

UNITED STATES OF AMERICA NUCLEAR REGULATORY COMMISSION

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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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1 UNITED STATES OF AMERICA
2 NUCLEAR REGULATORY COMMISSION

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4 BRIEFING ON NAS HUMAN FACTOR RECOMMENDATIONS

5 ***

6 [PUBLIC MEETING]

7 ***

8 Nuclear Regulatory Commission
9 Commissioners Conference Room
10 One White Flint North
11 11555 Rockville Pike
12 Rockville, Maryland
13

14 Thursday, May 19, 1988
15

16 The Commission met in open session, pursuant to
17 notice, at 2:05 p.m., the Honorable LANDO W. ZECH, Chairman of
18 the Commission, presiding.

19 COMMISSIONERS PRESENT:

20 LANDO W. ZECH, Chairman of the Commission
21 THOMAS M. ROBERTS, Member of the Commission
22 FREDERICK M. BERNTHAL, Member of the Commission
23 KENNETH CARR, Member of the Commission
24 KENNETH C. ROGERS, Member of the Commission
25

1 STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

2 S. Chilk

3 W. Parler

4 E. Beckjord

5 N. Moray

6 P. Hammond

7 H. Van Cott

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P R O C E E D I N G S

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CHAIRMAN ZECH: Good afternoon, ladies and gentlemen.

The purpose of today's meeting is for the National Academy of Sciences of the National Research Council to brief the Commission on their assessment of the current state of human factors in commercial nuclear power development and to make recommendations for future human factors research.

This is an information briefing. I would like to welcome Dr. Moray, Dr. Hammond and Dr. Van Cott to the Commission today. We appreciate very much your being with us.

On December 19, 1985 the Commission directed the staff to proceed with a grant to the National Academy of Sciences to conduct a study of human factors research needs for the United States commercial nuclear power development.

In response to the Commission directive, the staff contracted with the National Academy of Sciences in March, 1986 to conduct a study of those needs. Further, the Commission directed the NRC staff to expand the human factors research program.

The NRC staff has been preparing a human factors research plan which will depend to the extent appropriate on recommendations from the National Academy of Sciences. The NRC staff will brief the Commission on the human factors program scheduled now on Tuesday, May 31, 1988.

I believe today's briefing by the National Academy of

1 Sciences and the NRC staff briefing, also, will assist the
2 Commission in assessing future human factors research needs.
3 During my visits to the nuclear power plants in the country, I
4 generally spend some time with the control room operators in
5 order to gain an appreciation of their sense of responsibility,
6 their concern for safe operations and their general attitude.

7 I greatly respect the willingness that they have to
8 take on the challenging tasks of operating nuclear power plants
9 and the responsibilities associated with that. I emphasize to
10 them that they are an extremely important part of nuclear power
11 plant safety and that I believe that we should give them all
12 the assistance that we possibly can in the form of well
13 designed control rooms with good human factors engineering,
14 useful and usable procedures and helpful operator aids and
15 training.

16 I believe the NRC should apply focused and visible
17 efforts utilizing human factors professionals to address these
18 issues and we must provide operators with the best environment
19 practicable to operate the plants safely.

20 Commissioner Bernthal is not with us now and I expect
21 he will be joining us a little later. I understand slides of
22 the presentation are available today. Do any of my fellow
23 Commissioners have any opening comments to make before we
24 begin?

25 [No response.]

1 CHAIRMAN ZECH: If not, Mr. Beckjord, are you going
2 to begin or is Dr. Moray going to begin?

3 MR. BECKJORD: Dr. Moray is going to give the
4 presentation.

5 CHAIRMAN ZECH: Fine. Dr. Moray, you may proceed
6 please.

7 DR. MORAY: Thank you very much, Mr. Chairman.

8 DR. HAMMOND: Do you want me to do the slight
9 introduction that we did before?

10 DR. MORAY: All right.

11 [SLIDE.]

12 DR. HAMMOND: I am Brett Hammond. I am here
13 representing the other NRC, the National Research Council
14 today, the National Academy of Sciences. I am the Acting
15 Executive Director for the Commission on Behavioral and Social
16 Sciences and Education, the fourth item, I think, you see up on
17 the screen.

18 It was in our division that the study was done and I
19 just wanted to spend 30 seconds and place this in context. You
20 see before you Dr. Neville Moray, the Chair of the 14 member
21 panel that did the study. You also see to my right Dr. Van
22 Cott, the study director, staff of the NRC. The person you
23 don't see is Beverly Huey, the research associate, who spent so
24 much time. She is up in the control booth running the
25 electronics, I think, at this point.

1 CHAIRMAN ZECH: Fine. We welcome Beverly, too.

2 DR. HAMMOND: We are very pleased to be here. The
3 context I wanted to speak about is just one major point and
4 that is the way in which we do our work. We have at any one
5 time about 900 panels at the National Academy of Sciences
6 National Research Council working on projects like this and
7 across a broad range of other subjects.

8 The chief goal in all of this is to ask each panel to
9 make its conclusions and recommendations in light of a careful
10 review of evidence and scholarly research and other kinds of
11 information that might bear on a problem and the standards of
12 evidence are extremely high.

13 We have as our goal the achievement of balance and of
14 as much as we can objectivity in our reports and we have done
15 that here, too, by a careful process of appointing the group of
16 14 panel members with a broad range of expertise in
17 engineering, psychology, management, organizational issues and
18 other types of expertise from throughout the country and we
19 asked them to volunteer their services, no recompense.

20 In addition, we carefully review proposals. Our
21 governing body occasionally reject proposals that staff would
22 like to send out and we are careful to make sure that they meet
23 our standards of objectivity before they are released.

24 Finally, we let committees do their work but at the
25 end of that time we carefully review the results and we

1 jealously guard that privilege of careful review by asking
2 groups of people who were not involved in that report but who
3 were experts in the subject to look at every word of a report
4 on the basis of the following question: are the conclusions
5 supported by the evidence presented in the report.

6 Once that process has wended its way, we only then
7 release a report and that is the thing that you see before you
8 today, the "Human Factors Research and Nuclear Safety" that was
9 sent to this body in February and we are very proud of it. We
10 think it is a good job and I would like to ask Neville to spend
11 the rest of the time talking about the specifics. Thank you.

12 CHAIRMAN ZECH: All right. Thank you very much.

13 DR. MORAY: Mr. Chairman and Commissioners, I welcome
14 the chance to present this to you. I think you have now
15 probably had time at least to look at the Executive Summary
16 which we have given.

17 Throughout my presentation if I say, "NRC" I will
18 normally mean your NRC and not our NRC for clarity.

19 CHAIRMAN ZECH: Thank you.

20 DR. MORAY: I would like to add my thanks to the
21 members of my panel and to Beverly Huey and to all those who
22 gave us support. On the side of NRC, I would like particularly
23 to pay tribute to Dan Jones and Tom Ryan who went to enormous
24 trouble to provide us with material and taking a lot of their
25 time and were extremely helpful. In fact, everyone in NRC with

1 whom we had any contact was extremely helpful and supportive of
2 the study and we certainly appreciated that.

3 Beverly, next slide, please.

4 [SLIDE.]

5 DR. MORAY: The panel's charge you see up on the
6 screen and I would just like to comment very briefly on this
7 and I will try to run through what I have to say relatively
8 quickly to leave most of the time for you to ask questions
9 which I think is more important.

10 We were not asked to criticize the past program of
11 NRC in human factors. We were asked to decide what we thought
12 was most important in work which remains to be done in the
13 field of human factors in order to ensure the safe operation of
14 nuclear power plants in the United States.

15 There were a number of topics we might have
16 considered and did not. We did not consider radioactive waste
17 disposal programs. We did not consider matters of security.
18 We did not consider, for example, quality control during
19 manufacture.

20 These we decided to leave aside simply because given
21 the time and scope of the study and its urgency, we would
22 rather do better what we could do in detail. Those topics
23 certainly deserve review from the point of view of human
24 factors but you will not find references to them in the report.

25 We also found it necessary to rather extend the

1 definition of human factors. Human factors is sometimes
2 thought of as almost synonymous with what is in Europe perhaps
3 called ergonomics, knobs and dials, lay-outs of panels and
4 things of that kind.

5 That work although not widely used systematically in
6 industry is well understood. There is no reason why going to
7 existing data bases anyone who is constructing a large and
8 complex human machine system should not be able to solve all
9 their problems with those sort of designs merely by looking up
10 what exists. There is no need for research in that.

11 However, we did feel that it was apparent from our
12 collective knowledge and from the literature that we searched
13 that there were problems to do, for example, with management
14 and with maintenance which much widened the scope of human
15 factors compared with what, for example, the Human Factors
16 Society which is a professional organization in the United
17 States would normally consider part of human factors.

18 This comes out in the report in our deliberate
19 espousal of the systems approach and I will come back to that
20 later but it is important to realize what we have called human
21 factors is wider than many in the human factors community would
22 normally include and we think it is absolutely vital that that
23 extension be made.

24 Next slide, Beverly, please.

25 [SLIDE.]

1 DR. MORAY: In the report, you will find a list of
2 the people who were on the people and I just want very briefly
3 not to go through that list but to look at the way that we
4 carried out our work.

5 We had severn collective meetings as you can see
6 here. We had a fairly tight time schedule because nobody was
7 devoted full time to this study. We were doing it at the same
8 time of all our usual work. Nonetheless, I think we managed a
9 fairly thorough access to the relevant information.

10 Next slide, please.

11 [SLIDE.]

12 DR. MORAY: We were helped by briefings from a number
13 of organizations including the Nuclear Regulatory Commission
14 who gave us a particularly thorough briefing which we very much
15 appreciated. We talked also with various people from the
16 national laboratories, the Department of Energy and also
17 representatives from the industry of one sort or another.

18 Next slide, please, Beverly.

19 [SLIDE.]

20 DR. MORAY: We made a couple of site visits to the
21 Electric Power Research Institute which is a body which has its
22 own research program which is related closely in some respects
23 to the demands for human factors work in the nuclear industry
24 and also to Three Mile Island, particularly with the view to
25 letting those members of the panel who were not closely

1 familiar with the nuclear industry to have a first hand view of
2 the nature of the industry, what control rooms are like and so
3 forth. We appreciate the trouble that those bodies also went
4 to to allow us to visit them and to give us a briefing.

5 Next slide.

6 [SLIDE.]

7 DR. MORAY: The background of the report, I think,
8 should be seen against the accepted fact in a wide variety of
9 industries and government agencies and the military that
10 somewhere between 50 and 80 percent of accidents, incidents and
11 errors in almost all industries arise through some form of
12 human error or are at least human induced in some sense.

13 The figure of 50 to 80 percent I take, in fact, from
14 a report of the Atomic Industrial Forum of a few years ago.
15 That figure or variations on it you can find in as I say almost
16 industry that is looked at.

17 When one says, "human induced" or "human error" one
18 is not talking only about operators. It includes everything.
19 If one can imagine a fully automated industry in which the
20 human errors might turn up in the form of design errors which
21 are usually very difficult to find although not impossible; it
22 may be quality control during construction.

23 It is certainly during maintenance. In fact, there
24 is good evidence, I think, that a major component of the impact
25 of human error on the industry is through maintenance

1 activities.

2 Three Mile Island, in fact, was in one sense a
3 maintenance induced incident and also, management. It is
4 becoming increasingly obvious that management and management
5 attitudes and organization has a major role in determining the
6 frequency and severity of the impact of human errors on an
7 industry.

8 There is always particularly, I think, if you look at
9 Chernobyl. That was a management accident essentially. We
10 feel in view of this figure of 50 to 80 percent, that it is
11 unwise--

12 CHAIRMAN ZECH: Excuse me, let me interrupt.

13 DR. MORAY: Yes.

14 CHAIRMAN ZECH: You don't have to get into this now
15 if you don't want to but when you say that it was a management
16 accident, it seems to me that it was more than that.

17 DR. MORAY: The sense in which I meant that is that
18 had the decision not been made to carry out the particular
19 experiment, the accident would not have happened.

20 CHAIRMAN ZECH: All right, but there were design
21 problems and other features.

22 DR. MORAY: Certainly. That is really the point that
23 I wanted to make. The decision to do something unusual was not
24 an operator fault. It was a decision higher up the hierarchy
25 which resulted in the plant being moved into an unsafe domain

1 at which point the design features certainly played a major
2 portion.

3 CHAIRMAN ZECH: All right. Thank you.

4 DR. MORAY: Really the point I am trying to get
5 around to is that given the 50 to 80 percent figure which is
6 accepted, it would be unwise to conclude that all is well with
7 human factors in any industry. There remains a lot of research
8 which can be done in order to support safer and indeed more
9 productive operation.

10 Now the first recommendation we made was that NRC
11 should show a commitment to human factors research, a public
12 commitment and a firm one. This would require a decision to
13 increase staffing and financial support for those activities.

14 I am aware that a program has been or is the process
15 of being re-instituted. At the time this report was written,
16 of course, which is six or eight months ago now we were not
17 sure that that was, in fact, the case and we welcome very much,
18 very warmly, the decision to re-institute human factors
19 research.

20 The problem is that NRC had a number of very good
21 people who have now been scattered to the winds of other
22 careers and other employment leaving you with one or two very
23 good people still and we feel that some kind of public signal
24 is going to be needed in order to reinstate the program.

25 If you are to attract people of the caliber that are

1 required to deal with these very difficult problems in a very
2 complex industry, you are going to have to try to attract
3 people who have seen the demise of the earlier phase of the
4 human factors research program and convince them that this is a
5 long term and serious commitment to human factors research.

6 I think the panel collectively felt that might be
7 difficult in view of the demise of the program earlier. It is
8 also important that by making such a public commitment, it
9 sends a message to industry. In the absence of such a
10 commitment, we feel that many utilities would say that well if
11 NRC is not strongly supportive of human factors, clearly we
12 need not bother about it either.

13 As I am sure you know, it is frequently difficult to
14 convince industry that everything cannot be solved by hard
15 engineering. I think there has been a change in the last few
16 years but nonetheless, a signal needs to be sent.

17 Next slide, please.

18 [SLIDE.]

19 DR. MORAY: The next point which we regard as very
20 important is the idea of a systems oriented approach. Now it
21 is very fashionable and has been for a number of years to use
22 the words, "systems approach" when talking about almost any
23 large and complex plant, organization or system.

24 We wish to underline this very firmly. Following the
25 incident at Three Mile Island, a great deal of effort was put

1 into reviewing and improving control room design in nuclear
2 power plants in the United States.

3 That work, I think, has been extremely valuable and
4 has certainly resulted in significant improvements. However,
5 it would be a mistake to think that the interface between the
6 plant and the operator is the only point at which human factors
7 has an impact. It is clearly a very important one. If that is
8 bad, it is going to be very difficult for people to operate
9 plants well.

10 But beyond that, there is a whole hierarchy of
11 different levels of factors which have an impact on the way in
12 which people operate plants.

13 Next slide, please.

14 [SLIDE.]

15 DR. MORAY: It is this that we want particularly draw
16 attention to. On page 19 of the report, there is something
17 called a scenario in which we try to show this by discussing
18 the way in which one or two what seem to be fairly simply and
19 straight forward decisions to make changes in a plant have a
20 much wider impact than might be expected.

21 Next slide, please.

22 [SLIDE.]

23 DR. MORAY: That can also be sort of formally shown
24 by the picture on page 16 which is also shown here, I am happy
25 to say has come up visibly on the screen, I was a bit worried

1 by it, and this is sort of our organizational diagram.

2 If you look in the middle here, the technical
3 engineering system is the plant hardware and between that plant
4 hardware and the operators, there is an interface which we here
5 label "A" and that is the traditional control room, control
6 room panel interface or equipment which people are using.

7 That is where most of the research has been
8 concentrated and it is important as we will see later to
9 distinguish between research and application. It was clear
10 that the control room, for example, at Three Mile Island did
11 not support very adequately the information processing which
12 was done by the operators.

13 I personally think that the operators did an
14 extremely good job under trying conditions and when you look at
15 the impact and the way in which people behave under stress in
16 industrial accidents across-the-board, not just nuclear, one
17 is, I think, impressed by the fact that usually operators
18 behave very well under stress. There is remarkably few
19 occasions of panic or, "When in danger, when in doubt, run in
20 circles, scream and shout" as it is sometimes put. That really
21 doesn't seem to happen very often.

22 But nonetheless, humans are relatively limited
23 information processes and they do need to be supported by the
24 best possible design of displays and controls. However, if we
25 come in from the outside of this diagram, we are here talking

1 about environmental factors such as the public's view, public
2 perception of the industry, PUCs, regulations made by the
3 Commission and all of these determine to some extent what kind
4 of changes can be made in the inner parts of the diagram.

5 An industry is not free, for example, if they thought
6 it were a good thing to adopt an artificial intelligence
7 support for decision making or artificial intelligence
8 operating procedures without agreement from regulatory bodies
9 and people on the outside.

10 Therefore, the regulations, the regulatory style and
11 the regulatory content here determines to some extent what
12 hardware can be used in the inner parts of this diagram.
13 Similar, management's choices determine that.

14 Let's suppose that a decision is made to computerize
15 emergency operating procedures, a suggestion that has been made
16 from time to time by people who are in the computer and
17 software business and human factors. That immediately throws
18 up a number of problems.

19 For example, if you do that, how many displays are
20 you going to have to put in the control room? Is more than one
21 operator going to share the same console? If so, does one of
22 them overwrite the display which the other one is using every
23 time he changes it? If not, somebody has to decide, presumably
24 management, how many consoles and what type they are going to
25 put in there.

1 It is going to have an impact on training. It is
2 going to have an impact on manning levels. Do you need extra
3 people? Do you need fewer people? Management is entirely
4 responsible really for decisions such as shift work, patterns
5 of shift work and quality control both of materials and of
6 work.

7 You cannot solve a problem at any one level here. It
8 is important to realize that any change you make in an inner
9 loop here has an impact all the way out and similarly, any
10 change in regulations has an impact all the way in, both on the
11 choice of hardware, the design of hardware, the nature of
12 training, the nature of licensing and morale.

13 It may very well be that morale is one of the most
14 important ones. It is these sort of considerations that made
15 us broaden the scope of human factors.

16 It is also important to realize that with any complex
17 system, if you make a change in it for the better to remove a
18 defect of some kind, you do not end up with the system you had
19 before minus the defect.

20 The easiest way to see this is to look at the
21 notorious problem of trying to relieve traffic congestion in
22 cities by building beltways around them. In a naive sense,
23 people think that if you build a freeway around a city, it will
24 reduce the amount of traffic because they will take to the
25 freeway.

1 Without exception, it increases the amount of traffic
2 entering the city and causes worse congestion and the reason is
3 that what you are faced with now is not the old system minus
4 the roads you have altered but a totally new system which will
5 then find its own equilibrium.

6 And when you are dealing with very fine complex
7 systems like this, what appears to be a relatively minor change
8 to the control room design, let's say, may very well have
9 impacts all the way out and a relatively minor change in
10 regulation or management may have an impact all the way in. It
11 is essential that research should be seen in that context.

12 Next slide, please.

13 [SLIDE.]

14 DR. MORAY: And indeed, people who write research
15 reports should be encouraged to report in that context. We
16 recommend, I think, I hope it comes through clearly that when
17 somebody submits a report after doing a contract, they should
18 be asked to say not merely what their conclusions are about the
19 particular work they have done but what impact that is likely
20 to have at all the other levels with which their research has
21 not been primarily concerned.

22 [Commissioner Bernthal enters the meeting.]

23 DR. MORAY: We would like to see a broadening of the
24 people who are involved in planning, conducting and evaluating
25 the research program. In this, we agree with the Frosch Report

1 and indeed we found sympathy with a lot of their
2 recommendations.

3 Next slide, please.

4 [SLIDE.]

5 DR. MORAY: In particular, we would like to see peer
6 review both of proposed research and of the draft reports. The
7 reason for this is that at the moment we feel that the staff of
8 the NRC who are concerned with human factors are grossly
9 overburdened because of their small numbers.

10 The total output in the area of human factors which
11 NRC has sponsored is really quite commendable. It is about 125
12 reports since 1979. That is a very considerable amount of
13 research.

14 We feel that the quality of the research could be
15 improved by the use of peer review. It would be possible we
16 are sure to recruit on an ad hoc basis people from
17 universities, from consulting companies and from the industry
18 to vet both request for proposals, the proposals themselves and
19 the draft reports so that when the reports are finally
20 published, they will be of the highest possible quality.

21 There are some reports, NRC reports in these areas,
22 which have some strange contents which I have tried to read
23 almost all of the ones that have come out since 1980 and I
24 would emphasize that it is not in my opinion the fault of the
25 staff in RES that these -- here and there, there are strange

1 contents of the reports.

2 I can see no way given the staffing levels that the
3 people in RES could possibly have monitored all the reports in
4 detail and indeed, that is one reason why I think that the NRC
5 has made use of the national laboratories.

6 Now the national laboratories have played a very
7 important role in that respect but it does, of course, lead to
8 a dilution of funds through successive creaming off of
9 overheads as you go through a series of organizations and we
10 would like to see the NRC more directly manage its own program,
11 I think, in this.

12 You would closer to the work that you, yourselves,
13 are interested in. By using peer reviews, you could probably
14 off load some of the work. Ultimately, the reports are clearly
15 your responsibility and therefore, they should be monitored for
16 quality by yourselves.

17 We also would like to see in this respect closer
18 cooperation between the RES branch of NRC and other bodies that
19 do research or which don't do research, for example, INPO.
20 INPO by its charter and its definition is not a research
21 organization. Nonetheless, it has a very important role to
22 play as a broker, I think, between the results of research and
23 their application.

24 EPRI, Electric Power Research Institute, has an
25 excellent research program and that is, the Edison Institute

1 and there are a number of other bodies. We would like to see
2 cooperation as far as possible between research in NRC and
3 research done by these other bodies.

4 It would be cost effective and it would also, we
5 think, encourage the industry as reflected in its membership of
6 these organizations to see activities undertaken by NRC as
7 supportive of better and safer operation by the industry rather
8 than always seeing NRC as an antagonist which I am afraid it
9 seems to be the case.

10 I have talked to people connected with the nuclear
11 industry in Canada, Great Britain, the Nordic countries, France
12 and Italy and without exception they are sad, shall I put it
13 that way, sad to see the degree of antagonism between industry
14 and regulation in the states and feel that it is, well, there
15 is always such antagonism and indeed probably must be in order
16 to ensure good regulation, there is a feeling that it is higher
17 here than almost anywhere else possibly in the world.

18 We feel that cooperation in research is an area where
19 something could be done to reduce the tension while in no way
20 reducing the rigors of regulation and it would also lead to, I
21 think, as I said before cost benefit activities.

22 There are a lot of very bright people in universities
23 and in other places who would be willing to undertake research
24 in nuclear engineering departments, in psychology departments,
25 in mechanical and industrial engineering departments and they

1 should be tapped directly as well as through the national
2 laboratories.

3 Next slide, please.

4 [SLIDE.]

5 DR. MORAY: We are sensitive to the fact that some of
6 these suggestions may be difficult. We also are aware that one
7 of the major problems in all industries towards the adoption of
8 human factors results is that the laboratory studies done by
9 human factors people seem very remote from the actual
10 industrial day-to-day experience.

11 It is very often the case in university human factors
12 research, not always but very often, that the experimental
13 rigor is the prime criterion for good research and that means
14 over simplifying the research and that the results which come
15 out are not convincing.

16 If you are trying to tell a utility that on the basis
17 of this research, it should go off and spend a substantial
18 amount of money in order to improve things that they look at
19 the research and they do not find it entirely convincing.

20 Now it is very difficult for people who are
21 professionally qualified in human factors to get access to
22 research facilities which bear at least a face validity to the
23 kind of control rooms and systems which occur in real industry.
24 It would be very nice if those of us who wished to do research
25 in this area would be able to go to nuclear simulators but if

1 you approach any utility and ask if there is any possibility of
2 using their simulator, one is almost always told that it is up
3 and running for training and licensing pretty well 24 hours a
4 day.

5 There simply isn't spare time and also there is, I
6 think, an understandable unwillingness on the part of some to
7 let relatively unqualified university people play around with
8 their simulators which is understandable.

9 Now we feel that one of the things that NRC somehow
10 should do is to provide a bridge or provide access to research
11 facilities, to research simulators or training simulators which
12 would allow research to take place in situations which are
13 convincing to the industry.

14 It is all too easy to say that you don't have to
15 believe these results because, "Look, they weren't done in a
16 nuclear power station so why should we bother to take any
17 notice."

18 If one could undertake research on medium or high
19 fidelity simulators it would certainly improve the quality of
20 research and the plausibility and credibility of the research
21 and bearing in mind the whole time that the aim of this
22 research is not the self-aggrandizement of the researcher or
23 even indeed the acquisition of more and greater pure knowledge,
24 but knowledge which should be directly applicable to the
25 improvement of safety in the operation of nuclear facilities.

1 It must be applied research and the more closely the
2 situation in which the research is done is identifiable as the
3 real world, the more likely it is that the client industry will
4 both take the research seriously and indeed be able to see how
5 to use it cost effectively. So we would recommend the
6 promotion of joint activities on a scale greater than those
7 done in the past.

8 Next slide, please.

9 [SLIDE.]

10 DR. MORAY: There has been talk in the past of a
11 possible research facility at one of the national laboratories
12 which would include a simulator of a power plant control room
13 and we would like, I think, to put forward for your
14 consideration the possibility of something like a national
15 research center.

16 There are problems with such an idea. The cost is
17 coming down day-by-day because of the increase in the power of
18 computers and hardware. There would be, I think, problems in
19 deciding how to staff it and how to fund it although one would
20 assume that if it were successful, it would to some extent
21 attract funds from industry and, of course, there is always the
22 problem that you would have to some extent a generic facility
23 which some people would regard as not really like their
24 particular one.

25 But nonetheless, we don't see really any way in which

1 we can let people or give people access to facilities where
2 research can be done on the scale unless something like this is
3 done given the intensity of the use of existing simulators for
4 training and licensing. So we think that should be a
5 consideration.

6 Next slide, please.

7 [SLIDE.]

8 DR. MORAY: We feel very strongly that as we said at
9 the beginning there must be some kind of public commitment to
10 the research if you are going to attract the people you need to
11 do what is very difficult research.

12 In this respect we feel that it is important that a
13 program be mounted for a considerable time. It is not the case
14 that you can solve the human factors problems and then it will
15 be done once and for all.

16 We are now entering a period when although there are
17 no new plants being ordered, there is life extension work going
18 on and there is re-fitting and we are getting to a point where
19 some of the equipment in the earlier plants is having to be
20 replaced and in many cases the people who built the original
21 equipment are no longer there or the particular items of
22 equipment are not there.

23 Clearly, there is going to be new equipment put in.
24 There is going to be some kind of computerization even if only
25 decision aids and things of that kind and that means that there

1 is going to be a steady, ongoing need for human factors
2 research to make sure that the changes in the plants match the
3 requirements of the human personnel.

4 We feel that there has been in the past a tension
5 between the regulatory branch and the research branch at NRC.
6 Naturally enough, the regulatory people frequently find an
7 urgent need for information on some particular topic. The
8 research branch has tended to look at longer term research
9 efforts in several cases, many cases.

10 To give you an example to which I will return in
11 another section, any day now somebody is going to come along
12 and say, "We want to put an artificial intelligence SPDS system
13 into a plant." There are companies in the computer business
14 who are ready to sell these things.

15 At that point, a decision is going to have to be made
16 as to whether this is acceptable from a regulatory standpoint
17 and the regulatory branch is going to want to know whether it
18 is safe from a human factors standpoint.

19 We feel that the Research branch cannot do high
20 quality research if it is constantly having to interrupt its
21 program to support the urgent short term needs of the
22 regulatory branch and we would like to suggest that to some
23 extent these are separated, that what we came to call in our
24 panel, "responsive research," that is research which is
25 responsive to a particularly urgent question should be done

1 through the regulatory side; whereas, the longer view basic
2 research on human factors should be done by the Research
3 branch.

4 We feel that it is more important that there be
5 continuity on the Research branch than that the financial
6 effort be enormous. Good research can't be done by sudden
7 injections of one shot funds to solve a particular piece of
8 work which then may be halted which something else is done and
9 started up again.

10 Apart from anything else, you are not going to get
11 outside contractors to be prepared to work under those
12 conditions. I have heard from several consulting companies who
13 were involved in the earlier phase saying that they are
14 probably not going to bid on any future work because they found
15 it so difficult to carry out the work before.

16 That is a bad situation because you are in danger of
17 losing high quality people who could do the work. So we would
18 rather see a relatively small but prolonged program than a
19 massive short one and we believe that to be an extremely
20 important recommendation.

21 Next slide, please.

22 [SLIDE.]

23 DR. MORAY: Although we were asked to talk primarily
24 about the needs for research, we would like to draw your
25 attention to the fact that there is really a distinction to be

1 made between the need for new research and the need for
2 transfer of existing knowledge.

3 There is a very large amount of well-established
4 human factors knowledge which is available. The reason it is
5 not used is that engineers are not compelled to take human
6 factors courses when they are at universities and so they
7 seldom if ever come across this particular approach to design.

8 There is much information which could be used and
9 isn't. The most obvious example which comes to my mind is the
10 work on shift work. One of your own reports, NUREGs, recorded
11 an astonishing variety of patterns of shift work in the nuclear
12 industry almost as if people had chosen one from every
13 conceivable pattern that the human wit could think of.

14 There is a well-established body of knowledge about
15 good and bad shift schedules. That does not need much
16 research. What it needs is some mechanism of transferring the
17 knowledge from the data base to use a fashionable word to those
18 who actually are going to use it and we feel that there should
19 be an attempt to improve the transfer.

20 Even EPRI says that it is not happy about the
21 transfer of its own research findings to the industry and I
22 think they do a rather better job perhaps than the NRC. There
23 are two places; one is that we need to establish transfer of
24 information from existing human factors knowledge to the
25 nuclear industry and the other, we need to somehow improve the

1 transfer of knowledge from NUREGs, contract work, EPRI back
2 into the industry where it should be used.

3 We would like to see an attempt to do this again as a
4 cooperative undertaking. It would not in any way again reduce
5 the rigors of regulation and would certainly help to produce a
6 climate where people felt that research sponsored by NRC was
7 helping them rather than threatening them.

8 Next slide, please.

9 [SLIDE.]

10 DR. MORAY: We would like to see NRC, for example,
11 publish an annual review of human factors research relevant to
12 the nuclear power industry. This is not to be confused with
13 the annual report which NRC currently puts out its own program
14 because that is clearly a document for internal consumption.

15 If you read through it, it tells you what research is
16 being done inside the NRC but it does not provide enough
17 information or any indication of how it could be useful to me
18 if I am a utility manager trying to decide how to improve my
19 plant.

20 We are not even concerned here with only looking at
21 research done in the context of the nuclear industry. We are
22 thinking of an annual review or maybe bi-annual which would
23 provide a channel for the latest research across the field of
24 human factors which is seen to be of use to the nuclear
25 industry in particular regardless of where it comes from. It

1 might come from aerospace. It might come from military. It
2 might come from industrial research. It might come from basic
3 research in universities.

4 At the moment we were someone startled when we asked
5 for a list of all the human factors work that had been done by
6 the NRC, 125 reports at least, to find that NRC doesn't
7 actually have as far as we can find out any kind of data base
8 retrieval system whereby you can actually look up things from
9 your own reports under such titles and we feel that that at
10 least would help people to be aware of what work you have done.

11 [SLIDE.]

12 DR. MORAY: Nowadays, electronic data bases for
13 bibliographic searches are not very difficult or indeed
14 expensive to set up. If I want to look up relevant research, I
15 have a great deal of trouble now.

16 I have my own library of your reports but the fact
17 remains that if a utility wanted to look for data on some
18 particular problem which you have contracted and which you have
19 published, they would find it quite difficult to find it.
20 There is no easy way to search your own records and we would
21 like to see something done first about that.

22 Next slide, please.

23 [SLIDE.]

24 DR. MORAY: Secondly, to broaden that to a data base
25 which would include work done by EPRI, perhaps by INPO and

1 utilities and universities to make it really accessible so that
2 this data can be used. If it is not accessible, people won't
3 use it. That is quite clear.

4 COMMISSIONER BERNTHAL: It might make you feel either
5 better or worse to know that this agency is not unaware of that
6 problem. We have been floundering around with it for about,
7 certainly as long as I have been here. I think we are making
8 progress finally.

9 DR. MORAY: It makes me feel better.

10 [Laughter.]

11 DR. MORAY: Definitely.

12 COMMISSIONER BERNTHAL: But you are absolutely right.

13 DR. MORAY: Next slide, please.

14 [SLIDE.]

15 DR. MORAY: In fact, we will go straight on to the
16 one after that as well because we were just saying here that we
17 would like that.

18 [SLIDE.]

19 DR. MORAY: Turning now to the actual recommendations
20 for research areas, we did start by asking whether NRC should
21 support research at all, whether it is a job of a regulatory
22 agency to do so and we said, "Yes, there is no doubt about it."

23 The other avenues of research, EPRI, INPO, Edison
24 Institute and others, do not have the vested interest in
25 continuous support of human factors research for the nuclear

1 industry that you have and we feel the only way to guarantee
2 continuous support is for NRC to do it.

3 Next slide, please.

4 [SLIDE.]

5 DR. MORAY: We decided that there were three main
6 areas. There are some research topics which may have a
7 critical impact on safety and must be addressed immediately.
8 In some areas, research is needed as a basis for evaluation. I
9 will return to that in a minute and in some areas, a research
10 topic is not going to have an immediate pay off in a year or
11 two but is part of a building block for a long term program.
12 The particular thing we had in mind there is probably research
13 on human error.

14 Next slide, please.

15 [SLIDE.]

16 DR. MORAY: And we want to emphasize very strongly, I
17 think it is not written quite as heavily in black and white in
18 the report as we should have written it, that in all cases when
19 we talk about research we are aiming at research at management,
20 maintenance and other ancillary workers and not just control
21 room operators.

22 It is very easy to drop into the habit of thinking
23 that it is only control room operators. We think it is very
24 important to keep it broad.

25 Next slide, please.

1 [SLIDE.]

2 DR. MORAY: We nominated about five areas. In the
3 human-system interface design, control room work, probably the
4 highest priority topic is automation and computer-based job
5 performance aids.

6 As I mentioned before, there are companies who are
7 about to sell or try to sell computerized SPDS systems,
8 computerized EOPs, decision aids. The use of AI, artificial
9 intelligence, is getting to the point where it can have an
10 impact on the industry.

11 We firmly recommend that NRC do not get into the
12 business of doing research on AI, on artificial intelligence.
13 If I may put in a private opinion at the moment, I regard that
14 as one of the blackest of black holes of funding that has been
15 seen in many a year.

16 The important thing for NRC to do is to do research
17 on how to evaluate artificial intelligence and expert systems.
18 At the moment, there is no well understood methodology for
19 telling whether you have a good one or a bad one. The
20 characteristic evaluation of an expert system is that it
21 appears to behave like a human expert.

22 The whole point in the nuclear control room context
23 is that we want to go beyond the human expert. If the system
24 is only as good as a human, you have perfectly good humans
25 there already and it is not well understood how one evaluates

1 artificial intelligence and expert systems and indeed, computer
2 automated systems in general.

3 That is where we think you should put the effort in
4 this area, not in constructing them or doing experimental
5 research on their properties.

6 COMMISSIONER BERNTHAL: Pardon me, but did you find
7 in your studies that there was a consensus today at least in
8 the industry for the need to move aggressively to the kind of
9 automated systems interfacing that you are talking about here?

10 I ask that question because as recently as a very few
11 years ago, I think not today, but there wasn't even a consensus
12 on this Commission that it was a good idea to move toward an
13 automated rather than a human dominated system.

14 DR. MORAY: We believe that there are certainly
15 situations and ways in which computer aided decision systems
16 would help humans to make decisions. We did not find, we have
17 no evidence that there is an overwhelming urge by the industry
18 to put them in.

19 COMMISSIONER BERNTHAL: That's right.

20 DR. MORAY: But as in many industries in this
21 country, what happens tend to be technology driven. Once you
22 have vendors who have systems of this kind and they are selling
23 very aggressively their products, you are going to get requests
24 about whether or not they can be used and the evaluation of
25 those systems is not going to be easy.

1 To show that they work from a computer point of view
2 is not enough. We know that people get lost in hierarchical
3 data bases. That is empirically established. How to tell
4 whether you have a system which is good for people to use is
5 very difficult and is not fully understood. That is what I am
6 saying.

7 I don't think you can stop people wanting to put them
8 in because not the utilities but the computer industry is going
9 to develop them and try to market them and at that point,
10 somebody is going to ask whether or not they can put them in.
11 You have to know how to assess them.

12 COMMISSIONER BERNTHAL: But in some cases, I think,
13 the first step, the first threshold had not even been reached
14 of agreeing that it was a good idea at all in principle to move
15 in that direction.

16 DR. MORAY: That might be a good research topic.

17 COMMISSIONER BERNTHAL: Yes.

18 DR. MORAY: Essentially what one wants -- one doesn't
19 want to suppress innovation but one wants to make sure that you
20 have innovation with safety and that is largely a matter of
21 assessment and evaluation.

22 There are some other topics. EOP design still has
23 quite a lot to be done on it, I think. But basically, you will
24 find other topics mentioned in the report.

25 Next slide, please.

1 [SLIDE.]

2 DR. MORAY: I am going to skim the most important
3 items here because the others are in the report and I want to
4 leave time for you to ask me questions.

5 In the personnel subsystem, we felt there are three
6 areas. Now the last of these, shift scheduling and vigilance,
7 is probably a case where there is little need for research
8 other than in the research on how to get the knowledge
9 transferred to the industry.

10 Obviously, with things like the Peach Bottom problem,
11 vigilance and shift work is a serious human factors problem but
12 there is a lot of information out there which could be tapped
13 if industry chose to make use of it, if they knew about it. It
14 is not entirely their fault.

15 We feel that there is still room for improvements in
16 licensing examinations, in research to establish what aspects
17 of licensing examinations do, in fact, correlate with
18 performance indicators and subsequent good operating habits and
19 we feel that it is also important still to continue with
20 research into training because when a person is trained, their
21 skill will not be maintained unless they are retrained at
22 intervals.

23 The airlines do this regularly and the best way to
24 use simulators and the best way to re-train, the correct
25 interval, the best interval to do this are subjects for

1 research. We do not know for sure what they are.

2 It may very well be that part task simulators on PCs
3 could play a very important role as well as full scale high
4 fidelity simulators. This is the kind of thing and different
5 styles of training, embedded training, exploratory training as
6 it is called. There is a lot of research here that could be
7 done to significantly improve operator performance, we think.

8 Related to this is the question which I know is one
9 that is a matter of grave concern and that is over the degrees
10 for operating staff, academic qualifications. Clearly, if such
11 degrees are to be mandated, it is very important to know what
12 kind of degree curriculum and what kind of training should be
13 involved.

14 There is remarkably little evidence, well the
15 evidence that we have is that it is extraordinarily difficult
16 to get a transfer of skill from academic and theoretical
17 knowledge to operating knowledge and trouble-shooting.

18 In the empirical studies of which there are few,
19 about eight or nine that I know of in process, related to
20 process industries, none of them have shown significant
21 transfer as a result of exposure to theoretical training.

22 But the studies are all flawed. They are short. The
23 particular kind of theoretical training was probably not
24 sufficient to bring it about and the truth of the matter is
25 that we do not at the moment know how you should train somebody

1 with theory in order to get it to transfer to skill and that is
2 clearly an important and urgent topic for research.

3 How to do the research, I think, is fairly straight
4 forward but it needs to be done because otherwise, as one of
5 your own NUREGs again says, when you look at the syllabuses
6 that people who have taken degreed courses go through, they are
7 not clearly what is wanted in order to upgrade the operating
8 and trouble-shooting skills.

9 They are designed almost always for people who are
10 going to be nuclear engineers and not nuclear operators and as
11 I say, this is a field where there is a major lack of
12 information about how to do it well and we strongly recommend
13 research in that area.

14 Next slide, please.

15 [SLIDE.]

16 DR. MORAY: On the subject of human error research,
17 again we have a strong recommendation here which is linked to
18 probabilistic risk assessment. We strongly recommend that no
19 more research be done along the current lines for estimating
20 the probability of human error for human error reliability in
21 PRA.

22 At the moment as things stand, I think it is the
23 largest single area of research supported so far has been in
24 human error and PRA. The problem is that what the research has
25 done is provide increasingly sophisticated ways to get expert

1 to give you their subjective estimates about the probability of
2 human error.

3 In order to know whether those estimates are valid,
4 you need empirical data on how often errors do, in fact,
5 happen, but if you had the empirical data you wouldn't need the
6 subjective estimates.

7 The kind of research that is needed to improve our
8 understanding of human error is empirical data now, data banks,
9 not improved ways of getting experts to guess at what the
10 numbers are.

11 Furthermore, we think that while we understand the
12 reason for the reason for the emphasis on PRA and human error
13 reliability, we would like to suggest that there is a more
14 important way of looking at human error. At best, knowing the
15 probability of human error tells you how often a person will
16 make an error of a particular kind.

17 That is not actually the important thing to know.
18 The important thing to know is which error is this particular
19 person about to make now. If you can understand the causal
20 mechanisms of human error, then you can do something to stop it
21 or alleviate it or to support the person.

22 Merely knowing that the probability is that he will
23 make this error once in every 5,000 times that he performs the
24 action is not actually useful except for licensing. From the
25 point of view of management of safety. what you need is to

1 understand the cognitive mechanisms which give rise to errors
2 when humans do things. That is what we mean by causal errors.

3 [SLIDE.]

4 DR. MORAY: More particularly, we suggest that you
5 should regard error estimates as a way of coupling research
6 into error management using feedback. In any engineering
7 system, you normally use errors to derive a control signal to
8 control a system.

9 We feel that if you find using PRA techniques as an
10 area where people are likely to make errors, that is a sign
11 that something needs to be changed in the design of the system
12 in order to reduce the error and that is the classical negative
13 feedback control of errors which leads to reduction of errors.

14 You don't normally just measure the error. You do
15 something about it. Now we feel that it is of fundamental
16 importance to realize that what we need to understand is why
17 and when errors occur, of how they occur, so that they can be
18 prevented or mitigated not simply to know the descriptive
19 frequency with which they occur over a long period.

20 This a new field. Research has begun intensively if
21 only about the last seven or eight years. It is difficult. We
22 are beginning to see how to do it and it is clearly the case
23 that if you have research that tells you how to stop an error
24 or manage it, that is more valuable than knowing how often it
25 is going to occur.

1 We, therefore, strongly recommend research on causal
2 models of human error and no more research on how to get expert
3 estimates of the frequency of human error.

4 Next slide, please.

5 [SLIDE.]

6 DR. MORAY: We also recommend that there should be
7 research in the fields of organization and management. We
8 would like to see research on the impact of regulations on the
9 practice of management.

10 We have heard from utility people that some of the
11 managers who we think were telling the truth feel that they are
12 spending so much time meeting regulations that they haven't got
13 time to manage the plant and I am sure that you have heard
14 complaints directly from the utilities in this area. There are
15 disciplines which have studied the impact of regulatory style
16 on management.

17 Clearly, what you need do to is to find how to
18 produce regulations which encourage efficient management of the
19 plant at the same time as satisfying the regulatory
20 requirements.

21 We also feel that there is resistance on the part of
22 utility management quite widely to change and that research
23 should be done on how you create a climate of reliability, a
24 culture of reliability in which the entire plant from
25 management down are dedicated to safety and reliability.

1 There has been research done in the military. There
2 has been research done in other industries and we would like to
3 see that done in the nuclear area. In many respects morale is
4 clearly critical. Good management can create good morale and
5 get surprisingly good performance out of people with
6 surprisingly bad equipment in many cases.

7 We had a letter which is not included in the report
8 from some operators who said, "Above all please, for God's
9 sake, do something about shift work. It is terrible. We all
10 hate it. When we complained, our managers just said, 'Shift
11 work is part of your job, get used to it.'" That is not good
12 management and it is not management which is going to produce
13 high quality performance on the part of the operating staff.
14 There is clearly need for management research. There is a well
15 understood methodology.

16 Next slide, please.

17 [SLIDE.]

18 DR. MORAY: Finally, we come to perhaps a delicate
19 topic and one in which we are aware that perhaps we are asking
20 you to go out outside your own mandate from Congress. We feel
21 that regulation after all is an activity of humans for humans
22 and by humans and is, in fact, human factors and we would like
23 to see research done to try to discover the best style of
24 regulation.

25 Is there a mix of self-regulation and top-down

1 regulation which is likely to be more effective and safer than
2 the traditional one? At least, the human factors design
3 principles should apply to the regulations which come out so
4 that they are clear and unambiguous.

5 We think there is room here for improving regulation,
6 the way regulation is done, and that this probably would pay
7 off in better compliance and a better relationship between
8 utilities and the NRC.

9 We are aware that this may not be possible within
10 your mandate and we would like to make these suggestions. We
11 would like you to regard these suggestions as support for
12 anything which you wish to do in this area and not as a
13 criticism, but as something which you can show to other people
14 and say, "If you wish to, the Academy Report has also said this
15 is worth looking at."

16 Finally, because regulation is going to performance
17 regulation very often, it seems to be this change in
18 philosophy, that we would like to see research on what are the
19 performance measurement indicators, how do you tell that a
20 plant is being run well and that is not an easy topic and
21 certainly needs research.

22 Next slide, please.

23 [SLIDE.]

24 DR. MORAY: The conclusions are that we think that it
25 is certainly desirable and important and possible to mount a

1 renewed human factors research program. We say here
2 particularly something which I would like to draw your
3 attention to, and that is, we wish to say that we think that
4 human factors should be organized as a branch at NRC.

5 At the moment, it is being guided under reliability
6 broadly speaking. It has never had a branch head of its own.
7 We have no criticism of the way in which the people who are
8 currently responsible for the program are carrying out their
9 work, but the fact remains that I find it doubtful that if you
10 had a human factors branch, you would invite it to look after
11 thermal hydraulics and it is a field of professional expertise
12 which those who have not worked in it do not know and do not
13 understand its methodology.

14 Perhaps more importantly, as we understand it is only
15 at the level of the branch, an independent branch, that the
16 budget for research is secure for research on human factors.
17 Human factors is not the same as PRA and reliability research.

18 It is something quite different and with the best
19 rule in the world, we do not feel confident that if it is being
20 run by a branch head with primary responsibilities in another
21 area when the crunch comes that the budget for research in
22 human factors is going to be safe.

23 We are not and let me say this very, very explicitly,
24 we are not trying to write ourselves jobs either for the
25 members of the panel as individuals nor for our profession. We

1 have no objection to the person being an engineer who has
2 gained considerable experience over several years in human
3 factors work in one of the national laboratories or indeed
4 somebody from NRC itself.

5 We are not saying that you must rush out and hire
6 lots and lots of quotes, "human factors" people, all of whom
7 have Masters or Ph.D.'s in Human Factors from University
8 departments but we are saying that we do not feel confident
9 that without a human factors program at the level of a branch
10 that the program will be secure, continuous and of a quality
11 which will meet your needs.

12 Next slide, please.

13 [SLIDE.]

14 DR. MORAY: However, if you adopt at least some of
15 the recommendations which we are putting in this report, we do
16 think that you will have taken the steps necessary to provide
17 leadership in the critical area of human factors. Further
18 steps will have to be taken as this unfolds.

19 We hope that it will develop cooperation between NRC,
20 the industry and others and let me say finally that the feeling
21 of the panel, of my panel, was that we felt very strongly that
22 we were not out to criticize past or present programs. We felt
23 that the existence of a nuclear industry in this country is
24 contingent on it being shown to be safe.

25 Given the known rate of human error in all

1 industries, there is no reason to think that it is lower in
2 nuclear than any other industry or for that matter, higher and
3 that it is of the utmost importance to start up research again
4 in the area of human factors for nuclear safety for the benefit
5 of society, the safety of society, and the future of the
6 industry including the design of the next generation of
7 reactors.

8 We hope that you will find the work we have done
9 helpful to you and we will be happy to be at your disposal to
10 answer any questions either now or on other occasions. Thank
11 you very much for your patience.

12 CHAIRMAN ZECH: Thank you very much, Dr. Moray.
13 Questions from my fellow Commissioners, Commissioner Roberts?

14 COMMISSIONER ROBERTS: No, not at this time.

15 CHAIRMAN ZECH: Commissioner Bernthal.

16 COMMISSIONER BERNTHAL: Well, I apologize that I was
17 late getting here. The Chairman is getting used to it, I am
18 afraid lately. We are now out here instead of downtown and
19 when I have to go downtown, it is very hard to get back at two
20 o'clock but I think I got the broad gist of what I missed here.

21 I have a few comments and then some questions. One
22 of the things as you pointed out has been facing the Commission
23 and continues to be the issue of degraded operators and I would
24 appreciate any further comment you care to make in any detail
25 you have time to make today but the one thing that I would

1 appreciate your thoughts on is the question of whether it is
2 even practical to expect to be able to analyze the transfer as
3 you put it of an education or a degree, the transfer of that
4 knowledge, to operations and trouble-shooting as you put it.

5 It is unclear to me that that would be possible even
6 in principle and I don't think that is the intent or the idea
7 broadly speaking of education and certainly not in my mind at
8 least of education as it might apply to a nuclear power plant
9 operator.

10 Rather, you hope that the pool of talent is upgraded
11 somewhat by requiring a degree and that the degree then leads
12 to better training, that is, a better recipient for training
13 and from thence to a better operator, a better trouble shooter.

14 Would you care to comment on that because that seems
15 to me at least to be the philosophy behind asking for a degree
16 from every operator eventually?

17 DR. MORAY: Well, as you know throughout the world
18 the pattern of practice in this regard is very varied.

19 COMMISSIONER BERNTHAL: It is.

20 DR. MORAY: The academic educational backgrounds vary
21 from country to country enormously. I think it is a mistake to
22 think that it is the fact that people have degrees by
23 themselves is going to change anything. This is one of the
24 cases where a systems viewpoint is most important.

25 Certainly, I think all of us would assume that

1 somebody who has a greater knowledge of a discipline must be
2 able to exercise his knowledge and skills, put them to use, in
3 a better way than someone who hasn't. That in some sense must
4 be true.

5 The problem is that the exact way in which it
6 transfers, how that knowledge is useful, is not well
7 understood. I would hope in the interest of efficiency that
8 one would go further than your view. I mean the reason that I
9 would want somebody to be degreed would be that I knew, I felt
10 very strongly that as a result of that training, I could
11 definitely show that on all the tasks I might want him to do he
12 would be better whether it is controlling, fault management,
13 STA, whatever it may be.

14 Now the problem is that how he is going to be able to
15 use his knowledge is going to interact very strongly with a
16 number of other things. For example, in France the equivalent
17 of the STA, the safety engineer, is degreed but more
18 importantly he has the ultimate responsibility in the control
19 room.

20 If he says, "This is an emergency, we go to the
21 emergency procedures," you go. Here the STA gives advice if
22 called upon and we know that the role of the STA has turned out
23 to be very difficult because he has the academic training but
24 the operators frequently regard him as somebody who doesn't
25 operate and therefore is not somebody who has the same skills

1 they have.

2 So I think you have to see it, the whole point of
3 going for it is that it is worth having in the sense that it
4 improves the operation of the power plant and that is why. If
5 that is not what you are going for then it is clearly not worth
6 bothering about because I don't think that just having gone
7 through a degree is going to necessarily gain you much.

8 For one thing, it is fairly widely believed that
9 people with degrees, university degrees, for example, don't
10 like shift work and if all you are doing is turning your
11 operating staff into people who are going to be more resentful
12 of shift work than they were before, you are going to lose them
13 to other industries or lose them to other jobs.

14 So what you need is an understanding of exactly what
15 kind of training you should have at that level which will
16 support the activities which you know from doing a job in task
17 analysis are those which are critical for the safe management
18 of the station.

19 COMMISSIONER BERNTHAL: You seem to be using the
20 term, "degrees," and I will call it, education interchangeably
21 with training though and that, it seems to me, exactly the
22 point, that those in my mind at least are not at all the same
23 thing, that you get an education so you learn fundamentally how
24 to think and you have demonstrated the ability to absorb
25 knowledge and the ability to absorb training, if you will, and

1 one hopes then that with that first of all demonstration and
2 secondly with whatever you might have learned by way of thought
3 processes that you are going to be trained better and
4 therefore, ultimately operate better.

5 DR. MORAY: Well, I would like to go further than
6 hoping it. I would like to systematically design the training
7 and the education in such a way as to guarantee it.

8 COMMISSIONER BERNTHAL: But the training is what i am
9 emphasizing and the education, I think, you will never be able
10 to demonstrate that education except perhaps the point you
11 mention that education might be detrimental to your affection
12 for shift work but on the other hand, you have also mentioned
13 that we ought to do something about the antipathy toward shift
14 work.

15 DR. MORAY: Well, as a matter of fact, this brings me
16 to the other question you asked me, is it possible to conceive
17 of doing this kind of research and the answer to that is yes.
18 I have colleagues at Illinois in the aerospace area who are
19 doing precisely this kind of research now and I have myself, in
20 fact, begun to do research on exactly this issue.

21 It is not terribly difficult to see how to do the
22 research if you are human factors professional. It is actually
23 fairly straight forward. It just hasn't been done.

24 COMMISSIONER BERNTHAL: The research on what?

25 DR. MORAY: On how to ensure that knowledge -- to do

1 research on how you ensure that theoretical knowledge leads to
2 an improvement in skill. Certainly knowledge and skill are two
3 different things.

4 COMMISSIONER BERNTHAL: Right.

5 DR. MORAY: And the transfer between them is not
6 fully understood but it is very easy to do research to improve
7 our knowledge of that and I would strongly argue for that.
8 Yes, methodologically, it is not very difficult.

9 COMMISSIONER BERNTHAL: Well, it is a very important
10 issue as you point out. I also was particularly interested in
11 your comments on the approach to human error and what we should
12 study; that is, the cause of human error rather than the
13 statistics of human error, I guess, and in that regard I don't
14 know whether you care to comment but it is worth noting maybe
15 that every serious accident, truly serious accident, the most
16 serious accidents we have had in this business have occurred
17 between twelve midnight and six a.m. There must be a message
18 there. Even the Chernobyl event occurred in the wee hours of
19 the morning and maybe you have a comment.

20 DR. MORAY: Well, the numbers of really serious
21 accidents is rather small.

22 COMMISSIONER BERNTHAL: That's right.

23 DR. MORAY: But it is undoubtedly true what you say
24 and this is a case where the main factors, I think, are
25 thoroughly well understood and documented in introductory

1 textbooks on human factors which students get in their
2 introductory courses.

3 If you look at the history of accident research, the
4 two that spring to mind is a Swedish study in driving trucks
5 and an enormous study lasting over something like 30 years on
6 people reading meters in the gas industry including, I think,
7 something like 150,000 data points which is quite a study and
8 they all show this huge rise in errors in the early hours of
9 the morning apparently due to biological rhythms. That is
10 absolutely perfectly well understood.

11 Moreover, we know quite a bit about how that
12 interacts with shift work which is the important thing. I
13 mean, you are always going to get a rise in errors in the small
14 hours of the morning. The question is, how can you reduce that
15 and to what level can you reduce it and can you build systems
16 which will absorb the errors even if the errors are made.

17 COMMISSIONER BERNTHAL: I am not sure how much time
18 we have but would you care to offer a clue on some of the
19 things you do know about how shift work influences errors in
20 the wee hours of the morning?

21 DR. MORAY: Yes. Well, one obvious one, it is fairly
22 clear now that if you are working eight-hour shifts and you
23 rotate forward, morning, evening, night, you will get a much
24 better adaptation than if you rotate backwards.

25 It is generally agreed that because of the extreme

1 resistance in the biological rhythms to changing phase, at the
2 moment it is considered the best thing to do is to have sort of
3 two days on and then change shifts.

4 Don't put people on nights for a week because it
5 takes about three or four days, three or four 24-hour periods
6 to begin to seriously shift the biological clock around the
7 phase and by that time the week is virtually over and just as
8 they are beginning to adjust, you take them off again.

9 There is argument about this but the most commonly
10 accepted view at the moment is you rotate rapidly and just on
11 very short, two days on nights and then off again.

12 COMMISSIONER BERNTHAL: There is certainly nobody
13 that I am aware of in the industry doing that.

14 DR. MORAY: Oh, there are.

15 COMMISSIONER BERNTHAL: Are there some?

16 DR. MORAY: Yes. You will find it in your report.
17 Some of them are.

18 COMMISSIONER BERNTHAL: All right, but most are not.

19 DR. MORAY: And as I say, it looks rather like a
20 random selection from all possible permutations.

21 COMMISSIONER BERNTHAL: Most are not, I think. I am
22 not aware of any that do that.

23 DR. MORAY: Yes. Well, as you know, there are 12
24 hour shifts coming in in various places.

25 COMMISSIONER BERNTHAL: That's right. Do you have

1 any comment on that?

2 DR. MORAY: I have just been reviewing the literature
3 on that. It is very thin literature. What I can say is at the
4 moment empirically, there is no evidence that 12 hour shifts
5 increase the occurrence of accidents or incidents although
6 operators say that they think that they are getting more
7 fatigued.

8 On the other hand, they all appear to like it so much
9 that it is probably more than offset by the social thing. Now
10 the problem is, there are some significant problems. If I was
11 to run a 12 hour shift, overtime becomes extremely important.
12 A 12 hour shift, there doesn't seem to be any shift.

13 Somewhere between 12 and 16, you are almost certainly
14 beginning to get severe fatigue setting in so I would be very
15 careful about allowing overtime. I would be very careful about
16 apparent 12 hour shifts with say two hours driving on either
17 end to get home, you know, things like that. Twelve is, I
18 think, the evidence at the moment is that 12's are all right,
19 somewhat to my surprise.

20 COMMISSIONER BERNTHAL: Well, I think the argument we
21 have had is that whatever disadvantages there may be in the
22 boredom factor or the fatigue factor gets offset by the smaller
23 number of turnovers in 12 hours.

24 DR. MORAY: That appears to be the case, yes, and
25 better communications.

1 COMMISSIONER BERNTHAL: Yes. You also raised the
2 issue of a central research facility that I gather you feel
3 should involve a simulator primarily so the human factors
4 researchers could have access to a simulator.

5 I have two questions. One, how much does it matter
6 that there is a vast array of different control rooms in this
7 country so you really would have a lot of different simulators
8 or are they all generically okay for the human factors research
9 worker and secondly, as a rather pointed question, whether you
10 have thought about the possibility, maybe we ought to think
11 about the possibility, that the Tennessee Valley Authority
12 would be an appropriate entity being as it is a government
13 agency to step forward and take the lead in an area like that.

14 DR. MORAY: What we recommend is that steps should be
15 taken to help those who wish to do research in quasi-realistic
16 settings to get access to the facilities to do so. We
17 mentioned one possibility of a national facility because there
18 was talk about this a few years ago. I think Oak Ridge was
19 discussing the possibility.

20 Now I don't know what has happened to that suggestion
21 but it is not that so much, it is the question as to how we are
22 going to get people able to do research in a setting which will
23 be acceptable to the utility if the results of the research
24 show that they are going to have to make a considerable
25 investment.

1 They are more likely to accept it, I think, and also
2 the results are more likely to be genuine. I mean, if you take
3 somebody and stick him in a lab for two or three hours and run
4 then even on a simulation of some kind of plant as I do, you
5 don't see the behavior that you get with people running eight
6 hour shifts several days on end.

7 Particularly, for example, if you take something like
8 a new display design, say computer generated displays, SPDS,
9 whatever it may be, to evaluate that is really quite difficult
10 because the people, operators who have experience of previous
11 systems may well take some time to adjust to the new one and
12 the immediate impact of working with a new system may be rather
13 poor behavior because they are simply not used to it. They
14 don't know how to look at it. They don't know how to call it
15 up. They don't know how to manage it.

16 Now it will take certainly somewhere between ten and
17 100 hours for people to get used to a new display and probably
18 considerably longer to get up to the level of skill which they
19 will show after say a year or two unless you have a strikingly
20 better display in which case the operators will tell you
21 instantly.

22 So what I am arguing for is access to research
23 facilities where research can be done in a realistic way not
24 with artificial subjects people coming in for an hour or two,
25 not with undergraduates, not on an over-simplified PC desk top

1 graphics but on something which at least has a generic
2 similarity to real control rooms. Holden in Norway has this
3 kind of facility and do sponsor and I know you have relations
4 with Holden.

5 They are not easy to use. That kind of research,
6 that kind of quasi-field research is very difficult to manage
7 and very difficult to design but I think there is a case for
8 it. I would be quite happy if TVA were the people.

9 We are not telling you to spend all your money to go
10 out and build one or even recommending it, I beg your pardon, I
11 shouldn't say telling but we are just saying that we feel it is
12 important that that quality of research should be available,
13 access to those research facilities should be available.

14 COMMISSIONER BERNTHAL: There are two kinds of things
15 really that you are talking about it seems to me. One, the
16 fact that we have many different control rooms doesn't matter.
17 It sounds like in one case you are talking about testing the
18 efficacy of new hardware, for example, whereas you also seem to
19 touch on another area of research which would be observation of
20 the human performance on whatever the plant or the simulator
21 might be and one wonders whether you might not even be able to
22 carry that out within operating nuclear power plants.

23 DR. MORAY: Well, if I wanted to do research on fault
24 management, for example, what happens when an incident occurs
25 and people are faced -- one thing we feel very strongly about

1 is that research needs to be done on fault diagnosis for beyond
2 design basis faults and that is a difficult thing. How do you
3 train people for things you don't know are going to happen, the
4 unknown fault?

5 We believe there probably are generic ways of doing
6 that. If I wanted to carry out research on how people do fault
7 management, I don't think that I, let alone the utility or you,
8 gentlemen, would be very keen on my doing it in a plant.

9 COMMISSIONER BERNTHAL: No, I agree.

10 DR. MORAY: A simulator, yes, and certainly the exact
11 way in which somebody manages an incident is going to depend on
12 the exact physical system in the end. There are plants or
13 there were before the DCRDRs were done where a display was over
14 there and the control was over there and although the EOPs may
15 be written quite correctly, "Do this," you can't actually do it
16 without arms twice as long or eyes on storks.

17 Now generic research on say the logical processes,
18 the thinking processes, underlying diagnosis can be done
19 without having a simulator which matches any one particular
20 plant. The transfer of the particular plant can be done on a
21 relatively small scale bit of research for that transfer
22 situation.

23 COMMISSIONER BERNTHAL: Yes. The case that I really
24 had in mind if a utility were willing for carrying out at power
25 plants is like the instance you mentioned or the case you

1 mentioned where you were trying to assess performance over a
2 long period of time, over shift times, and you can't do that in
3 two hours on a simulator.

4 DR. MORAY: That you can do, yes. No, that you can
5 do.

6 COMMISSIONER BERNTHAL: That sort of thing it seems
7 to me if the utilities would cooperate observers in the control
8 room shouldn't be disruptive.

9 DR. MORAY: Indeed.

10 COMMISSIONER BERNTHAL: One other question and then I
11 give someone else a crack here, did you involve NASA, I am sure
12 you did at one level or another, but how much did you involve
13 NASA in your study? That is, NASA was at one time viewed as
14 something of a leader in this area. I don't know whether they
15 are still viewed as being a leader. I would hope they are.
16 Might the NRC have a good deal to learn from NASA in these
17 areas?

18 DR. MORAY: You mean in the generic areas of human
19 factors?

20 COMMISSIONER BERNTHAL: Yes.

21 DR. MORAY: Oh, yes.

22 COMMISSIONER BERNTHAL: Human factors research and
23 understanding.

24 DR. MORAY: Yes, certainly. We didn't go and talk to
25 NASA particularly because several people on the panel including

1 myself have done research for NASA as contractors. We are all
2 very familiar with the research they do and indeed with many of
3 the people who do it.

4 From inside the panel, that was part, I think, of our
5 background expertise as to why we were chosen to be on the
6 panel. Certainly, military, NASA, there are lots of people who
7 do good work.

8 COMMISSIONER BERNTHAL: And, again, it would be your
9 judgment that we have not had very good technology transfer if
10 you will from those agencies?

11 DR. MORAY: That's right, yes.

12 COMMISSIONER BERNTHAL: I agree. That is all for
13 now. Thank you.

14 CHAIRMAN ZECH: Commissioner Carr.

15 COMMISSIONER CARR: Have you asked anybody for time
16 on a simulator at a utility?

17 DR. MORAY: I have. I have asked a couple.

18 COMMISSIONER CARR: I am surprised that you can't
19 have it. They don't run that often.

20 DR. MORAY: Well, they told me that they are running
21 them day and night and they are too busy.

22 COMMISSIONER BERNTHAL: Yes, I question that, too. I
23 think you are quite right, Ken.

24 COMMISSIONER CARR: Maybe it is how we ask but how
25 much time are you talking about that you would need, six

1 months?

2 DR. MORAY: Depending upon the study, it might be
3 anything from a few days, a few hours a day, to a few hours a
4 day for a quite long period, six months or something. I can't
5 say that. You can't say that out of the context of a
6 particular investigation any more than you can in any other
7 science.

8 COMMISSIONER CARR: That seems like that could be
9 overcome reasonably easily.

10 DR. MORAY: Yes. I think, you see in the report we
11 asked for your role, NRC's role as a sort of broker between the
12 research community and the utilities or INPO or anybody because
13 I find it very difficult to believe that these things are
14 running seven days a week, 24 hours a day.

15 COMMISSIONER CARR: We have simulators that we
16 control.

17 DR. MORAY: Yes, I agree.

18 COMMISSIONER CARR: I think that is a problem that we
19 can overcome. Would you expand a little bit on the principal
20 human factors research areas that could significantly improve
21 maintenance?

22 DR. MORAY: There is a large body -- a lot of it is
23 again technology transfer. There is, for example, an excellent
24 publication by EPRI on design for maintainability. I would
25 start by trying to make sure that that was understood although

1 it is a little late now because --

2 COMMISSIONER CARR: I started to say if there are 104
3 of them out there already designed --

4 DR. MORAY: That's right and they have been designed
5 in a way which makes maintenance very difficult. A lot of it
6 is technology transfer because we know about labeling. We know
7 about how to write operations procedures. The EPRI study way
8 back in the late 1970's has a picture, a photograph, of a
9 maintenance man sitting on the floor with a manual which says,
10 "This photograph records the only occasion on which we saw a
11 maintenance person using procedures." Now when that is said,
12 there is something wrong.

13 COMMISSIONER CARR: So you don't think research is
14 really necessary in this area?

15 DR. MORAY: I think research is necessary to make
16 sure that what is known about how to train, how to write
17 operating procedures, maintenance manuals and so on, that that
18 knowledge is put to use.

19 COMMISSIONER CARR: But there it is a matter of just
20 taking it and using it.

21 DR. MORAY: Yes. I would start certainly by looking
22 at the transfer of training issue and there are some problems.
23 For example, the wrong unit/wrong train fault which is very,
24 very common. We were told by your people that this is the
25 single most common maintenance error.

1 Now that may simply be due to poor design in the
2 sense of incompatible labeling with the position of the
3 equipment. I mean there are cases where the label is up here
4 on top of one thing and the actual thing to which it refers is
5 side by side. Those are simple. You need a human factors
6 audit.

7 So I would certainly start by looking at transfer of
8 training and human factors audits for maintainability and then
9 I would start looking to see what else I need to do in the way
10 of better training, licensing even of maintenance and the
11 design of communications between the maintenance people and the
12 control room, things of this kind because I think there are
13 things there.

14 COMMISSIONER CARR: When you say "licensing," you
15 mean licensing maintenance personnel, have a minimum
16 qualification?

17 DR. MORAY: Yes. It worries me that very often
18 maintenance is contracted by companies as so I have been told
19 and once you start doing that --

20 COMMISSIONER CARR: Very often.

21 DR. MORAY: -- you don't really know where they are
22 coming from. Considering the importance of maintenance in
23 keeping the plant in a safe state, one really feels that there
24 ought to be some pretty strong constraints on licensing or
25 qualifications or minimum qualifications and some kind of

1 monitoring system.

2 It is interesting that if you go in the next
3 generation of reactors to increasing automation, you are faced
4 with a fact that a fully automated plant, probably the only
5 people who can cause human error is to have a day-to-day impact
6 are maintenance personnel and not operators.

7 The more sophisticated and automated a plant becomes,
8 the more the weak link becomes maintenance and not operation
9 and unless you also upgrade maintenance as you invent and
10 design more sophisticated plants, you are going to be left with
11 a plant that is actually weaker than it was when it was
12 manually controlled. There is room there for some prospective
13 research.

14 COMMISSIONER CARR: Thank you.

15 CHAIRMAN ZECH: Commissioner Rogers.

16 COMMISSIONER ROGERS: Yes. In many of these areas
17 that you have touched on as high priority areas, some of them
18 really relate to old problems that have been around for a long
19 time in industry and in management situations and have you in
20 setting up your priority system, did you try to include the
21 measurability of results as a way of ascertaining what can be
22 measured and what can't be measured in terms of effectiveness
23 of research?

24 Some of these areas strike me as very difficult and
25 they have been around for a long time, things that relate to

1 management effectiveness and they are difficult to measure.
2 There are so many elements that relate to individuals rather
3 than their training and education.

4 It seems to be that one of the biggest problems in
5 the whole human factors area once you get out of things like
6 man-machine interfaces is to develop measurables, something
7 that you can measure that you have done something, that it all
8 seems very plausible and it all seems very reasonable but has
9 it really made a difference and I wonder if you could comment a
10 little bit about the relationship between setting a set of
11 research priorities and being able to measure results of having
12 done that research.

13 DR. MORAY: Yes, certainly. At one stage we had a
14 shopping list of about 40 recommendations which we felt would
15 not be terribly useful to you and we tried to narrow them down
16 and make them more generic rather than giving great detail. We
17 did not include anything on that list which we felt we could
18 not ourselves measure were we given the opportunity.

19 We had several people on the panel, LaPorte, Shikiar
20 and one or two others, who have experience in doing research in
21 management and organization for the military and for other
22 industries and although it is not my particular area of
23 expertise, I am a human machine system person, those people
24 have in their careers certainly been involved in objective
25 measurement.

1 I think one important thin is to realize that there
2 are different things that one means by measurement. To the
3 engineer, if it is not measurable to two places of decimals and
4 highly repeatable, that is sometimes thought as not being
5 measurement.

6 In many cases, it is sufficient to use a weaker form
7 of measurement such as better than, greater than, less than.
8 It would, for example, I think be quite satisfactory if
9 somebody came and said, "Look, I want to institute this change
10 in the utility and I am not sure how much better it is going to
11 make things but all the research that we have done guarantees
12 that it won't make them worse," that that would be sufficient
13 grounds for saying, "Go ahead."

14 Certainly, I think everybody would agree that the
15 further you move towards a societal and a social and the
16 organizational aspects, the further you get away from the kind
17 of measurement in degrees Celsius or BTUs or whatever it may
18 towards ordinal measurement to use the formal term, greater
19 than/less than.

20 But it doesn't mean they can't be measured and
21 depending upon what kind of answer you require, you can
22 certainly establish the appropriate measurement. You may not
23 be able to say that it will go up by 22 percent. Indeed, that
24 may be undesirable.

25 For example, one has to be very careful. I once got

1 involved in some work on the 12 hour shift a few years ago and
2 the question was, would it increase error and for various
3 reasons at that time we came to the conclusion that the best
4 estimate ten years ago or so, eight years ago, was that it
5 would probably double the number of errors but doubling it from
6 10 to the minus 6 to two ten to the minus six, right, is one
7 thing. Doubling it from ten to 20 is something quite else and
8 expressing things in percentages may be actually grossly
9 misleading.

10 One can go for over precision or precision of the
11 wrong kind so my general answer is yes. If we didn't believe
12 that we could measure it, we would not have put it in the
13 report although in one or two areas, such as performance
14 indicators, we say that research is required to establish what
15 would be satisfactory measurement scales because at the moment
16 they don't exist.

17 COMMISSIONER CARR: Can I piggy-back on that
18 particular part because you said that you need to do research
19 on how can you tell if a plant is running well.

20 DR. MORAY: Yes.

21 COMMISSIONER CARR: How would you approach that?

22 DR. MORAY: I would want, I think, some kind of
23 clearly some kind of composite measure. The fact that it is
24 producing electricity with 90 percent availability is not in
25 itself an adequate criteria.

1 COMMISSIONER CARR: No. It could be doing that with
2 everybody out of the plant perhaps.

3 DR. MORAY: That's right, and that is clearly one
4 thing one would want to look at the number of incidents, LER
5 reports, the particular details inside them. When we want to
6 go in and certainly do some field studies, monitoring people,
7 seeing how they behave, looking at logs, looking at -- I would
8 want to interview the people and find out what they were
9 prepared to tell me about their working conditions and so
10 forth.

11 It is not easy. I mean we feel that one of the
12 problems about performance measurement indicators is that it is
13 not at all clear at present.

14 COMMISSIONER CARR: I guess it is not clear to me how
15 research could solve it.

16 DR. MORAY: No. The idea for the research would be
17 systematically to look for evidence of, for example, one thing
18 which I did one day while we were doing this report was to go
19 through the availability figures for the last three or four
20 years for different plants and see to what extent they are
21 correlated on a year-to-year basis because one might have
22 expected certain plants to be inherently good and certain
23 plants to be inherently bad.

24 In fact, the variability is fairly remarkable over
25 the years. If you have plants which are closely similar in

1 design and age and everything else and yet they vary greatly in
2 performance in terms of output and availability, then one
3 starts to look for other things such as management.

4 But I think what we felt was that we knew that people
5 were talking about moving towards performance based regulations
6 and we, ourselves, were uncertain as to what that measurement
7 would be.

8 COMMISSIONER CARR: But best it be an empirical look.

9 DR. MORAY: Oh, I think so, yes, and possibly a
10 conceptual one. But the point is rather than arbitrarily
11 guessing what such measures should be, we are saying as with
12 everything, it is worthwhile spending some money on research in
13 advance of deciding how to do things and if the answer comes
14 up, nobody knows, then that may give you pause about changing
15 things anyway.

16 COMMISSIONER CARR: Thank you.

17 CHAIRMAN ZECH: Commissioner Rogers, do you have
18 anything further?

19 COMMISSIONER ROGERS: Just that in conducting
20 research in this area, do you have any comments on how to bring
21 the systems approach, overall systems approach, to the research
22 itself? We always try to break things down into manageable
23 problems that we can deal with one by one but if what we are
24 really interested in here as an organization is the improvement
25 of overall safety, we are interested in the total system.

1 We are interested in the total performance of the
2 system not maximizing one element of it possibly to the
3 detriment of another element but really maximizing the overall
4 performance and safety of the system.

5 Do you see any simple way to impose that point of
6 view on the choice of topics and priorities within the research
7 program itself? Obviously, if it is a very small program then
8 that is not such a big problem but if one is looking at a
9 variety of possible activities in research and human factors,
10 could you comment in some way on how one relates the individual
11 topical areas which very often tend to be those things that
12 people think they know how to do rather than the things that
13 actually have to be done.

14 DR. MORAY: Yes.

15 COMMISSIONER ROGERS: How to relate a choice of
16 research topical areas to overall improvement in safety, not
17 just in one area but overall improvement in safety. Have you
18 tried to come to grips with that in some way?

19 DR. MORAY: I think clearly one is not going to do
20 monstrous experiments in which everything is varied
21 simultaneously. You may remember that I mentioned the fact
22 that we would like to see emphasis put in the RFPs, in the
23 proposals for research, on the people carrying it out should
24 take a systems viewpoint.

25 If you take as an example, let's say, computerization

1 of emergency operating procedures, now one can certainly do the
2 sort of piecemeal research. One can stick EOPs in a computer
3 and see how easy they are to use. Let's suppose that one can
4 and I think regard this as a very open question myself, get a
5 satisfactory format for them.

6 Now this opens up other questions. I think I would
7 expect the person who does that report, I would require him to
8 write his best estimate of other areas in which this might have
9 an impact. Does it have an impact on manning? Does it have an
10 impact on the -- can it be expected rather to have an impact on
11 the social organization in the control room? Is it likely to
12 have an impact to do with time of day? Is it likely to have an
13 impact on training?

14 Now I think some of these can probably be answered on
15 the basis of existing knowledge. In others, the reports of a
16 contract simply on computerization of EOPs would have at the
17 bottom, the best estimate is that the following three questions
18 are raised to which at least a small contract should be given
19 to follow it up.

20 And you can take that and now you have at least one
21 thing. You know this particular piece of equipment works. Now
22 let's try it with instead of having the full team of operators
23 in the control room, one of them falls sick and now you have
24 one fewer. Can you still use them? Take that as a sort of
25 cut. What impact will it have in incorporating the STA into

1 the decision making and those are probably relatively simple
2 experiments.

3 Now the further away you get, the more remote and
4 uncertain becomes the extrapolation from the fact of this work
5 in this situation to what will happen in extremely varied
6 situations but I think that I would start by insisting both in
7 the proposal and in the final report that the people
8 undertaking the work must somehow or other write into their
9 report their systems orientation.

10 Maybe they will have to go and hire other people.
11 Maybe they will have to as part of their research team, they
12 will have to hire somebody in organizational behavior for a day
13 and say, "Look, check over this thing and we want to see if
14 anything in this reminds you of something where you think there
15 may be difficulty" and then that has to be incorporated into
16 the report.

17 I don't see much more than that because it may differ
18 from every different research topic.

19 COMMISSIONER ROGERS: Of course, it has more and more
20 become common not in ordinary research but certainly in
21 educational research to look at outcomes as a requirement for
22 part of the completion of the project is a longitudinal study
23 of what the impact is.

24 DR. MORAY: Yes.

25 COMMISSIONER ROGERS: I think maybe some of those

1 concepts could be taken over here.

2 DR. MORAY: Certainly, yes, and I think, we also
3 mention in the report the importance of interdisciplinary
4 teams. It is very unlikely that you can get a really
5 generalizable result if I do the work by myself. I have been
6 trained in human factors and my work in the industrial
7 engineering department and my background is psychology but I
8 would certainly expect that I would have to team up with
9 nuclear engineers either in the university or outside to make
10 sure that the way that I perceive the problem is correct
11 because I have not worked as an operator and in order to ensure
12 that my vision of the actual implications of what I am working
13 on is correct I must have interdisciplinary contacts and I
14 think that again should be insisted on in the research designs.

15 COMMISSIONER ROGERS: Just one other thing and I
16 don't want to really prolong this by going off in another
17 direction but I wonder if and you touched on this question of
18 training versus education and the difference between them.

19 DR. MORAY: Yes.

20 COMMISSIONER ROGERS: I wonder if you are familiar
21 with the Education for Capability Program that has been tried
22 in Great Britain and promoted somewhat by the Royal Society of
23 Arts and whether there have been any studies of really the
24 effectiveness of that point of view of whether it is really
25 just philosophy or whether, in fact, there is some basis --

1 DR. MORAY: I am afraid I am not familiar with the
2 results of that program, no. It is a difficult area.

3 COMMISSIONER ROGERS: It really has been in the
4 polytechnics. It has not been at the university and it tries
5 to deal with that question of how do you meld education and
6 effectiveness which they call capability as distinct from
7 education.

8 Well, I would just like to say that we all are very
9 grateful to the enormous effort and time that I am sure that
10 the committee has put into this sort of thing and we are very
11 pleased to have the results of your fine work.

12 DR. MORAY: Thank you.

13 COMMISSIONER ROGERS: That is all I have.

14 CHAIRMAN ZECH: Dr. Moray, you have made a very
15 strong recommendation, your first recommendation, for increased
16 human factors research and financing and increased staff and so
17 on and we will certainly take that into consideration and I
18 would ask the staff when you talk to us on the 31st of May to
19 give us your thoughts on that, too.

20 But Dr. Moray, what I wonder is in your review of
21 this program which obviously you have gone into in some detail,
22 could you give us a specific research topic if you will or
23 going along with your strong recommendation, what would you
24 think would be the highest priority of the human factors
25 research program that we should undertake in order to perhaps

1 get the most benefit for our safety responsibilities?

2 DR. MORAY: I think if you are looking for a fairly
3 short term one, probably something in the area of the
4 introduction of computer aiding in the control room because we
5 know that people are going to want to introduce it.

6 CHAIRMAN ZECH: Well, that was my next question. The
7 control room itself, now let me get right to it. Is that what
8 you would say we should undertake, a computer aiding of the
9 control room operators?

10 DR. MORAY: No. I think you should support research
11 on how to assess the quality of any such systems which are
12 offered to the nuclear industry for use.

13 CHAIRMAN ZECH: We have computers in the control
14 rooms as you know.

15 DR. MORAY: No. I am thinking of computer aided
16 decision aids, particularly.

17 CHAIRMAN ZECH: I see.

18 DR. MORAY: Computer aided SPDS's which involve new
19 displays, quasi-artificial intelligence, expert systems as they
20 are sometimes called.

21 CHAIRMAN ZECH: Converting to the emergency operating
22 procedures or something like that?

23 DR. MORAY: Yes. I would take that as a short term
24 one because we know that any day now if you haven't had it
25 already, you are going to get a letter from somebody saying,

1 "We would like to implement this, may we?"

2 CHAIRMAN ZECH: How about a long term one?

3 DR. MORAY: The causal models of human error. If you
4 understand that, you will understand most of your problems. I
5 say that with a smile but it is possible to do research in that
6 area. It is very curious. Up until about seven years ago --

7 CHAIRMAN ZECH: I think the research would be
8 probably interesting. It would tell us that we as you pointed
9 out too, I think, most of our problems are caused by human
10 error or human error relates to those problems in a very high
11 percentage of cases but what would the research show you other
12 than that? What would it show you that you can do about it?

13 DR. MORAY: Right. The research would show you the
14 particular conditions of work, the conditions of the way
15 problems are presented, the effects of displays and controls,
16 the effect of training on pre-disposing a person so to process
17 information in his mind that he comes to the conclusion which
18 leads him to take the wrong action. It is pre-disposing causes
19 for incorrectly acting in the light of the situation in which
20 he finds himself at a particular instant.

21 Now I am not saying that it can be done like that
22 because there is some evidence that some errors are caused by
23 random processes in the brain, literally random in the sense of
24 random distribution. Others are certainly caused where the
25 patterns are related to understandable things, time of day,

1 lighting, lay-out, ambiguities in EOPs.

2 But the important thing is if one could understand
3 the pre-disposing factors in how people process information,
4 the cognitive activities of humans that lead to the wrong
5 outcome given data entering the brain, one would be in a strong
6 position to design better displays, design better EOPs,
7 determine training, all sorts of things like that and identify
8 potential moments when there might be an error but that is a
9 long term one.

10 CHAIRMAN ZECH: You brought up a degreed operator.
11 We have talked about that a little here, too. It is of
12 interest to me as many know but education and training are
13 different.

14 DR. MORAY: Yes.

15 CHAIRMAN ZECH: My view of getting a more educated
16 operator is based, I think, on at least my own view that
17 further education brings on or at least simulates intellectual
18 curiosity. It makes you interested in things perhaps you
19 haven't been involved in before. It kind of stretches your
20 brain a little bit. It increases your logic process and it has
21 a self-esteem type, self-confidence perhaps even, and a
22 willingness to accept additional knowledge. It stimulates more
23 knowledge.

24 Those are all things it seems to me that a person
25 takes advantage of his God given faculties and perhaps not

1 necessarily but perhaps makes him into a broader individual.
2 It doesn't necessarily make him a better operator. I am
3 convinced of that but it could contribute to a better interest
4 perhaps in some of the things that are going on.

5 But as much as anything in my view, it takes those
6 people who we have in the control room who although we do have
7 a number of college graduates most are high school graduates
8 and my perception and my experience in visiting the plants
9 around the country is that most of the people in management
10 positions have degrees and here we have a wealth of talent at
11 least in my view in our operators in our country that are not
12 used, are not given the developmental possibilities to move up
13 in the utilities and thereby bring their operational experience
14 up into the higher management positions.

15 If, indeed, most utilities do have a requirement or
16 at least if it is not a written requirement, it is an unwritten
17 requirement for degrees in their higher management positions,
18 it seems to me that we are just not taking advantage of the
19 tremendous amount of talent we have and the side benefit, of
20 course, is bringing people with more operational experience up
21 into the senior management positions.

22 That is as much my interest in getting degreed
23 operators as anything and I think the overall effect would be
24 more professionalism not only in the control room but in the
25 whole of the utility organization and those are just some of my

1 thoughts on it.

2 Let me just say, Dr. Moray, and to your colleagues
3 here with you and others who were on the panel with you how
4 much we really do appreciate what you have contributed to this
5 Commission.

6 We will certainly take your recommendations and
7 review them very seriously. We will be interested in the
8 staff's presentation here in a couple of weeks on the same
9 subject and I would ask the staff to comment on all the
10 recommendations during their presentation and to give us any
11 other views that you may have, Eric.

12 I personally think that we can do more in the field
13 of human factors and should do more. I think there is a pay
14 back in safety and, of course, that is our business and so I
15 would hope that this presentation and the work you have done is
16 going to lead us in that direction of seeing what we can do to
17 prevent human error, to see what we can do to make the job of
18 not only the control room operators as you, Dr. Moray,
19 correctly pointed out.

20 We are talking about maintenance people and auxiliary
21 technicians and all kinds of people in those power plants but
22 what we need to do in a human factors sort of way make their
23 job more sensible, more logical and as a result help them to
24 operate more safely.

25 So I think there is a pay back here and I hope we can

1 take advantage of the work you have done and we thank you very,
2 very much for a fine presentation.

3 DR. MORAY: Thank you very much, Mr. Chairman.

4 CHAIRMAN ZECH: Any further comments?

5 [No response.]

6 CHAIRMAN ZECH: If there are no further comments,
7 thank you very much. We stand adjourned.

8 [Whereupon, the Commission meeting was adjourned at
9 3:55 o'clock p.m., to reconvene at the Call of the Chair.]

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CERTIFICATE OF TRANSCRIBER

This is to certify that the attached events
of a meeting of the U.S. Nuclear Regulatory Commission
entitled: Briefing on NAS Human Factor Recommendations

TITLE OF MEETING: Briefing on NAS Human Factor Recommendations

PLACE OF MEETING: Washington, D.C.

DATE OF MEETING: Thursday, May 19, 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.

Marilynn Nations

Ann Riley & Associates, Ltd.

5/19/88

SCHEDULING NOTES

TITLE: BRIEFING ON NAS HUMAN FACTOR RECOMMENDATIONS

SCHEDULED: 2:00 P.M., THURSDAY, MAY 19, 1988 (OPEN)

DURATION: APPROX 1-1/2 HRS

PARTICIPANTS: NRC 5 MINS

- ERIC BECKJORD, RES

NATIONAL RESEARCH COUNCIL 45 MINS

- DR. NEVILLE P. MORAY, CHAIRMAN
PANEL ON HUMAN FACTORS RESEARCH NEEDS IN
NUCLEAR REGULATORY RESEARCH
COMMITTEE ON HUMAN FACTORS
COMMISSION ON BEHAVIORAL AND SOCIAL
SCIENCES AND EDUCATION

OTHER ATTENDEES

- DR. P. BRETT HAMMOND
ASSOCIATE EXECUTIVE DIRECTOR
COMMISSION ON BEHAVIORAL AND SOCIAL
SCIENCES AND EDUCATION

- DR. HAROLD P. VAN COTT, STUDY DIRECTOR
COMMITTEE ON HUMAN FACTORS AND
PANEL ON HUMAN FACTORS RESEARCH NEEDS IN
NUCLEAR REGULATORY RESEARCH
COMMISSION ON BEHAVIORAL AND SOCIAL
SCIENCES AND EDUCATION

**HUMAN FACTORS RESEARCH
AND
NUCLEAR SAFETY**

**PANEL ON HUMAN FACTORS RESEARCH
NEEDS IN NUCLEAR REGULATORY
RESEARCH**

COMMITTEE ON HUMAN FACTORS

**COMMISSION ON BEHAVIORAL AND SOCIAL
SCIENCES AND EDUCATION**

NATIONAL RESEARCH COUNCIL

THE PANEL'S CHARGE

"[to] identify study areas in the current and recent programs that may have received inadequate attention and to provide guidance to the Office of Nuclear Regulatory Research, the Nuclear Regulatory Commission (NRC), and other research and development agencies in government, private industry, and universities regarding an appropriate research program in human factors to enhance the safe operation of nuclear power plants."

OVERVIEW

STARTED: January 1, 1986

COMPLETED: February 29, 1988

APPROACH:

- * SEVEN PANEL MEETINGS**

*** BRIEFINGS BY:**

**Argonne National Laboratory
Department of Energy
Electric Power Research
Institute
Hanford Engineering Development
Laboratory
Institute of Nuclear Power
Operation
Nuclear Regulatory Commission
Westinghouse**

- **VISITS TO:**

- Electric Power Research
Institute**

- Three Mile Island**

- **REVIEW OF NRC AND OTHER RELATED
PUBLICATIONS**

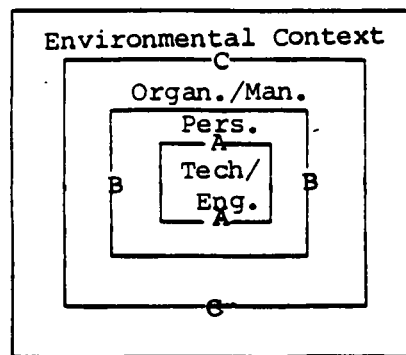
**RECOMMENDATION 1: COMMITMENT
TO HUMAN FACTORS RESEARCH**

**The 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.**

RECOMMENDATION 2: ADOPTING A SYSTEMS-ORIENTED APPROACH

The panel recommends that the NRC's research program maintain a broad perspective. The operator/maintainer-plant interface is extremely important.

However, other factors arising from the way in which a plant is organized, staffed, managed, and regulated and the way it interacts with other elements of the industry can also affect human performance, induce human error, and increase the level of risk of a plant.



**Components of a Integrative
System Safety Analysis**

**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 researchers
in planning, conducting, and evaluating
its research program.**

In addition, peer review of proposals and of 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 been the failure to provide 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 towards achieving this goal would be to create a national research facility for the study of human factors in nuclear power systems.

RECOMMENDATION 4: CONTINUITY IN THE RESEARCH PROGRAM

To be effective, a research program must operate coherently for an extended period rather than change in response to each new, immediate, external demand.

RECOMMENDATION 5: TRANSFER OF KNOWLEDGE

The panel recommends that the NRC take 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.

**RECOMMENDATION 6:
DISSEMINATION OF NUCLEAR
INDUSTRY HUMAN FACTORS RESEARCH**

**Several problems exist in the usability
and transfer of human factors research
reports prepared by the nuclear
industry that should be addressed.**

We are not aware that any central bibliographic data base or search service exists to abstract, index, and make available bibliographic or full text information, including NRC human factors publications.

**As a first step the panel recommends
the development of a bibliographic
system for NRC-supported human factors
reports.**

RECOMMENDATION 7:
A HUMAN FACTORS RESEARCH AGENDA

BASIS FOR DETERMINING RESEARCH PRIORITIES:

- Some research topics may have a critical impact on safety and thus must be addressed.**
- In some areas research is needed as a basis for evaluation.**
- A particular research topic may be an essential building block for a long-term program.**

NOTE: In all cases research should be aimed at management, maintenance, and other ancillary workers, as well as control room operators.

1) HUMAN-SYSTEM INTERFACE DESIGN

Highest priority topic:

- **Automation and computer-based job performance aids**

2) PERSONNEL SUBSYSTEM

Higher priority topics:

- Maintenance and enhancement of operational skill**
- Improvements in licensing examinations**
- Shift Scheduling and Vigilance**

3) HUMAN PERFORMANCE

Higher priority topic:

- Causal models of human error, especially for situations with unplanned elements**

CONTROL OF HUMAN ERROR

**Concentrate Research on Causal,
not Descriptive, Models**

**Couple Research to Reliability and
Risk Analysis using Error Data as
Feedback**

**The Human Element in PRA does not
Require more Research**

4) MANAGEMENT AND ORGANIZATION

High priority topics:

- **The impact of regulations on the practice of management**
- **Organizational design and a culture of reliability**

5) THE REGULATORY ENVIRONMENT

Higher priority topics:

- The appropriate mix of government regulation and industry self-regulation**
- Developing and tracking a wide array of performance indicators**

CONCLUSIONS

If a new human factors research program is implemented in 1988, receives strong support, is managed by a qualified HF specialist, is staffed by a multi-disciplinary team, and is organized as an independent branch, then...

**the initial steps of leadership
required of the NRC in this critical
area will have been taken. Further
steps will be taken as the NRC and the
industry review and implement the
recommendations made by the panel.**