUMAN FACTORS RESEARCH PROJECTS

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SUMMARY OF HUMAN FACTORS RESEARCH PROJECTS

1.0 INTRODUCTION.

This appendix provides brief summaries of the ongoing projects and planned research in each of the five areas of the Human Factors Research Program Plan (HFRPP). Additional project descriptions will be included in updates to this plan as they are developed. This appendix also provides information on other ongoing and planned activities to support the HFRPP.

Topics discussed under planned research include needs identified by the Office of Nuclear Reactor Research[1] (NRR), the Office of Nuclear Material Safety and Safeguards[2](NMSS), the Office for Analysis and Evaluation of Operational Data[3] (AEOD), and divisions of the Office of Nuclear Regulatory Research[4,5] (RES) as well as recommendations by the National Academy of Sciences[6] (NAS). These needs and recommendations are not yet addressed by ongoing research projects but are being reviewed and prioritized. The review and prioritization process is intended to develop an integrated approach for addressing human factors concerns and, thereby, to optimize the use of research resources. For example, identified needs within a single research area may be consolidated under one research project. In other cases, review of a particular need may indicate that the objectives of the requested research are unclear. In such a case, RES will work with the office identifying the need to clarify it to a point where useful research is viable. Because of limited resources, development of viable research projects to address every identified need may not be possible. Review and prioritization of the needs may also indicate that some are not sufficiently related to safety to warrant further Nuclear Regulatory Commission (NRC) sponsored research.

In addition to the programs summarized below, the HFRPP is expected to benefit from NRC participation in the Halden Research Project. The NRC is particularly interested in Halden's efforts in the following areas:

1. Computer-Based Procedures

2. Verification and Validation of Software

3. Disturbance Analysis Systems

4. Human Factors Aspects of Advanced Instrumentation and Controls

5. Operator Training Methods

Results of Halden's tasks in these areas are expected to provide useful information in the areas of nuclear power plant human-machine interfaces, procedures, and qualifications and training.

2.0 SUMMARIES OF ONGOING AND PLANNED RESEARCH.

2.1 Human Performance and Human Reliability Assessment.

Research projects in this area will identify basic human performance capabilities and the impact of performance shaping factors on those capabilities.

Research in this area will also identify situations in which human performance requirements exceed human performance capabilities. Finally, this area includes activities to estimate human error rates.

2.1.1 Ongoing Projects in the Area of Human Performance and Human Reliability Assessment.

2.1.1.1 Acquisition of Human Performance Data. The goal of this project is to collect data for use in estimating human error rates. Data will be obtained from the commercial nuclear power industry and from other sources. Data from sources outside the industry will be used when industry data are sparse or unobtainable and will serve primarily as "anchors" for estimating human error rates in nuclear power plants.

2.1.1.2 Data Base on Human Failure Rates. The goal of this project is to develop a comprehensive data base system for storing and processing human error and hardware failure rate data. This system, known as the Nuclear Computer Library for Assessing Reactor Reliability, will be the primary repository for data that were collected as part of AEOD's Integrated Risk Assessment Data Acquisition Program.

2.1.1.3 Cognitive Model to Predict Intended Human Action During Emergencies. The goal of this project is to develop and evaluate better methods for modeling the cognitive behavior of nuclear power plant personnel in situations involving plant safety. The project will concentrate on an artificial intelligence model of how utility personnel (including supervisors and

managers) form intentions to act in emergencies. The success of this project will result in a model capable of providing input to human reliability and probabilistic risk assessments.

2.1.1.4 Integrate Human Reliability Assessments into Probabilistic Risk Assessments. The goal of this project is to integrate human reliability assessments into the probabilistic risk assessment process. This integration will result in more realistic assessments of the human's overall contribution to nuclear power plant safety. The project will also permit improved analysis of data related to unresolved and generic safety issues.

2.1.1.5 Maintenance Personnel Performance Simulator. Human error during maintenance can be a major contributor to nuclear power plant safety concerns. For example, a 1984 staff study[7] determined that maintenance and testing activities were involved in 70% of those events that resulted because actions were performed on equipment in the wrong unit (of multi-unit sites) or wrong train (within a single unit). A more recent Licensee Event Report Compilation[8] (October 1987) showed that 20 of the 50 operational events involving human factors concerns were related to maintenance or surveillance. In response to this concern, the NRC sponsored development and validation of a computer model for evaluating maintenance practices and procedures at nuclear power plants. The Maintenance Personnel Performance Simulation (MAPPS) model is capable of simulating corrective and preventive maintenance tasks performed under both normal and abnormal plant conditions. MAPPS can be used to

evaluate existing maintenance practices and procedures as well as proposed improvements to those practices and procedures. The current goals of this project are to:

1. Collect data on the transferability and usefulness of MAPPS as a diagnostic and design tool to enhance maintenance practices and procedures

2. Analyze data from participating plants to identify common tasks which yield abnormally high success and failure probabilities, and, to the degree possible, determine the causal factors associated with those abnormally high probabilities

2.1.1.6 Criteria for Safety-Related Operator Actions. Current nuclear power plant designs require operator action in response to certain transients and accidents. NUREG-0471[9] identified a concern about whether operators would, under all conditions, have sufficient time to perform the actions required of them during transients and accidents. Generic Safety Issue B-17 responds to this concern by supporting development of time criteria for safety-related operator actions. These criteria will allow one to determine whether operators have sufficient time to perform actions required of them during transients and accidents or whether automatic actuations are required.

2.1.2 Planned Research in the Area of Human Performance and Human Reliability Assessment.

2.1.2.1 Operator Performance Under Extreme Conditions. There is little information about human task performance under extreme conditions that might reasonably occur during or after certain plausible events (e.g., high temperature and humidity, reduced lighting, and conflicting control panel indications during station blackout). NRR has requested research[1] to obtain information on human cognitive and physical performance under extreme conditions.

2.1.2.2 Severe Accident Management -- Habitability. Severe accidents might require nuclear power plant personnel to perform tasks under extreme environmental conditions. The Severe Accident Management Research Plan[5] identifies the need for research to determine what environmental conditions are to be expected during severe accidents and what protective measures will be required for personnel to perform under those conditions. Research on this topic and on "Operator Performance Under Extreme Conditions" (2.1.2.1 above) are expected to be merged.

2.1.2.3 Performance Indicators for Cognitive Errors. This project responds to an AEOD request[3] for a performance indicator for cognitive error. Research on this topic is expected to be based on results of the project to develop a "Cognitive Model to Predict Intended Human Action During Emergencies" (2.1.1.3 above).

2.1.2.4 Human Error Data Bank (Probabilistic Risk Assessment Methods). This project responds to a request from RES's Division of Regulatory Applications.[4] Plans to address this request are expected to be formulated as part of efforts to develop a "Data Base on Human Failure Rates" (2.1.1.2 above) and to "Integrate Human Reliability Assessments into Probabilistic Risk Assessments" (2.1.1.4 above).

2.1.2.5 Other Planned Research in the Area of Human Performance and Human Reliability Assessment. Research on two additional human performance and human reliability assessment topics has been requested[1]. The topics are:

1. Operator Performance Under the Stress of Emergency Operations
2. Advanced Control Rooms -- Evaluation of Operator Performance in Existing Control Rooms
3. Human factors in the transportation of spent fuel and other Type B packages

Summaries of the proposed work will be provided following coordination between RES and the requesting offices to clarify the objectives of the requested research.

2.2. The Human-Machine Interface.

Research projects in this area will support comparison of human performance requirements against human performance capabilities. It will also serve to confirm the effectiveness of human-machine interface modifications designed to resolve significant human factors safety concerns.

2.2.1 Ongoing Projects in the Area of the Human-Machine Interface.

2.2.1.1 Local Control Stations. Detailed control room design reviews at nuclear power plants have identified many displays and controls in the control room that exhibit human engineering discrepancies (i.e., features which are not consistent with accepted human factors principles). These discrepancies indicate a poor human-machine interface, and they are being resolved when assessment indicates that they can contribute to safety significant operator errors.

Documented (e.g., Davis Besse[10], Rancho Seco[11]) and undocumented reviews of local control stations (i.e., stations outside the control room) at nuclear power plants indicate that some displays and controls at these stations also suffer from human engineering discrepancies. Generic Issue HF 5.1 addresses this concern. Its resolution involves efforts to determine and quantify the risk to public health and safety resulting from poor human-machine interfaces at nuclear power plant local control stations. Results are expected to establish the magnitude of the risk involved, the potential for risk reduction, and the need for regulatory action to resolve human factors concerns at local control stations.

2.2.1.2 Control Room Design Standard. This project responds to item (now Generic Safety Issue) I.D.4 of NUREG-0660[12]. The planned resolution of the item was NRC development of a regulatory guide based on evaluation of industry control room design standards. RES review indicates that all operating plants and current applicants are conducting detailed control room design reviews in

response to NUREG-0660[12] item I.D.1. NUREG-0700[13] and acceptable alternatives are being used as control room design standards for this effort. Applications for future light water reactors shall include, per 10 CFR 50.34(g)[14], an evaluation of the facility against the Standard Review Plan[15]. Section 18.1 of that document addresses control room design and references NUREG-0700[13] as appropriate guidance for control room design.

Generic Safety Issue I.D.4 has been resolved by industry compliance with NUREG-0660[12] item I.D.1 and 10 CFR 50.34(g)[14]. Therefore, the generic issue has been closed. Standards for incorporating advanced technologies into existing control rooms and for advanced control rooms will be addressed by other projects within the HFRPP.

2.2.1.3 Improved Control Room Instrumentation. Generic Issue HF 5.2 was originally conceived as a broad issue addressing:

1. Computers and Computer Displays

2. Evaluation of Operator Aid Systems

3. Annunciators

4. Safety Status Indication and Applications of Automation and Artificial Intelligence

A review of this issue resulted in a decision to retain only the activities related to annunciators under the generic issue. The three other activities are being evaluated under a project entitled "Review Criteria for Human Factors Aspects of Advanced Control and Instrumentation" (See 2.2.1.4 below).

Research to resolve Generic Issue HF 5.2 will evaluate human factors concerns related to annunciators in nuclear power plant control rooms. The first step will be to determine the risk to public health and safety resulting from human error in the use of information from control board annunciators through the use of probabilistic risk assessment. Results will establish the magnitude of the risk involved and the potential for risk reduction through annunciator system improvement. A subsequent value/impact analysis will compare the cost of potential annunciator system improvements with potential risk reductions and will serve as an aid in determining whether regulatory actions are needed to address human factors concerns with annunciator systems. If regulatory actions appear necessary, additional research may be needed (e.g., a program to evaluate alarm reduction techniques). Results from other research (e.g., Halden's work on advanced alarm systems or the Electric Power Research Institute's work on annunciator systems) may also be used in developing appropriate regulatory actions.

2.2.1.4 Review Criteria for Human Factors Aspects of Advanced Controls and Instrumentation. The initial effort on this project will identify specific human factors concerns related to "high technology" modifications of existing

control rooms. Subsequent efforts will prioritize any safety concerns which are identified and, as appropriate, develop regulatory actions to resolve the concerns.

As part of the initial effort, the NRC is sponsoring a survey of the commercial nuclear industry's current and planned use of artificial intelligence, expert systems, and digital computers. The survey will identify existing and proposed uses of these high technology systems and, for proposed systems, the schedule for their implementation. The survey will also address the proposed use of such high technology systems in the advanced control room designs being developed by nuclear steam supply system vendors. As noted above, safety concerns identified by the surveys will be prioritized. Resources will then be allocated to resolving those concerns based on their priority.

2.2.2 Planned Research in the Area of the Human-Machine Interface.

2.2.2.1 Computer Classification. This project will respond to an NRR user need[1]. Its goal is to develop guidance and criteria for qualification of the various safety and non-safety applications of digital computer systems. Computers are being used increasingly at nuclear power plants to provide information to operators. In many cases the quality of the computer system is not appropriate to the way the information is being used. The guidance and criteria developed by this project will apply to the design, test, verification and validation, maintenance, and reliability of computer systems.

2.2.2.2 Impact of Over Reliance on the Safety Parameter Display System (Confirmatory Research Using Simulators). This project will respond to an NRR user need[1]. Staff evaluation of safety parameter display systems (SPDSs) implemented in nuclear power plants indicates that there is potential for over reliance on the SPDS during transients and accidents. There is also potential for underuse of the SPDS and for use by inappropriate personnel. This research project will examine the impact of SPDS misuse on safety.

2.2.2.3 Expert System Verification and Validation Methodology. This project will respond to an NRR user need[1] and to an NAS recommendation[6]. Its goal is to develop acceptance criteria and guidelines for the evaluation of expert systems. Artificial intelligence and expert systems are being introduced into nuclear power plants. These computer programs cannot be verified and validated using methods now available. This project will provide tools for evaluating expert system verification and validation methods.

2.2.2.4 Sealed Source Devices. NMSS has requested[2] that safety concerns involving sealed source devices be studied. The use of sealed sources in radiographic devices leads to a substantial fraction of documented overexposures, and the use of sealed sources in large irradiators has the potential for creating significant problems if mishandled. Safety concerns with sealed sources have been traditionally linked to inadequate human-machine interfaces. This project will identify, evaluate, and propose resolution of human-machine interface concerns with devices using sealed sources.

2.2.2.5 Improvements to Annunciator Systems. This project will respond to an NRR request[1]. This request is expected to be addressed by the project on "Review Criteria for Human Factors Aspects of Advanced Controls and Instrumentation" (2.2.1.3 above).

2.2.2.6 Impact of High Technology on Control Room Operators. Coordination between RES and NRR related to a request for this research[1] is expected to identify the need to address potential high technology modifications to existing control rooms other than artificial intelligence, expert systems and digital computers. The research approach for these modifications is expected to be similar to that used in the project to develop "Review Criteria for Human Factors Aspects of Advanced Controls and Instrumentation" (See 2.2.1.4 above).

2.2.2.7 Other Planned Research in the Area of the Human-Machine Interface. Research on two additional human-machine interface topics has been requested.[1, 4] The topics are:

1. Advanced Control Rooms -- Design Standard
2. Advanced Reactors -- Human-Machine Interface

Summaries of the proposed work will be provided following coordination between RES and the requesting office to clarify the need.

2.3 Procedures.

Research in this area will serve to identify the need to implement or improve procedures designed to resolve human factors concerns. Research will also serve to confirm the effectiveness of newly proposed procedures or improved procedures.

2.3.1 Ongoing Projects in the Area of Procedures.

2.3.1.1 Guidelines for Upgrading Other Procedures. The goal of this project is to resolve Generic Issue HF 4.4 through development of technical guidelines for upgrade of normal and abnormal operating procedures similar to those developed for emergency operating procedures. Results of one study[16] conducted under this program indicate a number of ways in which normal and abnormal procedures in nuclear power plants are discrepant from accepted human factors principles. The NRC is currently funding a value/impact assessment to determine which improvements to current industry programs for developing and implementing operating procedures will result in meaningful reduction in risk to public health and safety.

2.3.2 Planned Research in the Area of Procedures.

2.3.2.1 Presentation of Emergency Operating Procedures (Confirmatory Research Using Simulators). This project will respond to an NRR request[1]. Operators and others in the nuclear power industry have expressed concern about the size and complexity of Emergency Operating Procedures (EOPs). Most

EOPs are written in text format. Others are written in flow/chart or a combination of text and flowchart format. Computerized EOPs may be developed in the near future. Little is known regarding the safety implications involved in the different methods of presenting EOPs. This research project will address the safety impact of issues related to presentation of EOPs.

2.3.2.2 Chernobyl Follow-up -- Procedure Violations. Procedure violations at nuclear power plants are committed by licensed and auxiliary operators, plant technicians, maintenance personnel, and contractors. While the NRC believes that procedure violations are infrequent and rarely committed intentionally, the exact nature and extent of these violations and their consequences is unknown. This project will determine the extent and nature of procedure violations in nuclear power plants.

2.3.2.3 Materials and Fuel Cycle Procedures. Holders of materials and fuel cycle licenses are required to have and to follow procedures for all operations associated with nuclear materials. There has been no systematic review of these procedures for human factors concerns. NMSS has requested[2] such an effort. The project will identify, evaluate, and propose resolutions to safety significant problems with procedures used by materials and fuel cycle licensees.

2.3.2.4 Other Planned Research in the Area of Procedures. Research on one additional procedures topic has been requested.[4] That topic is:

Advanced Reactors -- Accident Management Procedures.

A summary of the proposed work will be provided following coordination between RES and the requesting office to clarify the need.

2.4. Qualifications and Training.

Research in this area will serve to identify the need to implement or improve qualification and training resolutions for human factors concerns. Research will also serve to confirm the effectiveness of proposals to implement or modify qualification and training requirements.

2.4.1 Ongoing Projects in the Area of Qualifications and Training.

There are no ongoing research projects in this area.

2.4.2 Planned Research in the Area of Qualifications and Training.

2.4.2.1 Training Effectiveness. This project responds to an NRR request[1] and an NAS recommendation.[6] The objective of the research will be to develop guidelines for evaluating the adequacy of the various methods and devices used currently by the nuclear industry for acquiring and maintaining operational skill.

Although the industry has committed to the Institute for Nuclear Power Operation's (INPO) accreditation program, it has not thus far demonstrated that there is a correlation between individual training and performance. This may be due to inconsistencies in the degree to which individual utilities

adhere to the INPO guidelines. This project will explore the degree of success of the current industry efforts to improve training. It will build on work done in both nuclear and non-nuclear areas to develop methods and criteria for measuring the effectiveness of the various training methods.

2.4.2.2 Personnel Qualifications. This project responds to an NAS recommendation.[6] Regulatory Guide 1.8, "Personnel Selection and Training," endorses ANSI Standard N18.1-1971. Together these documents provide holders of nuclear power plant licenses with guidance on acceptable personnel qualifications. The Regulatory Guide has not been updated with respect to qualifications of personnel other than licensed operators. However, errors by other personnel can affect safety. For example, maintenance personnel perform a large number of safety-related tasks of various levels of difficulty, at widely varying time intervals, and under stressful environmental conditions. This project will identify the need for development of qualifications criteria for personnel other than operators at nuclear power plants.

2.4.2.3 Training for Rare and Difficult Events. This project responds to an NAS recommendation.[6] The issue to be addressed is whether the operator and other utility personnel are trained adequately to deal with rare and difficult events. The project will consist of two phases. Phase 1 will address the engineering skills required for dealing with the occurrence of initiating events and safety system unavailabilities. Phase 2 will address the personality traits required for dealing with rare and difficult events, such as cognitive action, communication, and decision making.

2.4.2.4 Long Term Program on Training. This project responds to an NAS recommendation.[6] It will develop a systematic framework for defining the goals of a long term NRC research project on training. The experience gained from research on "Training Effectiveness", and on "Training for Rare and Difficult Events" (see 2.4.2.1 and 2.4.2.3 above) will assist in formulation of the plan for a long term effort. Several questions will be addressed (e.g., what topics should be explored by the NRC, how joint NRC/industry effort can be achieved, how related research and implementation efforts can be integrated). Results this effort will aid in determining the scope of any long term research program on training by the NRC.

2.4.2.5 Qualifications and Training of Materials and Fuel Cycle Licensees. This project responds to an NMSS request.[2] Qualifications and training are especially important for fuel cycle licensees, nuclear medicine licensees, radiographers, and irradiators. The project will identify and evaluate concerns related to the qualifications and training of such personnel. Regulatory activities to resolve safety significant concerns will be proposed.

2.4.2.6 Other Planned Research in the Area of Qualifications and Training. Research on two additional qualifications and training topics has been requested by user offices[5] or recommended by the NAS.[6] They are:

1. Severe Accident Management -- Training
2. Degree Requirements for Senior Reactor Operators

Summaries of any work proposed on these topics will be provided following coordination between RES and other offices to establish or clarify user needs.

2.5. Organization and Management.

Research in this area will address the relationship between organization and management and human performance to resolve human factors concerns. It will serve to confirm the effectiveness of proposed management and organization changes and to provide tools by which plant safety performance can be monitored.

2.5.1 Ongoing Projects in the Area of Organization and Management.

2.5.1.1 Shift Staffing. The goal of this project was to respond to Generic Issue HF 1.1 by determining the appropriate composition and minimum size of a shift crew for operation of a nuclear power plant. This goal was met by the "Licensed Operator Staffing Rule" which is now part of 10 CFR 50.54[14].. Two tasks remain. They are revision of Regulatory Guide 1.114 "Guidance to Operators at the Controls and to Senior Operators in the Control Room of a Nuclear Power Unit"[17] and of Standard Review Plan[15] Section 13.1.2 "Operating Organization" to conform to the Licensed Operator Staffing Rule.

2.5.1.2 Management/Organization Influence on Human Error Rate. The goal of this project is to develop methods to identify and evaluate the influences of supervisory and management policies, practices, and behavior on the safety performance of nuclear power plant personnel. Tasks to be undertaken in support of this goal include the following:

a. Develop an organization model of the site-specific operational units (operators, maintenance technicians, instrument and control technicians, etc.) that can impact nuclear power plant reliability. Indicate the relationship between these operational units and other site-specific units (e.g., security), corporate units (e.g., purchasing) and non-utility units (e.g., contractors).

b. Use the organization model to identify supervisory and management positions which may affect performance reliability.

c. Refine the organization model to pinpoint supervisory and management positions which may affect performance reliability.

d. Develop methodologies which can be used to evaluate supervisory and management factors affecting performance reliability.

e. Develop probability estimates of human reliability performance as a function of identified management and organizational factors.

2.5.1.3 Management Impact on Plant Safety. This project is based on the "Management/Organization Influence on Human Error Rates" project (see 2.5.1.2 above) and has the same basic objectives. Data from the "Management/ Organization Influence on Human Error Rates" project will be used to develop a set of performance indicators associated with management actions that could affect plant safety. Results of these projects will provide a method to determine trends in management effectiveness. Such a method could be useful to the current performance indicator program and will complement planned research on "Programmatic Performance Indicators" (see 2.5.1.4 below) Conversely, data collected by the program can be used to validate results of this program and the program on "Management/Organization Influence on Human Error Rates."

2.5.1.4 Programmatic Performance Indicators. The performance indicators provide an objective view of nuclear power plant operational performance and enhance the NRC's ability to recognize changes in plant safety. This new project on Programmatic Performance Indicators will enhance the NRC's ability to forecast poor or declining performance, particularly with respect to human factors. The goal is to develop indicators of the effectiveness of all plant programs affecting safety. Initial activities will identify indicators of maintenance and training effectiveness, and determine the most appropriate methods to validate these indicators. Long term efforts will include the development of indicators of both the thoroughness and effectiveness of plant programs such as maintenance, operations, training, radiation control, quality assurance, and management.

2.5.2 Planned Research in the Area of Organization and Management.

2.5.2.1 Shift Scheduling and Overtime. This project will respond to an NRR user need [1] and to the Commission's direction to the staff to explore development of a performance indicator associated with overtime practices at Nuclear Power Plants. Recent occurrences of operators sleeping on shift have identified the need to evaluate the safety significance of long work hours on the part of the operator. This project will build on previous NRR work[18] and will provide a quantitative basis for addressing nuclear power plant operator performance problems resulting from fatigue due to overtime and shift scheduling practices in nuclear power plants. NRC policies are based on non-nuclear experience and expert judgement. This project will provide a basis for evaluating and updating the current policies based on overtime and shift scheduling at nuclear power plants.

2.5.2.2 Shift Length (Confirmatory Research Using Simulators). This project will respond to an NRR user need[1] and to an NAS recommendation[6]. The research will focus on ways in which the state of knowledge outside the nuclear arena, especially in the area of vigilance, can be applied to nuclear power plant operations. As the NAS recommends, it will explore biological, social and environmental based solutions as opposed to hardware solutions. Issues such as boredom, work load, social interactions, and sleep-wake cycle will be considered.

2.5.2.3 Operating Staff Size and Composition (Confirmatory Research Using Simulators). This project will respond to an NRR user need[1]. Other personnel in addition to licensed operators (e.g., auxiliary operators, instrument and control technicians, radiation and chemistry technicians, health physics personnel, and maintenance personnel) play major roles during transients and accidents and during abnormal operations. Errors by any of these personnel may result in unnecessary challenges to safety systems or to significant safety concerns. The contribution of these personnel to risk has not been systematically reviewed. This project will address the contribution to risk of errors committed by personnel other than operators.

2.5.2.4 Team Performance. This project responds to an NRR user need[1]. The NRC presently evaluates a licensee's team performance during reviews such as emergency operating procedure audits or inspections, training audits or inspections, requalification and initial examinations and sometimes during incident reviews. However, adequate evaluation criteria for team performance are presently not available. The objective of this project is to develop such criteria. The scope of the work includes: identifying team skills, developing team evaluation criteria, simulator and field testing of criteria, and correlating measures of team performance with measures of safety.

2.5.2.5 Shift Technical Advisor Role and Function. A program addressing the Shift Technical Advisor may be developed in response to an NAS recommendation[6]. A pending Commission decision on degree requirements for Senior Reactor

Operators may affect the role of Shift Technical Advisers. Thus, the staff will evaluate the need for such a program after the Commission has decided the issue of degree requirements for Senior Reactor Operators.

2.5.2.6 Performance Based Regulation. This project will respond to Commission guidance[19] and an NAS recommendation[6]. The objective will be to assist implementation of the Commission's intent "to shift its regulatory emphasis away from detailed requirements toward a more general, performance-based requirements."

2.5.2.7 Other Planned Research in the Area of Organization and Management. Research on several additional organization and management topics has been requested by user offices[2, 5] or recommended by the NAS[6]. They are:

1. Severe Accident Management -- Organization
2. Organization and Management Influence on the Safety Performance of Materials and Fuel Cycle Licensees
3. Organizational Design and a Culture of Reliability
4. Operational Decision Making
5. Timely Recognition of Emergencies
6. Characteristics of Managers

Summaries of any work proposed on these topics will be provided following coordination between RES and other offices to establish or clarify user needs.

2.6 OTHER ACTIVITIES

Conduct of the HFRPP will involve related activities which are not, themselves, classified as research. Such activities will be planned and conducted to the extent that they are necessary to assure the HFRPP's support of the NRC's mission.

2.6.1 Ongoing Projects in Other Activities.

2.6.1.1 Event Reporting. This project responds to an NRR request[1]. Present reporting systems identify human factors concerns which contribute to reportable events, but they often do not provide sufficiently detailed causal information. This project is developing a structured protocol that can be used by NRC personnel to identify human factors concerns which were at the root of, or contributed to, reportable events.

2.6.2 Planned Research in Other Activities.

2.6.2.1 Human Factors and Materials Licensing. A Study Group supporting development of the NRC's Strategic Plan has concluded that human factors is an important concern in materials licensing. That group also produced a matrix 20 of "best-judgments" about the most effective means for resolving human factors concerns related to the broad spectrum of licensees in question. NMSS has requested[2] a detailed follow-up of the Study Group's activities related to

human factors. The objective of those activities is "... to develop a good agenda with suitable priorities to obtain more effective treatment of human factors in materials licensing."

2.6.2.2 Bibliographic System for NRC-Supported Human Factors Reports. The NAS[6] recommended that "mechanisms to improve the dissemination of human factors results throughout the industry be developed." As a first step, the panel recommended "... development of a bibliographic system for NRC-supported human factors reports." In response, RES initiated a project to: (1) identify the desired characteristics of a human factors state of knowledge system; (2) determine which of those characteristics can be satisfied by human factors information systems currently available to RES through the NRC Library, Public Document Room and Department of Energy Laboratories; (3) develop a specification for computer software to download information from currently available systems and to accommodate information from sources not available to those systems, and (4) do a cost analysis for developing a computer software package responding to the characteristics identified under (1) and taking advantage of existing information system resources determined under (2).

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ENCLOSURE 2

Enclosure 2

STAFF USE OF THE NAS RECOMMENDATIONS FOR HUMAN FACTORS RESEARCH

The purpose of this enclosure is to describe to the Commission the staff's use of National Academy of Sciences (NAS) study panel recommendations for human factors research. The NAS panel, comprised of experts in the areas of the behavioral and social sciences (human factors), nuclear power operations and nuclear physics, was brought together in response to a grant from the Commission (ref: SECY-85-353 dated November 6, 1985, and Commission concurrence dated December 19, 1985). The panel's charge was to identify study areas in current and recent human factors programs that may have received inadequate attention and to provide guidance for human factors research that could enhance the safe operation of nuclear power plants. In February 1988, the study panel published its findings and recommendations in a report titled, "Human Factors Research and Nuclear Safety." The report makes two types of recommendations: (1) Recommendations 1 through 6 to .... "facilitate the initiation, planning, management, conduct and use of human factors research," and (2) Recommendation 7 ..."on specific research topics to be investigated by the NRC and the rest of the nuclear community" (p. 2).

The remainder of this enclosure presents the NAS recommendations, as they pertain to the NRC, and the staff's responses. Additionally, NUMARC, EPRI and INPO were requested to review the NAS report for comments on its recommendations and the topics they may wish to pursue alone or through cooperative research with the NRC.

In summary, the NAS report recommends that the NRC facilitate its capability for carrying out human factors research by: (1) staffing and maintaining continuity of the program at the branch level, (2) adopting a systems-oriented or socio-technical perspective to the research, (3) utilizing independent peer

reviews to enhance the quality of research products, and (4) establishing improved mechanisms for transferring research results to user communities by means of annual written reviews and a bibliographic search system. Additionally, the report recommends that the staff conduct human factors research in the areas of improved methods and criteria for assessing the adequacy of: (1) computer-based systems for processing and displaying plant status information including those which involve expert systems technologies; (2) personnel training, qualifications, staffing and shift scheduling; (3) individual, team, management and organizational performance, and (4) the regulatory environment.

In reviewing each of the NAS panel's recommendations, the staff determined whether or not NRC regulatory user needs corroborate the recommendation. This enclosure describes the ongoing or planned research, or other means for addressing the recommendations, e.g., solicit the involvement of industry. For the most part NRC had already ongoing or planned research that addresses the NAS's recommendations. In some areas NRC participation in the Halden project will provide information that addresses a number of NAS recommendations. This is especially true in the area of Human-System Interface Design.

As is shown in Table 1 and subsequent sections of this enclosure, the staff is implementing, or is planning to implement a majority of the recommendations. The column headed "Status" indicates whether the recommendation or the research is: "Ongoing", "Planned", or "No action planned at this time". "Ongoing" denotes either that the policy question raised is answered by the current program or that the research question identified is being addressed as part of current initiatives. "Planned" denotes that the recommended research is be planned but not yet underway. "No action planned at this time" denotes that the program either partially addresses the recommendation or the question will be considered as the program is periodically updated in view of related research.

In the pages following Table 1 each of the seven NAS recommendations for undertaking human factors research is followed by the staff's narrative response. Where appropriate, NAS recommendations are broken out into topic areas corresponding with the entries in Table 1.

Table 1

Summary of NAS Recommendations and NRC Staff Responses

Recommendation	Status
1. Commitment to human factors research	
a. Staffing/financial support	Ongoing
b. Qualified manager	Ongoing
c. Branch level program	Ongoing
2. Systems-oriented approach	Ongoing
3. Peer reviews	
a. Research planning	Ongoing
b. Research reporting	Ongoing
c. Plant access	No action planned at this time.
d. National research facility	No action planned at this time.
4. Continuity	Ongoing
5. Transfer of knowledge	No action planned at this time.
6. Dissemination of results	Ongoing

Table 1 (cont'd)

Summary of NAS Recommendations and NRC Staff Responses

Recommendation	Status
7. Research agenda	
a. Man-machine interface design	
(1) Computer-based systems	
Human-system interfaces	Planned
Safety parameter display systems	Planned
Disturbance analysis systems	Ongoing
Function allocation	Ongoing
Operating procedures	Ongoing
Expert systems	Ongoing
(2) Software development	
Software psychology	No action planned at this time.
Guidelines for software development	Ongoing
b. Personnel sub-system	
(1) Training	
Effectiveness	Ongoing
New approaches	Planned

Table 1 (cont'd)

Summary of NAS Recommendations and NRC Staff Responses

Recommendation	Status
(2) Qualifications	
Degree requirement	Ongoing
Licensing exams	Ongoing
Tester qualifications	Ongoing
Team licensing	Ongoing
Licensing non-control room staff	Planned
(3) Staffing	
Shift Tech Advisor	No action planned at this time.
Screening/Selection	No action planned at this time.
Shift Scheduling	Ongoing
Vigilance	Ongoing
c. Human performance	
(1) Error mechanisms	Ongoing
(2) Computer models	
Computer simulation	Ongoing
Operations, maintenance and organizations	Ongoing
Use of non-nuclear research	Ongoing
Theoretical and empirically based	Ongoing
(3) Industry participation	Ongoing
(4) Operational experience data	No action planned at this time.

Table 1 (cont'd)

Summary of NAS Recommendations and NRC Staff Responses

Recommendation	Status
d. Management/organization	
(1) Impact of regulations	No action planned at this time.
(2) Design and culture	Ongoing
(3) Decision making	Ongoing
(4) Emergencies	Ongoing
(5) Characteristics	Ongoing
e. Regulatory environment	
(1) Models of regulation	No action planned at this time.
(2) Performance indicators	Ongoing

NAS Recommendation 1: Commitment to Human Factors Research

"The NAS panel recommends that the NRC make a firm public commitment to applied behavioral and social science (human factors safety) research. This would require a decision to increase staffing and financial support. Without such a commitment, the public and the nuclear industry can reasonably assume that human factors is not regarded by the NRC to be a matter of importance, nor will the NRC be able to attract the highly competent staff it will need. In addition, the human factors program should be directed by a qualified human factors specialist at the level of branch head, not as a subdivision of the reliability branch. Finally, the branch should be staffed by ....a team of multidisciplinary scientists."

NRC Staff Response

The NRC made a commitment to human factors safety research in its April 12, 1987, reorganization which reestablished a human factors capability within RES's Division of Reactor and Plant Systems/Reliability and Human Factors Branch (DRPS/RHFB). In addition, the Commission's Policy and Planning Guidance (NUREG-0885, Issue 6, September 1987) directed RES "...to develop a program for Commission review in the area of human factors/performance consistent with agency needs." That plan is presented in the previous enclosure. It provides the framework for a strong, stable, and sustained program in human factors research.

Staffing and financial support have already increased. Human factors staffing in RES is currently four-times what it was prior to the April 1987 reorganization. The staff consists of a multidisciplinary team of eight professionals whose backgrounds include academic training and experience in psychology, human factors engineering, industrial organization, operations research, computer systems/control systems, mechanical engineering, and nuclear engineering. The staff possesses a total of four Ph.Ds and ten Masters Degrees, with each of the areas above covered with at least one Masters Degreed person. The staff has a combined total of over 170 years of professional experience with more than 100 staff years devoted to human factors. The branch manager is qualified both by education in operations research and organizational performance and by experience in directing NRC programs that evaluated the human factor.

Current funding for human factors research is also above previous levels, that is, from a peak of about 2.2% of RES's total budget in FY 1983 -- to about 3% of the total RES budget in FY 1988. The Five Year Plan commitment for funding human factors research is currently more than $4M annually.

NAS Recommendation 2: Adopting a Systems-Oriented Approach

"The NAS panel recommends that the NRC's research program maintain a broad

perspective"... "Further, the panel firmly believes that research that recognizes a systems approach, in which the 'system' is broadly defined, has great potential for delivering results that yield useful recommendations for safety improvement....by a systems approach, we mean a way of looking at a nuclear power plant not as composed of components whose properties can be examined in isolation, but rather as a collection of components including human components, each of whose properties affects and is affected by the other dynamically from moment to moment, so that to predict the performance of any component requires that one consider the state of, in general, many others."

NRC Staff Response

This NAS recommendation is consistent with the approach outlined in the Human Factors Research Program Plan (previous enclosure) because the totality of human factors can be grouped several ways. General correspondence between the NAS topic areas and the topic areas of the Human Factors Research Program Plan is shown below:

NAS Topic Area Recommendations	NRC Human Factors Research Program Topic Areas
Human-System Interface Design	- Human-Machine Interface - Procedures
Personnel Subsystem	Qualifications and Training
Human Performance	Human Performance and Human Reliability Assessment
Management and Organization	Organization and Management
Regulatory Environment	Organization and Management in the area of programmatic performance indicators

Within the NRC's research program plan there are other topic areas that approach human factors systematically because these other topic areas transcend the topic areas listed above in both columns. Specifically, research into maintenance, performance indicators, and accident management transcend

both individual human factors topics and hardware. This program approaches safety research fully cognizant of the interactive nature of the individual topics and the fact that they are part of a collective entity with its own emergent properties.

NAS Recommendation 3: Peer Review and Enhanced Access to Nuclear Power Research Facilities and Personnel

"The panel recommends that the NRC involve a diverse group of knowledgeable researchers in planning, conducting, and evaluating its research program. In addition, peer review of proposals and draft reports by behavioral science experts is needed to ensure the quality of sponsored research. One of the barriers to effective human factors research has to do with providing behavioral science researchers access to realistic settings, to facilities such as simulators, and to people such as experienced operators. While the panel recognizes the practical difficulties involved, we strongly urge the NRC and the nuclear industry to take significant steps that enhance researchers' access to these facilities and people. One step to achieve this goal would be to create a national research facility for the study of human factors in nuclear power systems."

NRC Staff Response

The staff appreciates the usefulness of peer reviews at some stages of regulatory research. Human factors research currently benefits from frequent informal and formal inputs from diverse sources. Those sources use the mechanisms listed below to identify research needs, to redirect, and to evaluate research projects/results against those needs.

- Staff and management reviews within RES using RES in-house expertise in the behavioral sciences and other relevant disciplines

- Reviews of RES projects and recommendations by personnel with diverse disciplines from other NRC offices

- Technical reviews of project proposals, draft reports and final reports prior to and during conduct of the work, using outside consultants

- Reviews by the ACRS, including the ACRS Subcommittee on Human Factors

- Reviews of research program areas by an independent advisory committee called the Nuclear Safety Research Review Committee. This committee is made up of outside experts and reports to the Director, RES.

- Publication of research results in refereed journals

We consider access to realistic settings and experienced personnel to be important to the success of human factors research. Currently, we do not have an ongoing or planned research activity directed solely at achieving access to plant personnel during operations. However, the work on Maintenance Personnel Performance Simulation (MAPPS), involves utility personnel to assure that useful products are developed.

Regarding a national research facility for human factors, RES currently provides funding to the Halden Research Project in Norway. Halden has appropriate facilities and a multidisciplinary staff capable of doing human factors-related research. Projects to address NRC human factors research needs, especially in the area of advanced displays and expert systems, are being developed with Halden. Other means of jointly funded and cooperative research are being explored with EPRI. Because of EPRI's access to nuclear facilities and personnel, joint NRC-EPRI research projects might serve in lieu of research done at a national research facility. Similar coordination of research projects may also be explored with INPO. Therefore, the staff has no current plans to establish a national research facility solely for the study of human factors.

NAS Recommendation 4: Continuity in the Research Program

The NAS panel recommends that..."a NRC human factors research program operate

coherently for an extended period rather than change in response to each new, immediate, external demand. Since effective research is cumulative, continuity is as important as level of expenditure."

NRC Staff Response

The staff is revitalizing the human factors program in RES. It has developed a plan to carryout this program (see previous enclosure). The research budget for human factors, as projected in the Five Year Plan, will remain stable.

Further, NRR, AEOD, and NMSS also supported the need for continuity of human factors research through their user need letters. Finally, the Human Factors Research Program Plan presented in the previous enclosure emphasizes the need for coordination between the RES and user offices to assure existing research needs are satisfied and new needs are identified in an orderly manner. The plan will be updated periodically to reflect revised and new user needs as well as the resolution of current needs resulting from completed research.

NAS Recommendation 5: Transfer of Knowledge

"The panel recommends that the NRC take the greatest possible advantage of existing research in the behavioral and social sciences by increasing the transfer of knowledge to the nuclear industry. To this end, the panel recommends that the NRC publish an annual review of the human factors research relevant to the nuclear power industry."

NRC Staff Response

The staff understands that transferring knowledge gained from research to the utilities is necessary before safety can be enhanced. Results of research are made available to the utilities and the public through publication of NUREG reports, technical articles, and participation in international conferences. RES has, for a number of years, presented the results of its research in sessions of the annual NRC Water Reactor Safety Information Meeting. Water

Reactor Safety Meetings are widely attended by the industry and other interested parties. Some projects, such as the one to develop MAPPS, achieve direct transfer of knowledge to participating personnel from the nuclear utilities. The agency also publishes NUREG-0304, Regulatory and Technical Reports Abstracts Index Journal. This document is published quarterly and annually, and contains abstracts of all NRC published reports including those on human factors. The feasibility and advisability of publishing additional reviews will continue to be examined with industry groups such as NUMARC, EPRI and INPO.

NAS Recommendation 6: Dissemination of Human Factors Research by the Nuclear Industry

The NAS panel recommends that "mechanisms to improve the dissemination of human factors results throughout the industry be developed" ... by the NRC and industry. "One element is to use or develop a bibliographical search service" ... of relevant human factors publications by other government agencies, DOE laboratories, industry and academia. "As a first step the panel recommends the development of a bibliographic system for NRC-supported human factors reports."

NRC Staff Response

Dissemination of human factors research results has the potential to be important to continued improvements in nuclear safety. As described in our response to Recommendation 5, above, RES disseminates the results of its research projects publicly. Additionally, the staff has initiated a project to explore the possibility of enhancing the dissemination of human factors research results. That project will: (1) identify the desired characteristics of a human factors state of knowledge system; (2) determine which of those characteristics can be satisfied by human factors information systems currently available to RES through the NRC Library, Public Document Rooms and DOE Laboratories; (3) develop a specification for computer software to download information from currently available systems and to accommodate information from sources not available to those systems, and (4) do a cost analysis for

developing a computer software package responding to the characteristics identified under (1) and taking advantage of existing information system resources determined under (2). RES is also coordinating with EPRI on the dissemination of its related research projects.

NAS Recommendation 7: A Human Factors Research Agenda

The NAS panel recommends research in five major areas (man-machine interface, personnel subsystem, human performance, organization and management, regulatory environment). It followed three criteria ..."in determining higher priority topics within the areas." First, research issues having a critical impact on safety and thus must be addressed immediately. Second, research issues whose resolution will lead to better evaluations of plant safety. Third, short-term research issues whose resolution will serve as essential building blocks for longer-term research. The NAS panel states that..."in all cases research should be aimed at management, maintenance, and other ancillary workers, as well as control room operators."

a. Human-System Interface Design

1. Computer-Based Information and Display Systems

NAS Recommendation Regarding Human-System Interfaces

The NAS panel recommends research on methods and criteria for assessing improved human-system performance and for evaluating the adequacy of new human-system interfaces and decision aids. Developing these measuring techniques is the highest immediate priority.

NRC Staff Response

RES is planning a research activity to address recommendations on both the methods and criteria issues. The key elements of this activity are: (1) review the pertinent literature to identify existing human-computer interface

models which may be relevant, (2) conduct a workshop to evaluate each model and select one to serve as an integrating framework for methods and criteria development, and (3) develop and test candidate methods and criteria for assessing human-systems performance and the adequacy of new human-system interface and decision aids.

NAS Recommendation Regarding Safety Parameter Display Systems

The NAS panel recommends research on improved methods and criteria for evaluating the adequacy of existing and proposed Safety Parameter Display System (SPDS) designs.

NRC Staff Response

Useful experiences with computer-based interfaces resulting from the SPDS have been summarized in NUREG-1286, Supplement Number 1, March 1988, SER Related to the Restart of Rancho Seco Nuclear Generating Station, Unit 1. That experience is being used to guide ongoing and planned research directed toward methods and criteria for evaluating human-computer interfaces.

2. Automation and Computer-Based Human Performance Aids

NAS Recommendation Regarding Disturbance Analysis Systems

The NAS panel recommends research on disturbance analysis systems as a means of providing useful diagnostic and emergency management information to human problem solvers in nuclear power plants.

NRC Staff Response

RES is currently supporting research on disturbance analysis systems as a participating member of the OECD Halden Reactor Project. One study in FY 1988 involves an evaluation of a rule-based expert system for diagnosing faults in a nuclear power plant. Knowledge gained from this study will be

useful to the NRC in formulating guidelines to the industry on expert systems. The NRC, however, does not do developmental research on new systems. This is the rightful responsibility of industry.

Additionally, RES is planning a research activity whose objective is to establish criteria for assessing the adequacy of human factors aspects of advanced controls and instrumentation. The existing human engineering guidelines for nuclear power plant control rooms are ostensibly for today's controls, displays, and information concepts. While these guidelines may be adequate for the current generation of plants, they may be inadequate for advanced designs and for major revisions to existing control rooms. Major revisions to control rooms will include digital computers as well as new technologies such as artificial intelligence and computer graphics. This study will evaluate current practices and technologies available, and will develop a regulatory position on such systems.

NAS Recommendation Regarding Function Allocation

The NAS panel recommends research on better methods and criteria for allocating functions between the human and automated systems in nuclear power plants. More specifically, it recommends research on the merits and methods of dynamic function allocation between the human and system. Also, the NAS panel recommends research to determine the appropriate role of the human in future plants, especially with regard to higher-level decisionmaking and supervisory functions.

NRC Staff Response

RES is currently funding research as part of the OECD Halden Project to investigate the potential role of integrated surveillance and control systems for control rooms. One of the goals of this study is to evaluate a fully computerized control room. The staff anticipates that a better understanding of human execution of a function (e.g., manual control) versus automated functions (e.g., automated control system) will emerge from this Halden work.

These results may also prove useful in evaluating the period of time after a reactor trip before a need for operator action is mandatory .

NAS Recommendation Regarding Operating Procedures

The NAS panel recommends research on operating procedures because they are inherently a part of the human-system interface. The report discusses the issues associated with computer-based Emergency Operation Procedures (EOPs). It states: "at present, there is no coherent theory for the design of EOPs, and this requires research to develop such a theory."

NRC Staff Response

The NRC is supporting research in the use of computer-based procedures as a participating member of the OECD Halden Reactor Project. One of the ongoing studies at Halden is a controlled evaluation of a computerized procedure system. The objective of this research is to identify and assess problems with present day manual procedure systems. Some of these problems are the very issues discussed in the NAS report. The current project at Halden will evaluate operator acceptance for the functions performed and the man-machine interface of the computerized procedure system being evaluated. As a participating member of the Halden Project, the NRC will help direct and will receive the results of these tests. These results will be used to help NRC evaluate computerized procedure systems and what further research is needed in this area.

NAS Recommendation Regarding Expert Systems

The NAS panel recommends a review and evaluation of literature on expert systems and artificial intelligence simulation of cognition. The nature of validation as applied to such systems should also be examined. Research should concentrate on the validation and assessment of such systems, leaving their development to industry.

NRC Response

The NRC is a participating member of the OECD Halden Project which is conducting several studies on computer-based man-machine interfaces, including expert systems, for use in nuclear power plants. These studies involve control room operators to conduct man-in-the-loop tests of these interfaces. The NRC staff anticipates that the knowledge obtained from these studies will help to establish methods to specify and evaluate new interfaces and decision aids.

3. Human Factors in Software Development

NAS Recommendation Regarding Software Psychology

The NAS panel recommends a review of the literature on software psychology. The purpose of the review is to identify potential applications of such a psychology in the development of nuclear power plant computer software programs.

NRC Staff Response

The NRC regulates the design and use of computer software that performs safety-related functions. One example of this type of software is the computer program in a computer-based reactor trip system. In special circumstances, the NRC also regulates software that performs non-safety related functions. One example of this type of software is the computer program for the Safety Parameter Display System (SPDS). However, the scope of regulation for non-safety-related applications is much less than for safety-related applications. NRC does not regulate the software in the plant process computer. Because of other high priority issues and limited resources, the staff does not plan to begin research on software psychology. The staff feels that this topic could be more effectively addressed by the industry since the industry designs and develops computer software. We will pursue with industry (e.g., EPRI) the need to conduct this research.

NAS Recommendation Regarding Human Factors Guidelines in Software Development

The NAS panel recommends research on guidelines for incorporating human factors concerns into the design of computer software systems.

NRC Staff Response

At the present time RES does not have an ongoing or planned research activity in this area since there are publications that address this issue. For example, EPRI NP-3701, Computer-Generated Display System Guidelines, Vol. 1: Display Design, and Vol. 2, Developing an Evaluation Plan, is one example of human factors guidelines for computer-based displays. Another example is ESD-TR-86-278, "Guidelines for Designing User Interface Software," by Sidney L. Smith and Jane N. Moser of MITRE. This latter report is for the United States Air Force. It contains 944 guidelines for designing software to support the user interface to computer-based information systems. The staff believes these and similar publications provide some guidance to designers for incorporating human factors concerns into software development.

b. Personnel Subsystem

NAS Recommendation Regarding Training Effectiveness and New Training Approaches

The NAS report recognizes that the availability of properly trained and qualified utility personnel is essential for effective and efficient job performance. Also, it acknowledges that the NRC, as well as the industry, has made advances toward improving training and qualifications of nuclear power plant personnel. It concludes, however, that additional research is needed on a number of topics. Specifically the NAS panel recommends:

1. Research on the effectiveness of existing training techniques and tools for acquiring and maintaining operator skills.

2. Research on alternate approaches to training utilizing current advancements of training techniques such as "exploration training," "embedded training for rare and difficult events," and "problem-solving training. More specifically, research is recommended to determine their usefulness and adaptability to a nuclear power plant context, especially for managing abnormal events in the complex social environment with many people involved and sharing responsibilities for managing rare events.

3. Longitudinal research, in conjunction with the industry, on all aspects of training as a central element of the human factors research program. This research should focus on the types of skills required in the nuclear power plant context and on the systems approach to training pursued in the industry accreditation program.

NRC Staff Response

Regarding Recommendation 1, the staff is initiating research during FY 1988 to develop guidelines for evaluating the adequacy of various training techniques and devices currently used by the industry for acquiring and maintaining operator skills.

Although the industry is committed to INPO's accreditation program, thus far it has not demonstrated that there is a correlation between individual training techniques and performance. This may be due to inconsistencies in the degree to which individual utilities adhere to the INPO guidelines. The study being initiated by RES, will explore the degree of success of the current industry efforts to improve training. This in itself will be difficult since no objective measures of performance in the context of nuclear power plants have been established. This difficulty notwithstanding, there is considerable activity on training technologies dealing with the "what" and "how" to measure training effectiveness. The Journal of Human Factors Society in its special issue on training (Vol. 27, No 3) focuses specifically on methods for measuring training effectiveness. By building on work already done in this area outside the nuclear industry, the staff expects to be able to develop criteria for

measuring the success of the various training approaches or training devices being pursued by industry. Finally, regarding training simulators, the NRC has imposed on industry a requirement to install whole-task, plant-referenced simulators by 1991. The staff intends to defer consideration of research on training simulator effectiveness in the short-term and recommends that industry take the lead to determine the effectiveness and benefits of part-task versus full-task simulators for acquiring and maintaining operator skills.

Regarding Recommendation 2, as the the panel points out, the industry should take the lead in striving for excellence, and hence advancement of training should be one of industry's greatest concerns, especially since the adaptation of better training can have economic as well as safety benefits. However, since the potential safety significance of operator readiness to deal with complex physical as well as human-factor phenomena during rare events has been demonstrated (e.g., Chernobyl), the staff will initiate research in FY 1989 on general criteria for evaluating training adequacy. Special attention will be given to skill achievement and sustainment training for responding to rare events. This effort will be pursued as a potential joint industry and NRC effort.

Regarding Recommendation 3, the staff agrees with the NAS panel that longitudinal research on training should be undertaken jointly between the NRC and industry. Therefore, the staff is planning to extend its research on all aspects of training, including cooperative studies with industry, into the 1990s.

NAS Recommendation Regarding Qualifications (Degree Requirements, Testing and Licensing)

The NAS panel recommends research on personnel qualifications in the following areas:

1. advisability of requiring a baccalaureate degree for control room staff, and if a degree is required, the recommended course content.

2. reliability and validity of licensing examinations, and on improvements in the process of administering these examinations.

3. qualifications of the regulatory staff and contractors engaged in licensing NPP operators.

4. factors that affect team performance.

5. qualifications of personnel other than licensed operators at nuclear power plants, especially maintenance personnel.

NRC Staff Response

Generally the staff agrees with the NAS recommendations listed above.

More specifically, with regard to Recommendation 1, the NRC (RES and NRR) has conducted numerous studies to determine the academic knowledge needed by an operator and to determine in which types of degrees that knowledge can be obtained (NUREG/CR-4051 Assessment of Job-Related Educational Qualifications for Nuclear Power Plant Operators and NUREG/CR-4411 Assessment of Specialized Educational Programs for Licensed Nuclear Reactor Operators). The extent to which college engineering curricula cover job-related academic knowledge has been assessed. Therefore, the staff does not perceive a present need for research on knowledge and course content for operators at this time.

With regard to Recommendation 2, NRR has completed, or has ongoing work in the areas of testing and licensing of operators. For example,

- a new pilot requalification exam is being tested and implemented which is responsive to industry concerns and is responsive to the need for crew level evaluation.

- NUREG-1122 Examiners Handbook, provides test specifications which are based on operator knowledge and abilities (KAs) which in turn are based

on empirical studies. In addition, examiners now develop tests that test KAs in proportion to the level of rated importance of the KAs.

- o NRR is also developing a performance-based simulator examination. NRR has constructed performance-based rating scales that represent the skills required of operators. In addition, with regard to the simulator exam, NUREG-1291 BWR and PWR Off-Normal Event Descriptions presents BWR and PWR simulator scenarios that test the important knowledge and skills of operators.

- o NRR is currently studying the development of a "Fundamentals" exam which would be standardized and centralized. The exam would cover the fundamentals of nuclear power and would be given nationwide in several locations each year.

- o NRR has contracted with several consultants to evaluate the adequacy of current licensing examinations. Recommendations from these evaluations have resulted in changes to the examination.

With regard to Recommendation 3, NRR has an ongoing program to develop a new "Initial Examiners Training Program." This training program has two parts, (1) training on relevant technical NPP issues and (2) training on techniques for giving examinations.

With regard to Recommendation 4, RES has initiated research in the area of team performance. This research is directed toward developing criteria to evaluate team performance.

With regard to Recommendation 5, RES will initiate research in FY 1989 on the qualifications required of NPP personnel other than licensed operators, especially in the area of maintenance.

NAS Recommendation Regarding Staffing (Shift Technical Advisor, Screening and Selection, Shift Scheduling and Vigilance)

The NAS panel recommends research on:

1. how to improve the effectiveness of the Shift Technical Advisor (STA), especially the STA's role vis-a-vis other members of the control room crew.

2. potential screening and selection based on psycho-physiological profiles. problem-solving skills, and standardized performance tests.

3. shift scheduling and vigilance addressing the issues of work schedules, overtime, boredom and work rotation.

NRC Staff Response

With regard to Recommendation 1 on the STA, NRR has already completed substantial work in this area. NRR first reviewed the practices in selected foreign countries for providing engineering expertise on shift and the results were published in NUREG/CR-2952, Engineering Expertise on Shift: The Foreign Experience. NRR also had a contractor examine different approaches that have been used by U.S. utilities in implementing the STA requirement. Next, NRR had a contractor conduct interviews with utility personnel which led to the publication of NUREG/CR-3396, Experience with the Shift Technical Advisor Position. Lastly NRR published NUREG/CR-3785, Alternative Approaches to Providing Engineering Expertise on Shift. After the degree requirements issue for SROs is resolved, the NRC staff will review the need for research in the area of the STA. It is expected that the STA role will be easier to define after decisions on qualifications of the SRO have been established.

With regard to Recommendation 2 for research on personnel screening and selection, the staff has not done research on these topics. The staff believes that it is more appropriate for industry to undertake research in this area and we will make this known to industry.

With regard to Recommendation 3, the staff is initiating research during FY 1988 on shift scheduling and vigilance. This research builds on previous work in this area (NUREG/CR-4248, Recommendations for NRC Policy on Shift Scheduling and Overtime at Nuclear Power Plants, ongoing work at EPRI and at individual plants). It also takes cognizance of recent problems of operator alertness on shift.

FY 1988 research on shift scheduling will focus on:

- o confirmatory research on shift schedule and overtime data collection and analysis. Nuclear power plant data on the effects of overtime, shift scheduling, shift rotation, and staffing will be collected and analyzed to assess the adequacy of the current technical basis for existing NRC policies. The results of this research will be used as a basis for updating policy revisions if appropriate.

- o shift duration, shift rotation, and operator alertness. This will be exploratory research recognizing that new approaches such as "informed innovation" (NAS Report, p. 70) may be required to address each of the above issues. More specifically, this research will focus on ways in which the state of knowledge outside the nuclear arena, especially in the area of vigilance, can be applied to nuclear power plant operations. It will explore, as the report suggests, biological, social and environmental based solutions as opposed to hardware solutions. Issues such as boredom, work-load, social-interactions, and sleep-wake cycle will be considered.

c. Human Performance

NAS Recommendations:

The NAS report recognizes that human performance (human error) can play a major role in the malfunctioning of nuclear power plants. The report concludes, however, that there is too much uncertainty in measuring human error rates, since current quantification methods rely primarily on expert judgement

and on very limited operational experience data. Finally, the report concludes that the greatest limitation of these methods and data is in the area of cognition.

The report recommends that research be directed toward a more fundamental understanding of the nature (mechanisms) and causal factors of human performance (including error), and subsequently toward more quantitative and theoretically based models and methods which are not only capable of producing credible snapshots of performance, but which are also capable of predicting performance in rarely occurring events and in response to system design changes.

More specifically, the report makes the following recommendations regarding performance measurement and performance data.

1. Develop a better understanding of the mechanisms of human error so that circumstances and conditions under which such errors occur can be predicted beforehand, rather than merely on a subjective probability basis.

2. Develop performance measurement models and methods, using computer simulation techniques where possible, which are qualitative and quantitative, and are theory driven and empirically based. These models should capture both behavioral and cognitive aspects of performance, should be predictive as well as descriptive, should be capable of identifying and diagnosing causal factors, should be capable of analyzing individual, team and organizational performance, and should be applicable across performance situations and plants. The empirical base should include operating experience, laboratory experiments, and controlled studies on plant simulators.

3. In developing these models and methods, focus on operations, maintenance and organizational aspects of human performance at nuclear power plants.

4. In developing these models and methods, build on work done outside the nuclear industry (e.g., military, aerospace),

5. Commence research on these models, methods and data acquisition mechanisms immediately, and focus on both theoretical and empirical aspects of plant operations, maintenance and organizational performance measurement.

6. Pursue an industry-wide effort in this area with a single organization, preferably the NRC, integrating the theoretical, analytical and empirical results.

7. Develop mechanisms for acquiring valid operating experience data and unencumbered (not confounded by instructor interference) training simulator data to insure greater certitude in modeling performance and its associated causal factors.

NRC Staff Response:

Performance measuring techniques which rely primarily on expert judgement are only an interim solution.

With regard to Recommendation 1, we are examining the feasibility of RES engaging in such as effort. While we agree with the general thrust of the recommendation, we currently do not sponsor controlled laboratory studies of the type that are needed to fully address the issue due to a lack of laboratory facilities and to a lack of an appropriate human subject pool. We have, however, developed computer-based simulations which we believe can provide us with insights into probable mechanisms of human error on both cognitive and behavioral levels.

With regard to Recommendations 2 through 5, we have developed or are in the process of developing performance measurement models and methods which generally are: (1) theory driven and empirically based, (2) qualitative and quantitative, (3) predictive as well as descriptive, (4) capable of analyzing behavioral and cognitive aspects of performance and their causal factors, (4) focused on operations and maintenance activities, (5) capable of analyzing individual, team and organizational performance, and (6) applicable across

performance situations and plants. The majority of models and methods emerging from this research are computer-based, and build on knowledge developed in other industries and academia.

For example, we have developed and tested a Maintenance Personnel Performance Simulation (MAPPS) computer model based on stochastic techniques cited in the NAS report. MAPPS logic takes advantage of thirty years of modeling experience gained in the military and the aviation industry. It is capable of simulating the activities of maintenance mechanics, electricians, instrumentation and control technicians and supervisors in groups of two to eight. It allows the analyst to assess human performance using a series of qualitative and quantitative indexes including success probability. It allows the analyst to preview the potential effects, on performance, of man-man and man-machine retrofits. Finally, it allows the analyst to investigate on a limited basis the effects of operations and maintenance interfaces on organizational performance.

We have developed and are testing a Cognitive Environment Simulation (CES) for analyzing intention formation (decisionmaking) aspects of human performance. CES is computer-based and currently resides at the Westinghouse Research and Development Center (our contractor) facility. CES employs the latest artificial intelligence/expert systems processing techniques. CES allows the analyst to investigate decisionmaking performance and its causal factors, and to preview alternative cognitive strategies resulting from man-man and man-machine retrofits. Finally, CES allows the analyst to investigate individual and team decisionmaking behavior. CES is currently undergoing operability testing. Unlike MAPPS, CES is deterministic and does not quantify human performance on a probabilistic basis. Therefore, as part of the CES project, a Cognitive Reliability Analysis Technique (CREATE) which converts CES outputs to error probability statements has been developed and is being tested.

We also have research ongoing to develop indicators of individual, team and organizational performance. These indicators are being developed based

primarily on existing plant data sources (e.g., Licensee Event Reports [LERs], Nuclear Power Reliability Data System [NPRDS], In-Plant Reliability Data System [IPRDS]).

Finally, we have recently initiated research using a theoretical and empirical model for analyzing organizational and management performance influences on safe operations. Subsequent methods development will use the results of the research, if successful, as a basis for integrating management factors into the probabilistic risk assessment (PRA) process, and as a basis for developing new indicators of organization and management performance.

With regard to Recommendation 6, there is presently no industry-wide research program directed toward human performance models and measurement methods. It should be noted, however, that much of our research in this area involves industry groups, the utilities and other research and regulatory agencies. For example, we are just completing a human reliability analysis (HRA) methods evaluation in conjunction with EPRI and the Commission of European Communities (CEC). We are also pursuing a cooperative agreement with the CEC, and U.S. and European utilities, to employ the MAPPS computer code as an analytic and design tool for helping resolve maintenance related issues of interest to the utilities. This study is part of the MAPPS technology transfer process. Finally, we have and will continue to use independent review groups composed of a broad spectrum of industry representatives to assist us in each of the modeling and methods programs described above.

With regard to Recommendation 7, we consider the paucity of operational experience data and training simulator data to deter human performance assessment. Currently, we do not have ongoing or planned a research activity directed solely toward collection of training simulator data. However, we have requested that the Halden Project provide to us training simulator performance data it collects as part of its ongoing research activities, for input to our HRA/PRA data bank, known as NUCLARR, and located at the Idaho National Engineering Laboratory. We are also looking to the NRC training simulators located at Chattanooga, TN as potential sources of performance data.

Developmental research was completed on a third party reporting system concept of the type currently being employed by other U.S. regulatory agencies and the military. We have also initiated research with the George Mason University to investigate the feasibility of a method for systematically equating, on both behavioral and psychological levels, human tasks performed outside the nuclear industry (military, aviation, ground transportation), on which considerable operating experience data exist, with tasks performed by operators and maintainers of nuclear power plants. Such a method would allow us to employ non-nuclear industry data as surrogate measures of performance, especially for doing probabilistic assessments.

In summary, the research staff feels that it has ongoing and planned research fully responding to the NAS recommendations except for: (1) mechanisms of human error, and (2) an industry-wide program. In the case of mechanisms of human error we will continue to study the feasibility and propriety of establishing a long-term basic research program, within the NRC and/or in conjunction with industry, to more fully address this issue. In the case of the industry-wide program, the staff will continue to examine ways in which the NRC, industry and academia can work more closely to achieve and validate performance models and methods of mutual interest.

d. Management and Organization

The NAS report recognizes that management decisions impact many aspects of plant safety, both directly and indirectly. The primary concern voiced in the NAS report in the area of organization and management is the extent to which the organization is able, quickly and efficiently, to prevent, detect, and react to any threats to overall system safety. The NAS panel therefore recommends research on the following topics.

1. The impact of regulations on the practice of management Research in this area should answer questions such as "are there organizational conditions that produce a sense of regulatory overload?"

2. Organizational Design and a Culture of Reliability Research in this area should answer questions concerning the effects on performance of such factors as span of control, vertical height, horizontal breadth, functional specialization, interunit coordination, and the linkages between staff and line. Research should answer how these variables affect safety.

3. Operational Decision Making Research in this area should answer questions concerning the effects on performance of communications between groups such as management and operators, or corporate and plant management.

4. Timely recognition of emergencies Research in this area should answer questions concerning the effects on performance of organizational designs to deal with emergencies since organization designs for normal operations may not be effective.

5. Characteristics of Managers Research in this area should answer questions concerning the effects on their performance of supervisor and manager demographics such as interpersonal skills, academic training, corporate training and on-the-job experience.

NRC Staff Response

The staff recognizes that management and organizational factors attending the operation of nuclear power plants appear important. In recognition of this, the NRC has funded several research and technical advisory service projects in this area over the past six years. The staff also recognizes that solution to some of the issues surrounding effective management and organization climates at nuclear power plants will require a long-term effort. Finally the staff recognizes that research of this type will require cooperation among the NRC, EPRI and INPO who also have research and development interests in this area.

Regarding Recommendation 1, the staff considers regulatory philosophy to be a policy as well as a research issue.

Regarding Recommendations 2 through 5, the staff has an ongoing research project whose results will be used as one basis for developing additional research in the management and organization area. This project builds on results of work in this area completed during the past six years within RES and NRR. It is directed toward methods for identifying and evaluating the influences of management on plant performance from both human factors (qualitative) and human reliability (probabilistic) perspectives. It involves tasks leading to identification of: (1) a dynamic model (characterization) of the plant organization; (2) supervisory and management functions and roles critical to performance; (3) profiles of supervisory and management influences; (4) data required for assessing those functions and roles, and means for acquiring such data; and (5) an algorithm for integrating those measures into reliability and risk assessments. Objectives 1 through 4 respond to the the NAS recommendation for human factors research in the management and organization area. In addition, Objective 5 includes an approach to applying the results of the research to probabilistic risk assessments.

e. The Regulatory Environment

NAS Recommendation Regarding Models of Regulation

The NAS panel recommends research on:

1. the possibility of assigning regulatory activities to different organizations and transferring some regulatory functions from the regulatory bodies to the utilities themselves.

2. a closer examination of the effects of regulation.

3. human factors practices within the NRC itself.

NRC Response:

With regard to Recommendations 1 and 2, mechanisms for ensuring that regulatory

activities enhance safety without placing undue burden on the industry do exist (e.g., the regulatory analysis process, review by the Committee to Review Generic Requirements, and the "Backfit Rule"). Efforts to allow the industry to play a larger role in regulation (e.g., in the area of training) also exist.

With regard to Recommendation 3, the staff believes that increased NRC management and staff awareness of the human factors discipline and its potential role in achieving the Agency's mission is important. However, the staff does not plan any research on methods for increasing human factors awareness at this time.

NAS Recommendation Regarding Plant Performance Indicators

"The fundamental purpose of performance indicators," the NAS panel states, "is to readily monitor and assess individual plant performance and take actions when appropriate". The report recognizes that the NRC has made progress in this area. It points out, however, that the current indicators are based on publicly available data which are limited and do not allow monitoring of all important facets of safety, in particular, monitoring indicators of diagnostic value. The report concludes that additional work is needed.

The use of incentive-based indicators monitored by the public utilities is also discussed in the NAS report. It points out that we do not exactly know how such indicators affect safety; some positive as well as negative aspects are mentioned. It recommends research in the area which will allow us to, first, evaluate safety effects and second, improve safety by developing regulatory mechanisms based on combined safety and utility incentives.

Specific NAS recommendations on performance indicators can be summarized as follows:

1. Pursue research on better performance indicators based on data not currently available to the NRC staff. This should include data on "inputs" to plant operations, "throughputs" and "outputs." Also, data should reflect

performance at different levels, that is, at the individual operator level, at the team level, and at the plant level. Finally, performance indicators and the data upon which they are based should be continually updated and validated as part of the research effort. "Plant performance" is a variable depending on many time-dependent parameters, (such as plant aging, regulatory changes and technology changes), affecting the validity of an indicator.

2. Pursue research on the effectiveness of incentive programs currently in use by the public utilities, especially in terms of their safety significance Focus research on the interactions of three variables which may provide a basis for structuring regulatory mechanisms for improving both safety and performance: (a) incentive-plan characteristics, (b) utility responses, and (c) plant performance.

NRC Response:

The NRC plans for research on performance indicators are consistent with the NAS recommendations. The NAS report correctly states that publicly available data are not sufficient to support monitoring all variables important to safety.

The NRC is developing performance indicators, especially at the plant level, beyond those already in the program. The current set of indicators is based on the developmental work by an interoffice task group during FY 1986-87. Ongoing research and development activities on performance indicators can be summarized as follows:

- Risk-based indicator work is focused on "outputs" and some aspects of "throughputs" of plant safety performance, e.g., frequency of events, equipment availability. As part of this effort, an indicator of safety system unavailability has been identified (and theoretically tested utilizing PRA methods) as a measure of safety (System Unavailability Indicators, BNL draft report, Sept. 1987). As a result of this work the NRC is reviewing alternative ways to collect the needed data. The

development of risk-based indicators is continuing and is aimed at improved methods of monitoring safety by analyzing plant performance outputs.

- Efforts to develop programmatic performance indicators are focused on internal parameters of plant performance such as "inputs" and "throughputs." In FY 1987, work was limited to analyzing publicly available data and determining future data needs. As a result of this work, a set of measures was determined based on monitoring 'causes of reportable events' such as operator errors, personnel errors, maintenance problems and others (Programmatic Performance Indicators, PNL Draft Report, March 1988). Furthermore, the study illustrated the limitations of readily available data for indicators suggested by experts as true safety indicators (such as percentage of contaminated areas). In FY 1988 work is ongoing to analyze data beyond those that are publicly available in order to identify leading indicators, that is, indicators that are intended to act as early signals of changing trends in plant performance. This is not a trivial task because it deals with the whole spectrum of plant operations. The questions of what "inputs-throughputs-outputs" to measure and how, have yet to be resolved. For this purpose, a structured framework describing relationships between functional areas of plant performance and safety is being pursued. It is expected that such an approach will allow the determination of a coherent set of effective measures.

In addition to these developmental efforts, AEOD is continuing to work on program improvements. Issues such as: the monitoring and interpretation the current set of indicators, the implementation of new indicators, the impact of indicator application to plant safety, the time-dependency of plant performance, indicator update, and real-time validation, are being analyzed and evaluated by the AEOD implementation activities and the results are fed back to research programs.

NRC's current efforts on performance indicators are quite extensive. The main focus is on measures of performance at the plant level which is what the NRC regulates. Individual or team performance indicators would discriminate plant performance in a very detailed level. Finally, we will include in the indicator validation part of our research the indicator-update, in order to incorporate the effects on plant performance from external factors such as regulatory changes, technology changes and incentive plans.

With regard to Recommendation 2, the NRC currently tracks, using NUREG-1256 Incentive Regulation of Nuclear Power Plants by State Public Utility Commissions, the economic performance incentive plans used by the utilities, and studies them on a generic basis. Although we have some concerns for the safety implications that these plans might have in the long-run, (by shifting the emphasis of plant operations from safety to incentive-plan goals), the NRC has not yet performed detailed analyses of the effects of these incentive-plan goals on safety. However, AEOD has recently initiated a program to monitor the performance of plants, as measured through performance indicators, that are under the incentive regulations of public utilities commissions. This is a first step towards determining the impact of economic incentives on safety performance.

ENCLOSURE 3

NRR'S HUMAN FACTORS PROGRAMS

I. Licensing Issues

Human factors was established as a significant area of endeavor within NRR after the accident at Three Mile Island. Since that time, programs and criteria have been established addressing: 1) control room design reviews, 2) safety parameter display systems, 3) emergency operating procedures, 4) plant personnel training, and 5) operating examinations and licensing. Generally, the focus of these programs involved licensing issues. The status of these ongoing programs is summarized below.

CONTROL ROOM DESIGN REVIEWS

On December 17, 1982 the NRC issued generic letter No. 82-33, "Supplement 1 to NUREG-0737--Requirements for Emergency Response Capability," to all nuclear power plant operating reactor licensees and holders of construction permits. One of the elements of this generic letter was for each licensee and applicant to conduct a detailed control room design review (DCRDR). The objective of the DCRDR was to improve the ability of nuclear power plant operators to prevent accidents or cope with accidents by improving the information provided to them. This design review was to identify any modifications of control room configuration that would contribute to a significant reduction of risk and to enhancement in the safety of operation.

As of the end of fiscal year 1987, NRR had issued DCRDR safety evaluation reports (SERs) for approximately 88 nuclear power units. Of this number, 16 have been closed out, having all control room improvements implemented. Another 30 units have proposed satisfactory improvements but have not yet completed implementation. Staff review efforts associated with DCRDRs has been reduced in FY1988 due to higher priority NUREG-0737 activities. The staff is considering alternate approaches to bring closure to the DCRDR process.

SAFETY PARAMETER DISPLAY SYSTEMS

One of the recommendations of the Three Mile Island Unit 2 Lessons Learned Task Force was that a minimum set of plant parameters, descriptive of plant processes, should be concisely displayed in the control room to provide plant operators with a simple, integrated measure of plant safety status. The safety parameter display system (SPDS) was another element contained in Supplement 1 to NUREG-0737. Its stated purpose was to aid control room operators in rapidly and reliably determining the safety status of the plant during an emergency. Since rapid deployment of the SPDS was a design goal, the NRC staff review was established to minimize interference. Thus the staff undertook post-implementation reviews of the in-place SPDSs.

By April 1986, the staff had issued SERs for about half the nuclear power plants. These SERs were based on documentation reviews and meetings with licensee staff. Because there was a concern that the basic requirements for the SPDS were not being met, six SPDS onsite progress evaluations were conducted. It was concluded that many SPDSs may not be achieving the goal of aiding control

room operators in rapidly and reliably determining the safety status of the plant during an emergency. Additional visits to review SPDSs, claimed to be operational, have further confirmed that very few of the systems are fully meeting the requirements. The staff is currently developing a revised approach to determining the acceptability of the SPDS.

EMERGENCY OPERATING PROCEDURES

Another element of Supplement 1 to NUREG-0737 was the upgrade of emergency operating procedures (EOPs). The primary intent was to ensure that EOPs be human factored and function oriented to improve human reliability and the ability to mitigate the consequences of a broad range of initiating events and subsequent multiple failures or operator errors, without the need to first diagnose specific events. Licensees were required to reanalyze transients and accidents and prepare technical guidelines. The required analysis was to identify operator tasks, and information and control needs. In addition, the analysis was to serve as the basis for integrating upgraded EOPs and the DCRDR and verifying the SPDS design. It was further required that licensees submit Procedure Generation Packages (PGPs) which would be reviewed by the staff. On an audit basis at selected factilities, the staff would review upgraded EOPs developed using the PGP.

Currently, all licensees have submitted their PGPs for review by the staff, and SERs have been issued for approximately one third of those. Nineteen implementation audits and inspections were conducted to evaluate the adequacy of the PGP implementation, with disappointing results. Consequently, the staff has instituted an accelerated inspection program that focuses on the adequacy of the EOPs themselves. As part of this effort, it is anticipated that about 28 EOP inspections will be conducted during FY1988, with special emphasis on BWR Mark I plants. Review of PGPs has been minimized due to redirection of resources to the inspection program.

PLANT PERSONNEL TRAINING

On February 7, 1985 the Commission adopted the Policy Statement on Training and Qualification (50 FR 11147). The Policy Statement endorsed the INPO-managed Training Accreditation Program and the industry, through NUMARC, commitment to have 10 programs at 61 sites ready for accreditation by December 31, 1986. In approving the Policy Statement, the Commission deferred rulemaking on training and qualification for two years in recognition of industry efforts and directed the staff to independently evaluate implementation of improvement programs. NUMARC met its commitment and the staff has proposed that the NRC continue to endorse the accreditation program.

As of December 31, 1987 INPO had conducted 134 team visits covering 605 programs. They also conducted 16 team visits covering 72 programs at 10 new facilities. A total of 575 programs have been accredited at 67 sites. NRC staff has observed 19 visits and conducted eight post-accreditation reviews.

OPERATOR EXAMINATIONS AND LICENSING

Section 107 of the Atomic Energy Act of 1954, as amended (42 U.S.C. 2137), requires the NRC to prescribe uniform conditions for licensing individuals as operators of production and utilization facilities, to determine the qualifications of these individuals and to issue licenses to such individuals. Regulations to implement these requirements are set out in Part 55 of Title 10 Chapter 1 of the Code of Federal Regulations. These regulations were updated in March 1987 to meet NRC responsibilities under Section 306 of the Nuclear Waste Policy Act of 1982.

Reactor operator and senior reactor operator licensing written examinations and operating tests are scheduled and administered through the NRC Regional Offices. Regional office personnel also conduct operator requalification examinations and requalification program evaluations at all licensed facilities. Recently, a methodology for the evaluation of certified simulation facilities was issued. This methodology will be used to ensure that simulators are adequately designed for use in the conduct of operating tests.

Program oversight of the operator licensing function is maintained at headquarters in the Division of Licensee Performance and Quality Evaluation. Responsibilities include regional support and oversight, examination development and simulation facility evaluation.

II. Operations and Maintenance Issues

The focus of the efforts of NRR in the area of human factors has been gradually shifting from licensing issues to an emphasis on plant operations and maintenance. Industry representatives have estimated that roughly 50 percent of significant operating events involve human performance issues. Therefore, it is no longer sufficient to focus on hardware as the sole determinant of plant safety. Rather, the impact of plant personnel on safe plant operations and maintenance must be embraced as an integral factor in the Agency's decision-making processes and determinations of corrective actions.

To support this shift in emphasis, NRR has become involved in the evaluation of performance and the assessment of risk associated with human factors issues. These efforts are described below.

LICENSEE MANAGEMENT AND ORGANIZATION

The Division of Licensee Performance and Quality Evaluation has provided support to the human factors evaluation of licensee management and organization through its active participation in team investigations. Such participation has occurred in the evaluation of management effectiveness at the Davis Besse, Peach Bottom, and Turkey Point plants. In addition to these evaluations, human factors evaluations have been an integral part of the diagnostic inspections conducted at the McGuire and Dresden plants.

HUMAN RELIABILITY AND RISK ASSESSMENT

The Division of Radiation Protection and Emergency Preparedness has a project underway with the Brookhaven National Laboratory (BNL) to estimate the sensitivity of risk parameters to human error rates. The objective of this effort is to identify and characterize risk significant human actions or categories of actions using PRAs from two plants. As part of the effort human factors specialists will be utilized to address the adequacy of the data base and make an assessment of the adequacy of the modeling of human errors in the PRAs. This project will be integrated with a related RES-sponsored program and is intended to result in the development of a method for estimating the contribution of management influences to risk in operating plants.

ENCLOSURE 4

OFFICE FOR ANALYSIS AND EVALUATION OF OPERATIONAL DATA

ACTIVITIES IN HUMAN FACTORS

The Office for Analysis and Evaluation of Operational Data currently has a number of activities that involve evaluation of human factor considerations on the safe operation of nuclear power plants and nonreactor activities and radioisotope uses licensed by the NRC. Human factor issues, such as training, procedures and personnel actions have been incorporated, or are the specific subject of our ongoing review of operating experience. The office has firm commitments for some near term activities for performance indicators that involve human factors; some of these activities are being performed jointly with the Office of Research. In addition, the Technical Training Center of AEOD has the capability to support additional potential future work by the Office of Research.

I. Ongoing and Continuing Activities

Both divisions of AEOD have programs that involve assessing the impact of human factors on the safe operation of nuclear power plants.

A. Division of Safety Programs

One of the major sources of information on the operation of nuclear power plants is the licensee event reports. Each report is reviewed by several engineers to assess the significance of the event. In addition, each report is encoded for computer retrieval, with emphasis on coding of causes of the events and corrective actions.

When a series of events are identified as stemming from a common cause, an engineering evaluation or a special study of the events may be prepared if the problem appears to be generic. In the past, AEOD has frequently assessed human performance and human factors considerations in its studies of operational experience; for example, one of the AEOD studies concerned the contribution of labeling to operator errors involving the wrong unit, train, component or channel.

The causes of events (cause codes) and corrective actions are identified through expert evaluations of the licensee event reports for monitoring in the Performance Indicator programs. Three of the cause codes, namely: Licensed operator error, other personnel error, and administrative control problems directly involve human factor issues. Similarly, several of the corrective actions, such as training, discipline, and management changes involve human factors.

Events reported for nonreactor operations are also reviewed to determine the significance of the event, with the reports encoded for computer retrieval. Most studies of nonreactor events devote a substantial portion of the study to the human factors aspects of the events. Past studies have included medical misadministration, radiography

overexposures, and ruptures of sealed well logging sources. Since manual operations dominate these type of events, human factors were found to be a substantial contributor to the events. These human factors included lack of quality assurance plans, absence of procedures, and failure to follow procedures. A current study of events at large irradiators includes an assessment of such factors as the contribution of management to the occurrence of events at these facilities.

B. Division of Operational Assessment

DOA incorporates human factors issues in both the Incident Investigation Team (IIT) and the Diagnostic Evaluation Team (DET) programs.

The IIT manual specifies that the team investigating a reactor event should include experts in human factors as well as operations (licensed operator). The findings by these team members are included in a separate section of the team report. These provisions assure that the human aspects of the event are given adequate attention by the team.

The DET goals include identifying actions and involvement of licensee management and staff in safe plant operation. To make this identification, both corporate and plant management effectiveness (strength and weaknesses) are evaluated. In addition, the DET attempts to identify problems of an organizational climate that could contribute to performance problems. The DETs have included human factors experts from the NRC staff, as well as management consultants.

The Technical Training Center is currently providing training to NRC staff who inspect licensee emergency operating procedures and to operator license examiners who examine license candidates.

II. Possible Future Activities

The Technical Training Center now has three reactor simulators. Although their first priority must be dedicated to training NRC staff, they could also be used in support of programs by the Office of Research. These programs might include: assessment of operating team performance; studies of staffing composition; evaluation of operator performance under stress; studies of shift duration and operator vigilance; studies of optimum reliance on the Safety Parameters Display System; and use of the simulators in support of the Cognitive Environment Simulation program.

Several of the Technical Training Center instructors held Senior Reactor Licenses. These individuals are an agency resource that might be used in conducting some of the research programs that use the NRC simulators.