

Naval Health Research Center

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# PROCEEDINGS THE COMBINED EFFECTS OF MULTIPLE STRESSORS ON OPERATIONAL PERFORMANCE

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EDITED BY  
E. K. E. GUNDERSON

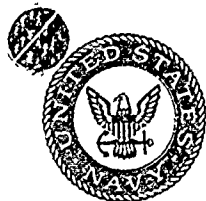
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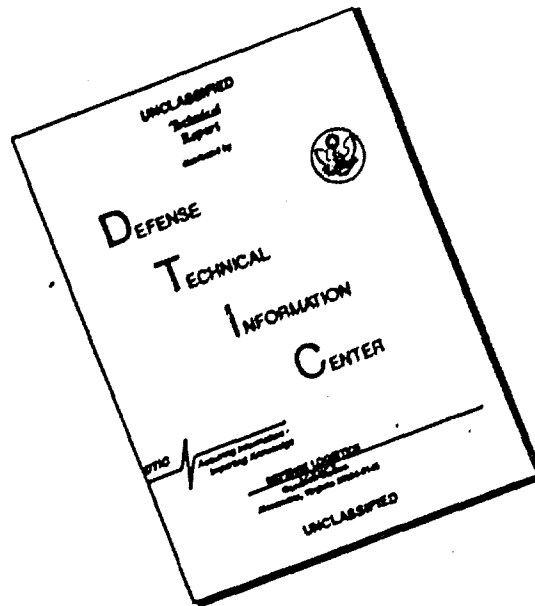
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Proceedings  
The Combined Effects of Multiple Stressors  
on Operational Performance

Edited by E. K. Eric Gunderson

Seapoint Hotel  
San Diego, California  
4-5 April 1989

Host:  
Naval Health Research Center  
San Diego, California

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## Program Schedule

**Tuesday, 4 April 89**

0800 - Welcome	Captain Chaney, NHRC
0815 - Orientation	Captain Gaugier, NMRDC
0825 - Introduction	Dr. Gunderson, NHRC
0845 - Livermore Conference	Mr. Banks, Livermore
0915 - Stress in Air Crews	Dr. Helmreich, U Texas
0945 - Army Modeling Research	Dr. Cherry, Vector
1015 - Coffee Break	
1030 - View from the Top	LCDR Petho, OP-11B1
1100 - Cold	Dr. Goforth & LCDR Kelleher, NHRC
1145 - Lunch	
1300 - Heat	LCDR Banta, NHRC
1320 - Physical Work Load	Dr. Englund, NHRC
1340 - Sustained Vigilance	LT Kobus, NHRC
1400 - Sleep Loss	Dr. Naitoh, NHRC
1420 - Coffee Break	
1435 - Individual Differences/ Group Characteristics	Dr. Vickers, NHRC Dr. Palinkas, NHRC
1500 - Multiple Stressors	LCDR Banta, NHRC
1525 - Data Integration for Model Development	Mr. Pugh, NHRC
1545 - MicroSAINT	Dr. Hodgdon, NHRC



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Wednesday, 5 April 89

0800 - Discussant Panel

Dr. Zornetzer (ONR)  
Dr. Dobie (NBDL)  
Dr. Carroll (OP-01)  
CAPT McCullah (HSETC)  
CDR Mateczun (NH Portsmouth)  
Dr. Wittmers (U Minnesota)  
Dr. Kripke (UCSD)  
CDR Fraser (NMRDC)

1030 - Coffee Break

1045 - General Discussion

1145 - Lunch

1300 - Review and Wrap-up: LCDR Kelleher and Mr. Banks

1430 - Adjourn

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## Preface

This Proceedings represents the collective efforts of many participants who attended the meeting. The authors were given the opportunity to edit transcripts of their remarks. In the final editing I added, deleted, or changed material only as seemed necessary to provide consistency or continuity.

The conference was organized principally to pursue two objectives: (1) to survey available data sources at the Naval Health Research Center and elsewhere that may be relevant to assessing the effects of stress on performance, and (2) to provide an expert forum to evaluate the feasibility of constructing new models to represent performance degradation under stress and/or incorporating human factor variables into existing combat simulation models.

The meeting followed an earlier one at the Lawrence Livermore National Laboratory in November-December 1988 which was designed to enhance awareness of models that already existed in the Department of Defense and to consider whether these might have utility for Navy applications.

The meeting was divided into three parts. Introduction and background for the issues to be discussed were provided by Mr. Bill Banks of the Livermore Laboratory who had played a key role in the previous meetings; Dr. Bob Helmreich of the University of Texas who reviewed stress in air crews; Dr. Peter Cherry who gave an overview of the Army's experience with modeling; and LCDR Frank Petho from the Chief of Naval Operations' office who gave an account of the impact of the VINCENNES incident on efforts to gather information on stress effects that might be useful for training naval personnel. The second part of the meeting presented reviews of research on a number of environmental and situational variables and human factors believed to affect military performance. These reviews were conducted by NHRC investigators who were deeply involved in their respective research areas. The final part of the meeting was devoted to comments by a panel of experts drawn from universities and various Navy programs concerned with stress effects.

The panel discussion was wide-ranging and reflected a variety of professional and institutional perspectives. In addition to considering the need for continuing research and development to build useful human performance models, the panel provided

insights into the institutional context in which models would be used. Some of the limitations as well as the unique capabilities of computer models were noted.

The meeting was sponsored by the Naval Medical Research and Development Command, Bethesda, Maryland, and hosted by the Naval Health Research Center, San Diego. The assistance of the Medi-Transcriptions LTC, Audio/Video Cassette Recording Company, San Diego, and Ms. Brenda Crooks, Editorial Assistant, Naval Health Research Center is gratefully acknowledged.

E. K. Eric Gunderson

## Combined Effects of Multiple Stressors on Operational Performance

Captain Robert D. Chaney, MC, USN  
Commanding Officer, Naval Health Research Center

CAPT CHANEY: Good morning. I'm Bob Chaney, Commanding Officer at the Naval Health Research Center (NHRC). We are very delighted to have you here on a bright, sunny, San Diego day. Of course, they're all like that. Everybody believe that now. The temperature yesterday was warm, today it's going to be warmer, which brings me to the first admin announcement. You are welcome to go to lunch any place you wish; however the Admiral Kidd Club is right down the street. They have an outside salad bar and sandwich bar which is very inexpensive. For about \$4.50 you can eat all you would ever want to eat and it's very enjoyable and very pleasant. We have vans, as you see, parked outside the window here. We will run as many runs as necessary to take people over there and return if you wish.

This evening, we have a social hour planned at the Submarine Base at Point Loma, which is about 10 minutes from here, at the Officer's Club. Again, it has a little outdoor veranda—it should be a very pleasant evening to sit and watch the big gray boats go past. We will again have vans moving back and forth. Unless you have a sticker of some type on your rental car, you probably won't be able to get aboard the sub base, so I recommend that you ride in the vans. We would like everybody to attend that can, and we will return you to the hotel or take you to the Admiral Kidd Club, or wherever within this area, or wherever you would like to be redelivered after the social hour. You can walk to a great many things within this area. Please feel free to come and go as you wish, but we'd like you to attend those two functions if you can. With that in mind, I will once again say "welcome" and explain to you what this thing is all about. It is to look at the combined effects of multiple stressors on operational performance. We have had occasion, as have several of the laboratories, to look at stress and human performance in operational settings, trying to get maximum results.

To begin with, we are under the command of Naval Medical Command and under the direct command of Naval Medical Research and Development Command (NMRDC) in Bethesda. Under NMRDC we are one of several laboratories. There are three

overseas units; we have a Submarine Medical Laboratory in Groton, an Aerospace Laboratory in Pensacola, a Naval Biodynamics Lab in New Orleans, and a Naval Dental Research Lab. We have representatives here from all the labs, I think, except the dental lab, and you may hear from each of them

This is our mission. It is a long, involved statement, which says our job is to do what we can to make the job of the individual easier, more productive, safer and more efficient. And, at NHRC, if it does not impact on the operational forces, it is not something we will be doing. It's as simple as that. We are working to take care of the individual.

It is fortuitous that we are located out here on Point Loma, because in this immediate area, you can see the number of military facilities with which we have the opportunity to work. We currently have ongoing research projects with Camp Pendleton, NTC, COMNAV Base in San Diego, SURFPAC, Naval Amphibious Base, Naval Station, Sub Base, and NAS North Island.

We do all this with roughly 107 people. We have a Chief Scientist, 12 high grades, 13 military officers, and 13 enlisted people. Of those, we have four physicians in uniform, one civilian. We have six Ph.D.s which you see listed as MSCs, which really stands for Ph.D., and we have 15 Ph.D. civilians.

This is a breakdown, a little more discretely of who does what. We now have an aerospace physiologist; we have 11 physiologists onboard now; we have an environmental health officer; we have five statisticians, two epidemiologists, and 27 psychologists. We have coming onboard yet this summer two more uniformed psychologists and a uniformed medical officer.

In addition, we fully support and utilize American Society for Engineering Education (ASEE) representatives, and in the past year we had nine representing eight separate universities.

Also, we have at any given time, a minimum of 30 students under contract from San Diego State University. They start at the bachelor level and a great many of them work throughout their entire training. Several of our staff have gone through that

THE COMBINED EFFECTS OF MULTIPLE  
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4-5 APRIL 1989

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THROUGH RESEARCH, DEVELOPMENT, TEST,  
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PSYCHOLOGICAL ASPECTS OF NAVY AND  
MARINE CORPS PERSONNEL HEALTH AND  
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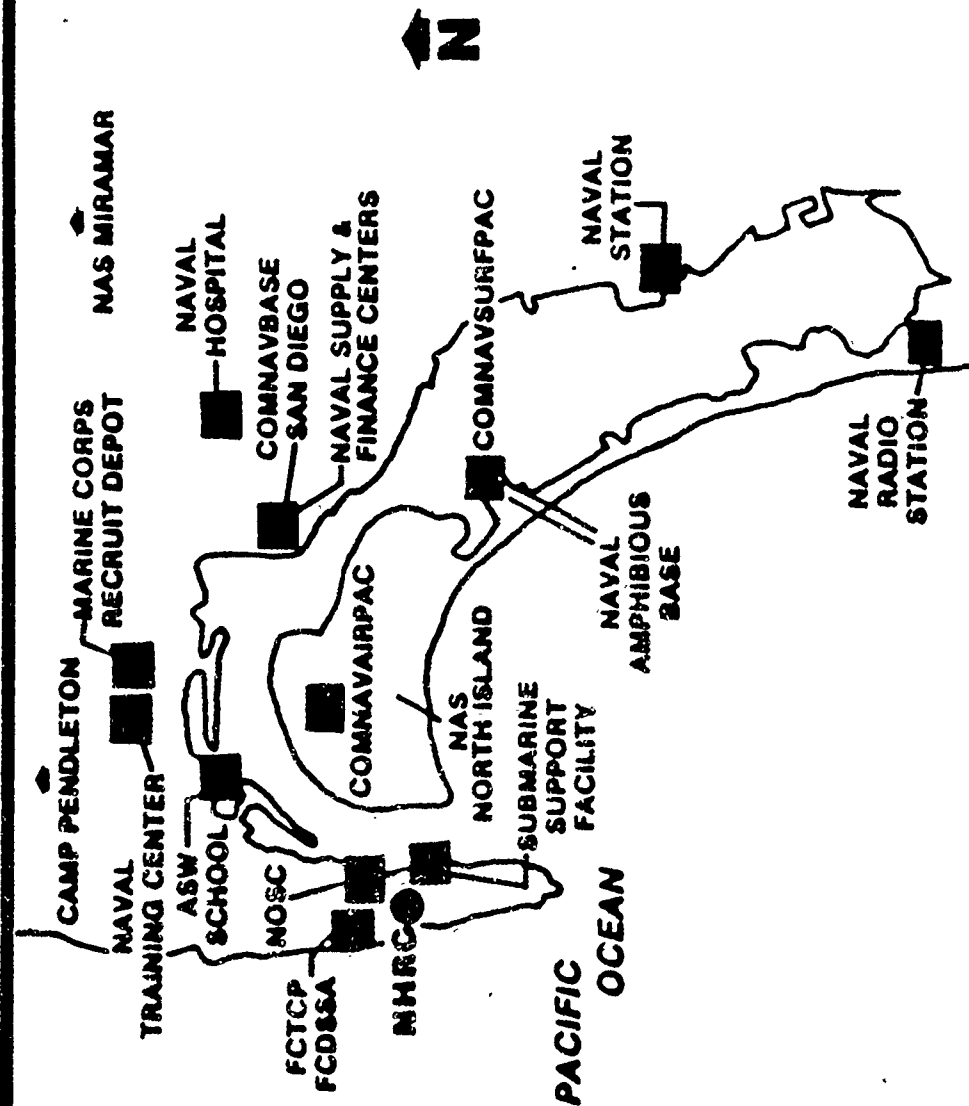
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MILITARY OFFICERS	13	13
ENLISTED	13	13
PROFESSIONAL PERSONNEL		
	MILITARY	CIVILIAN
MD	4	1
PhD	6	15

## PROFESSIONAL STATISTICS

<u>Profession</u>	<u>Military</u>	<u>Civilian</u>	<u>Total</u>
Medical Officer	4	1	5
Psychologist	5	22	27
Physiologist	2	9	11
Physiologist (Aerospace)	1	—	1
Environmental Health	1	—	1
Statistician	—	5	5
Epidemiologist	—	2	2
	13	39	52



## NAVAL HEALTH RESEARCH CENTER

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EDUCATION (ASEE) FACULTY:  
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UNIVERSITY OF CENTRAL FLORIDA  
NORTHERN ARIZONA UNIVERSITY  
IOWA STATE UNIVERSITY  
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SYRACUSE UNIVERSITY (2)  
MESA COLLEGE  
WASHINGTON UNIVERSITY

30 STUDENTS UNDER SDSU CONTRACT  
1 CANDIDATE FOR PhD PROGRAMS IN PSYCHOLOGY  
13 CANDIDATES IN MASTERS DEGREE PROGRAM  
16 STUDENTS WORKING AT THE UNDERGRADUATE  
LEVEL FOR BS/BA DEGREE  
2 POST DOCTORAL (NRC):  
1 ATTENDED UNIV OF HAWAII IN MEDICAL  
ANTHROPOLOGY  
1 ATTENDED UNIV OF NEVADA IN SOCIAL  
PSYCHOLOGY

entire cycle, starting at the bachelor level, master level, Ph.D. level, and have joined the staff. We also have two National Research Council Postdoctoral individuals.

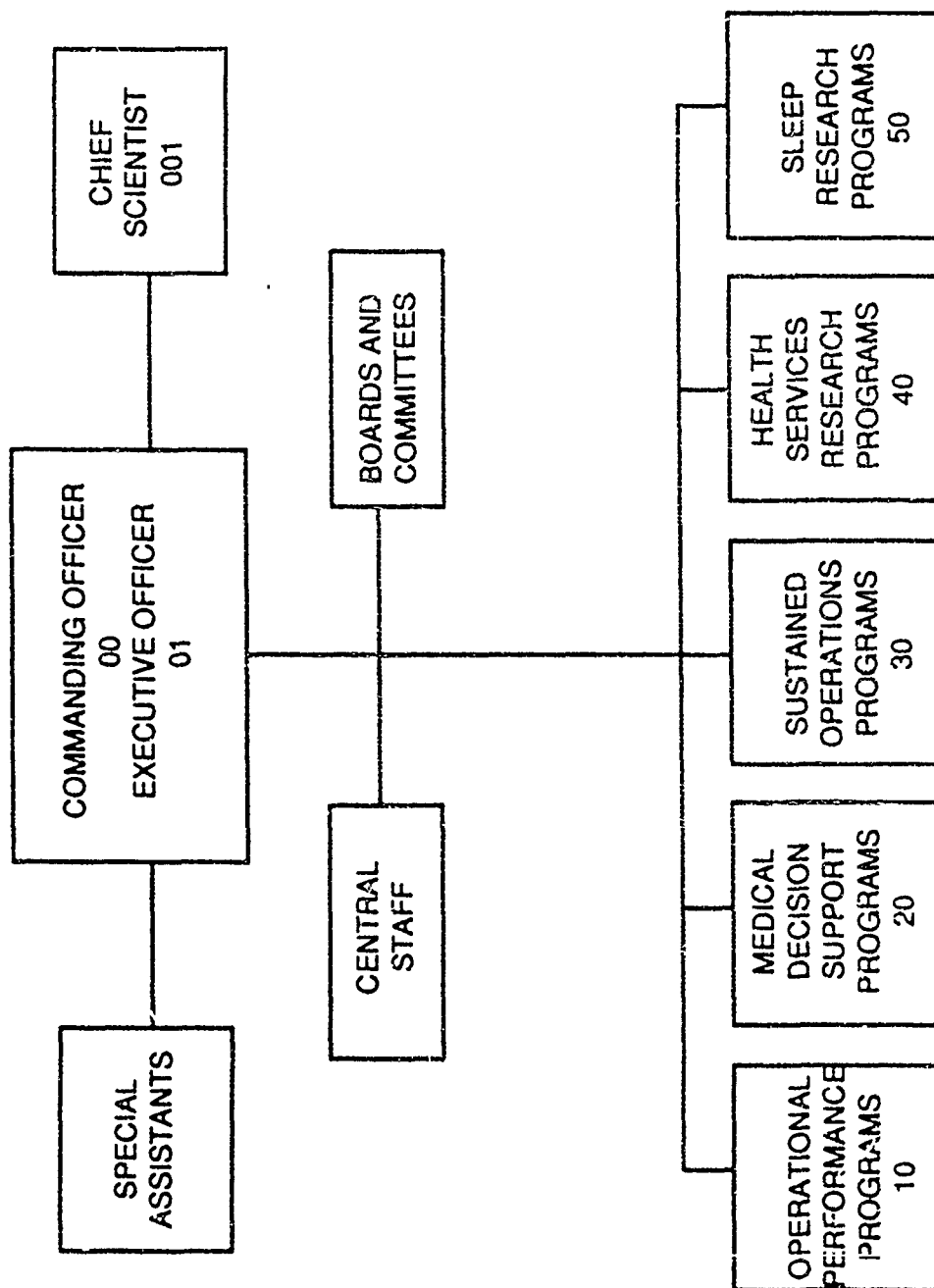
You can't give a Navy briefing without showing a wiring diagram. It is against the law. Therefore, I will show you our wiring diagram. We have a Chief Scientist, Special Assistants and five separate research codes. The first code is Operational Performance Programs, and you will hear from several representatives later on today; stress immunology is one and you will hear from Dr. Ross Vickers shortly; Special Warfare, which is represented by Hal Goforth and others, and Cold Weather Operations, in the course of which you will hear from Lieutenant Commander Kelleher regarding joint Norway-Marine Corps training and so forth.

Under Medical Decision Support Programs, we are deeply involved in the disease, nonbattle injury program. After that program began, somebody said maybe we better go back and look at battle injuries as well. We are also working in computer assisted diagnosis for the medical care persons aboard ship, independent duty corpsman, and so forth. The illness and injury case management module of NOHIMS enables us to look at the enormous amount of money which is being spent in shipyards for FECA claims that go on and on and on. We are trying to find some way to get a handle on this enormous amount of money so as to keep track of these individuals and get them back to work.

The Sustained Operations Program is a very large program and very important program which has a lot of ramifications. We have been working with the Army in the Chemical Defense Program for a very long time. We are finishing up Phases IV and V, and then we can devote more and more energies to the SUSOPS program. Any time a ship goes to sea and operates around the clock, it is a sustained operation. Any time Marines go into the field in an environment such as Norway and work around the clock, it is a sustained operation. Every time someone dons the MOPP gear (Chemical Defense gear) it is definitely a sustained operation, but unfortunately, they cannot function utilizing that for a very long time.

Biopsychometric Program. A very large portion of our effort in sustained operations is in the Biopsychometrics Program. We had occasion to go to the Gulf to study ships at sea, in harm's way, on two occasions. You will hear about some of that later on today under the title "Human Performance Evaluation Projects."

# NAVAL HEALTH RESEARCH CENTER



# DEPARTMENTAL PROGRAMS

- OPERATIONAL PERFORMANCE
- MEDICAL DECISION SUPPORT
- SUSTAINED OPERATIONS
- HEALTH SERVICES RESEARCH
- SLEEP RESEARCH

## **OPERATIONAL PERFORMANCE PROGRAMS (10)**

- STRESS IMMUNOLOGY
- SPECIAL WARFARE
- SPECIAL WARFARE TRAINING
- COLD WEATHER OPERATIONS



## MEDICAL DECISION SUPPORT PROGRAMS (20)

- PROJECTION OF DISEASE AND NON-BATTLE INJURY (DNBI) RATES
- DETERMINATION OF BATTLE INJURY (BI) RATES FOR OPERATIONAL SCENARIOS
- COMPUTER-ASSISTED MEDICAL DIAGNOSIS
- ILLNESS AND INJURY CASE MANAGEMENT

## **SUSTAINED OPERATIONS PROGRAMS (30)**

- SUSOPS
- CHEMICAL DEFENSE PROGRAMS
- BIOPSYCHOMETRICS PROGRAM
- MEDICAL HUMAN PERFORMANCE EVALUATION  
PROJECTS

Health Services Research. We are the ones who established the guidelines for the Navy PRT. This has been revisited on several occasions, and we are the organization that sets the standards for that.

Operational Medical Research. One of the most pressing issues is Women in the Navy. Also, the case management evaluation program called OPTICOMAP that I referred to earlier, regarding the shipyards encompasses two major NHRC departments which proves we are not parochial; we are not turf defenders; we work together at NHRC between departments, and we work together with all of our sister labs, the idea being to serve the program and get the job done.

In addition, we are the keyholders for the HIV data for the entire Navy. We are the ones who actually analyze all HIV information, and it has been very closely held. Just recently, the HIV information has been released for publication, and we are finally in a position to talk about it and publish some of the results we have been tracking now for almost three years.

Last, but certainly not least, Code 50 has to do with Sleep Research Programs. One of the things we learned in the Gulf which you will hear more about is that in sustained state of combat readiness, personnel are watching for danger from every vantage point on the ship. But since there are only so many people aboard and all of these watch stations have to be manned, it is definitely a sustained operation mode. Sleep is the one thing which is frequently compromised at all levels of command. The personnel work very hard and very diligently for a very long period of time. So, sleep research is very important. We need to look at the best way to get maximum utilization or benefit from what sleep one can get. This is the basis for the study of sleep/work cycles and naps.

Thank you very much.

One last quickie here—I have five seconds. This meeting is a follow-up to the Lawrence Livermore Laboratory meeting which we sponsored and which Lawrence Livermore set up for us. It was very well attended. A lot of interesting things developed from that. You will hear more from Bill Banks about this meeting. First of all human factors are not now included in combat simulation models. We had a chance to look at all the various things which are being done from the line side, JANUS and the rest of them. In Navy Medical Research and Development Command we have hun

factors people who can help to develop a model in this field. The Proceedings of the Livermore meeting are available on your table. That big "Sears Roebuck catalog" you see there is the "put together" which we have gleaned from the information Bill Banks put together for us.

This conference today is to be a follow-up to that conference. I definitely encourage people to talk. We will try very hard to keep the speakers, at least my speakers, on track and on time. I encourage the intercourse between people. We will take breaks. Please feel free to ask questions. If we move too fast and someone has something to say, we will stop and let that person talk. The idea is to get information out and that is our #1 goal here. If the coffee break looks like it is taking too long, that means people are talking and so we will let it take too long. Please feel free to get to know everybody, get a chance to talk about these things and, hopefully, we will have a very worthwhile conference.

Again, thank you very much for attending.

## **HEALTH SERVICES RESEARCH PROGRAMS (40)**

- HEALTH AND PHYSICAL READINESS
- OPERATIONAL MEDICAL RESEARCH
- CASE MANAGEMENT EVALUATION
- HIV PROGRAM

## **SLEEP RESEARCH PROGRAMS (50)**

- DRUG EFFECTS ON PERFORMANCE
- SPECWARFARE PERFORMANCE ENHANCEMENT
- EVALUATION OF SLEEP/WORK CYCLES IN SUSOPS

# **NAVAL HEALTH RESEARCH CENTER**

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## **LIVERMORE CONFERENCE ON MODELING OF HUMAN PERFORMANCE**

- \* Human factors are not now included in combat simulation models
- \* The Livermore Conference defined NMRDC's needs and surveyed current models available (e.g., JANUS, SEES, AURA, and NARA)
- \* NMRDC labs can provide human factors input data to expand existing models or develop a new model
- \* Products of the Livermore contract included the Proceedings of the Conference and two technical reports surveying and evaluating the literature in this field
- \* This conference on "The Combined Effects of Multiple Stressors on Operational Performance" is a Naval Medical Research and Development Command follow-up to the Livermore conference.



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CAPT CHANEY: And now, Captain Gaugler.

Captain R. W. Gaugler, MSC, USN,  
Naval Medical Research and Development Command, Bethesda

CAPT GAUGLER: They say if you don't have much to say the least you can do is be brief, so I'm going to be real brief.

I am very happy to be here representing the Naval Medical Research and Development Command. I want to convey to everyone the apologies of our Commanding Officer, Captain Jim Woody. Unfortunately, this week he has to attend an ASBREM meeting which is somewhat critical for our work. ASBREM is the Tri-service R&D Commanders group that monitors and coordinates all of the DOD Medical Research. Since he must be personally involved in that meeting, he couldn't be here today.

I think everyone here recognizes the importance of the topic we are going to talk about in the next two days. This is something that really relates to how our operating forces actually work. I am very happy that our command was able to support a conference such as this, to be able to get the kind of interchange that Bob Chaney was talking about and to try and actually begin to look at the way in which various stressors, instead of one at a time, have an effect on performance. Unfortunately, this is not one of my areas of expertise so I'm going to be listening over the day and a half as attentively as anyone else, trying to get myself up to speed on something which is relatively important in our overall program. Having said that, I think I should stop here and let us begin.

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CAPT CHANEY: And now, I will introduce Dr. Eric Gunderson, Chief Scientist, Naval Health Research Center.

E. K. Eric Gunderson, Ph.D., Chief Scientist, NHRC

DR. GUNDERSON: I would just like to give you a short introduction to the meeting we have planned. I'll provide a little background to expand on what Captain Chaney has just said. In a few moments Bill Banks will give us a summary of the contents of the previous meeting and give us, perhaps, some analysis and evaluation on its continuity with this meeting. I trust you all got a copy of the Proceedings Captain Chaney mentioned. If you did not get it for some reason, we will certainly provide it.

I think the greatest use of modeling to date has been for combat simulation and command training purposes. A major concern has been that the human factors portions of the equations just have not been represented, and, therefore, there is a lack of realism with respect to representing and predicting human behavior under combat or operational conditions. We were rather surprised about this at the previous meeting but found a very strong interest in working together among modelers and researchers to try to find a way to efficiently introduce human factor variables into models. But, as researchers, I think we are beginning to see that modeling techniques may be a powerful tool to help us in conceptualizing and developing theory and, in general, guiding the research process. I think that is one of the things that has emerged, at least in my mind, as very important about what we are trying to do. The objectives of the conference very simply are to identify important stressors that affect military performance, to evaluate research data that presently exist or need to be obtained to support the development of performance models, to explore how we can combine the effects of multiple stressors to build accurate models, and examine the possibility of incorporating human factor variables into existing simulation models. The conference will be organized to take advantage of expertise inside and outside the laboratory.

After this introductory session, a few experts from outside the laboratory will be asked to provide knowledge and information that is really beyond the scope of NHRC and our programs. These are Dr. Helmreich from the University of Texas, Dr. Cherry, and Lieutenant Commander Petho from CNO's office.

The major part of the program will be dedicated to reviewing in some depth a number of environmental stressors and human factors that are under study in this laboratory; we feel that they are probably important in operational performance. NHRC researchers will try to answer the questions I mentioned earlier:

What are the most important variables? How can these variables be incorporated into existing models? How can these models be used for concept and theory development?

So, they will have an opportunity to not only review the existing data in terms of a short overview but also to evaluate to some extent whether they meet the criteria for consideration in model development.

Then, a very important part of the program is scheduled for tomorrow. We would like a panel of experts to react to, comment upon and give us further information about these issues--anything that would contribute to better understanding of the issues and what we are trying to do in this meeting. We certainly appreciate that we don't have all the answers, and we may not have the best answers in some of the specific areas we intend to review, but we would certainly invite all the input we can get from panel participants. We will also have a general discussion session where we will have the same objective.

Before concluding, I would like to offer the following diagram of the effects of various stressors on physiological and psychological equilibrium and performance. This is a very general representation of some of the relationships we would like to study.

## STRESS PARADIGM

Important Stressors	Strain	Adaptation	Performance
Heat	Physiological changes	Homeostatic responses	Degradation? (Task related response scored on standardized scales or measured in terms of speed and accuracy)
Cold			
Sleep loss	Psychological changes	Coping responses	
Heavy physical work			
Sustained vigilance			



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DR. GUNDERSON: Without further ado, I would like to introduce Bill Banks from Livermore National Laboratory. Bill will fill us in on how this process got started and any comments he has on the previous meeting. Bill.

William W. Banks  
Lawrence Livermore National Laboratory, Livermore, California

MR. BANKS: My name is Bill Banks, and I am with the Lawrence Livermore National Laboratory (LLNL). I'm very pleased to be here today, and I would like to personally thank many people for giving Lawrence Livermore an opportunity to provide technical assistance to the United States Navy. Specifically, I would like to thank Dr. Gunderson, Dr. James Hodgdon, LCDR Kelleher, Captain Chaney, and Dr. Bob Carroll; I certainly would not be here today if it hadn't been for Dr. Carroll's tutelage at the University of Maryland.

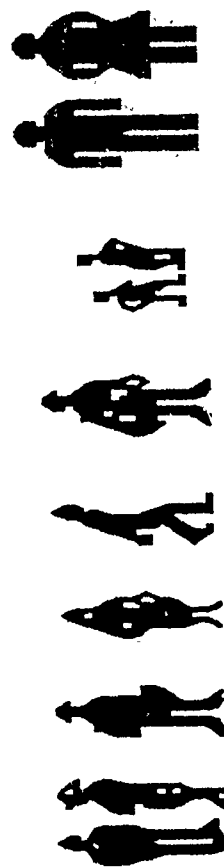
Let me give you some background about this particular project. Livermore was asked earlier in the year, December 1988, to host a conference for NHRC on the subject of combat simulation modeling.

LLNL felt this was an important topic, not just for the Navy, but for the nation as well. As we enter this new fiscal year and the fiscal years to follow, we will find resources becoming increasingly tight. Some friends of mine at Camp Pendleton recently had their travel budget cut by 1/3 over last year. This is the view of things to come. This means we are going to have to work smarter if we are going to take advantage of technology, and leverage technology wherever we possibly can to save dollars. The JAMSCI meeting, which stands for Joint Agency Meeting on Combat Simulation Issues, was multidisciplinary in complexion. I want to stress this because this is important. We had representatives from the medical community, Operations Research, physics, engineering, psychology, statistics—they were all at this meeting.

One of the important conclusions drawn from the JAMCI meeting was that human performance data are missing in combat models and are needed to enhance existing simulation models. You may argue and say that in certain isolated cases there are some human data included in models, but we have not really found that to be consistently true.

# THE JAMCI MEETING WAS MULTIDISCIPLINARY

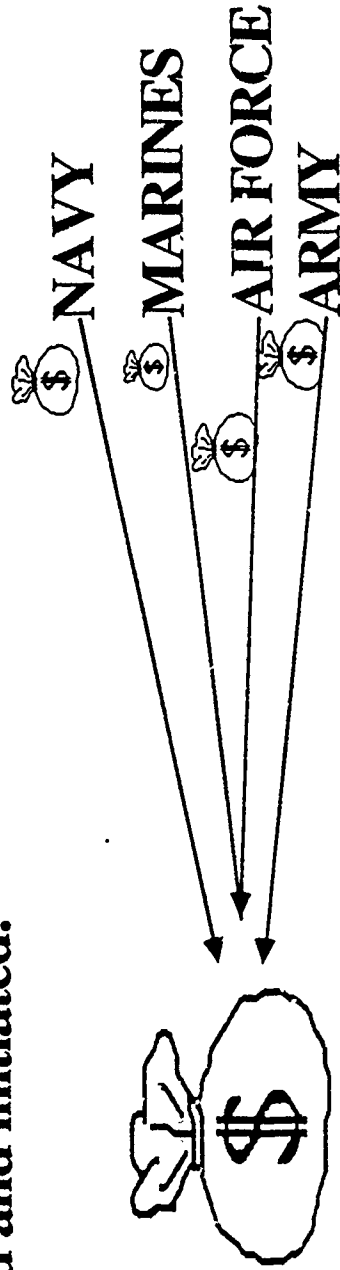
- Operation research
- Behavioral science
- Computer science
- Engineering
- Mathematics
- Statistics
- Physics
- etc.





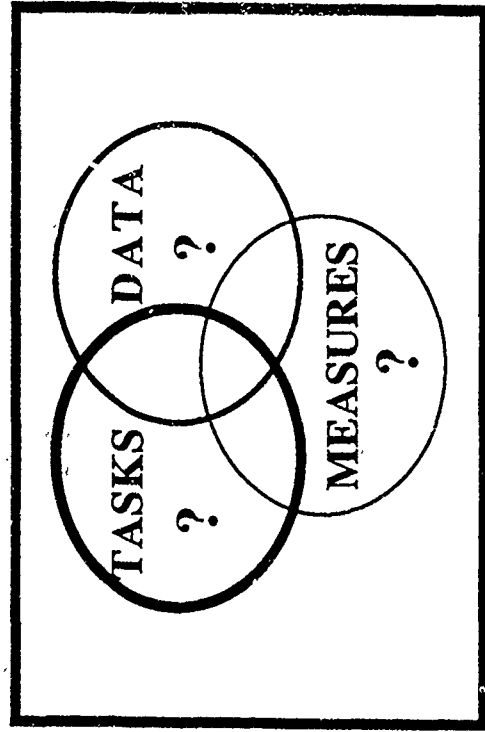
# Several important conclusions were reached at JAMCSI

1. Human Performance Data and Models are needed to enhance combat simulation models
2. First Order Estimates or Rough Approximations of the Data could serve as a starting point.
3. Planning for Multiple Sources of Funding should be organized and initiated.
4. The Initial Focus should be on Small Combat Unit Performance (Fire Team, Squad, Platoon)



**Several important conclusions were reached at JAMCSI (cont'd)**

- 5. We need to IDENTIFY CRITICAL COMBAT TASKS**
- 6. We need to IDENTIFY EXISTING OR CURRENT DATA and determine its suitability and scenario compatibility**
- 7. We need to develop a MATRIX of INDEPENDENT and DEPENDENT VARIABLES OF INTEREST**

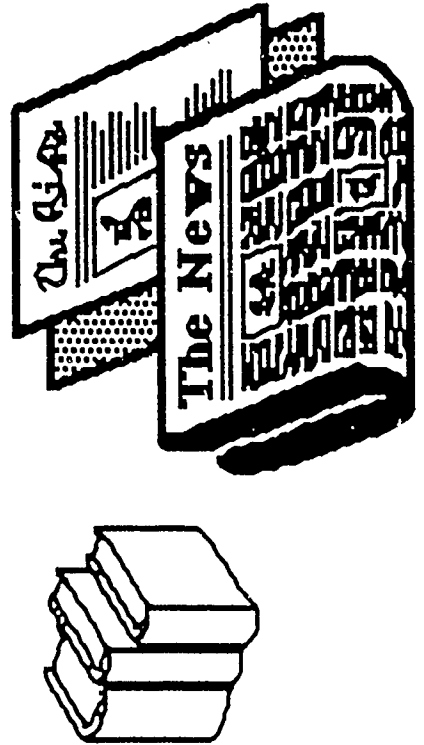


**Several important conclusions were reached at JAMCSI (cont'd)**

**8. We need a DIRECTORY OF COMBAT SIMULATION MODELERS**

**9. We need a CLEARING HOUSE FOR MODELING INFORMATION**

**A PUBLICATION IS NEEDED TO PROVIDE THE MODELING COMMUNITY WITH HUMAN PERFORMANCE DATA**



The second conclusion drawn was that first order estimates or even rough approximations of human performance in existing models would be better than what we have today, which is pretty close to nothing. There are a few models that gave some data, but for the most part they are missing, including JANUS, the premier simulation model which is used for strategic studies of nuclear exchanges. JANUS makes certain assumptions about human performance which, until about a year ago, were not accurate. Human performance was ignored.

The third conclusion drawn was that whoever involves themselves in this particular modeling activity should realize that planning for multiple sources of funding is absolutely necessary. That is to say, the Navy should not have to foot the bill for benefits that are going to be derived from the United States Army, the United States Air Force, and the Marine Corps.

The fourth important conclusion derived from the JAMCSI meeting was that we need to identify critical combat tasks. I want to underscore critical combat tasks. We do not wish to model the world. We do not want to approach modeling in that particular fashion. We think that would be excessive. The point is, where do you cut modeling off. You cut off modeling research at that point where you have identified those variables that can account for most of the variability in the phenomenon you are studying (critical combat tasks) at the lowest dollar cost.

We next need to identify existing or current data and determine its suitability for infusion into existing combat simulation models. We also want to make sure it is compatible with the scenarios of interest.

The fifth conclusion drawn was that we need to develop a systematic representation of all the dependent variables, in a matrix form, so we can study them, taking one at a time, two at a time, three at a time, and so forth.

Now I'm getting into a subjective area. I think these are mostly my opinions and I certainly don't speak for the entire Laboratory, but I can tell you from experience that these things would really help get this program off the ground.

Number one, if we took a poll in this room about who's using combat simulation modeling, who's developing them, where they are located, etc., I think we may find several individuals who are quite knowledgeable and the rest of us might be very naive about it. So how do we correct that?

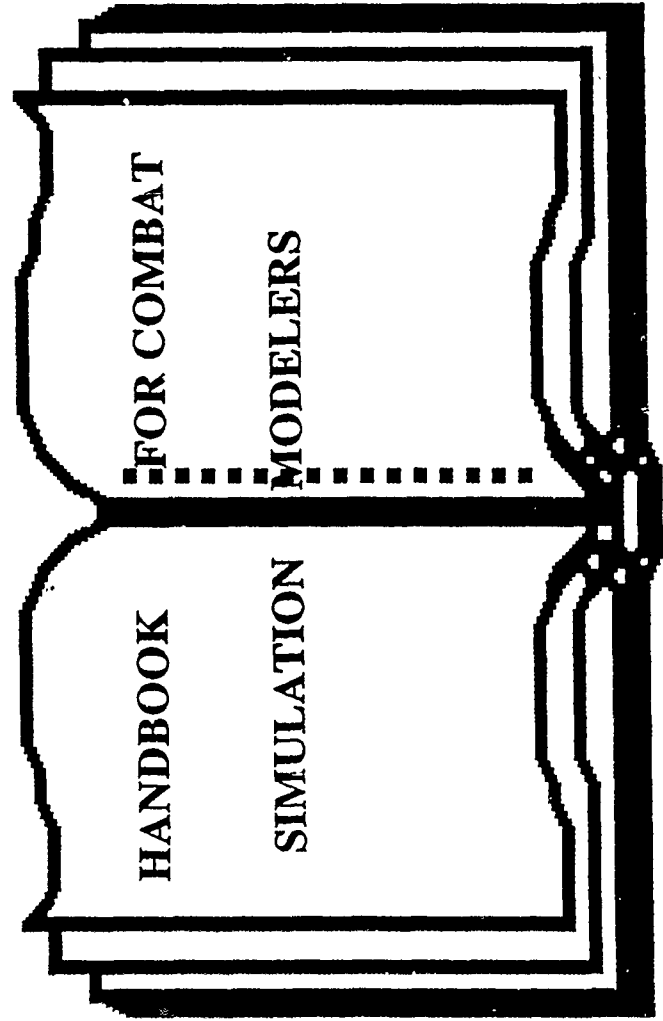
- (1) We provide a directory of combat simulation modelers. Who's doing it? Where are they doing it? What resources do they need? What kind of models are they using? What are their operational problems?
- (2) Going back to Captain Chaney's mission, we need a clearing house for modeling information (a forum) in which the community can share that information.

I'm not talking about operations research folks sharing information. They do that pretty well. They've been doing that for twenty years, but how many people here are participating in that exchange of information? Through the years, the OR community has gotten very tightly inbred and that information is not being diffused out into the broader scientific community. It's not being diffused to physicians, certainly not to psychologists. Maybe some physiologists have been involved in it, but I don't think as many as I would like to see. So, a clearing house concept would be valuable to get information out to other disciplines. In other words, perhaps a publication is needed to provide the modeling community with human performance data that are relevant to the combat missions and the operational scenarios, and is amenable to the modeling community at large.

I have a real strong bias that I will share with you. About a year ago I started looking for a handbook for combat simulation modelers. What I found was a fragment of twelve or thirteen small reports (like tech reports) that would address things like algorithm development, and attrition, etc., but there was not a unified, systematic document that I could go to and ask real applied kinds of questions and get answers. I couldn't do it. I thought perhaps there might be a way of bringing together physiologists, psychologists, operations research folks, and physicists to help develop an integrated handbook on combat simulation modeling. The reason why you want to involve many disciplines in this effort is that it brings the community closer together and also expands it at the same time. People begin sharing information. We think this

## **10. WE NEED A**

# **HANDBOOK OF HUMAN PERFORMANCE FOR COMBAT SIMULATION MODELING**



could be very valuable. Pieces of this book may already exist but not in any integrated fashion.

LLNL further recommends that if you are going to initiate modeling efforts then "start small." By starting small I mean pick one, two, or possibly three models to support. You can't support large models with limited funds and you can't support many of them, especially in times of diminished economic resources.

One model we thought was very operational tuned was explained to us by Major Anderson at Camp Pendleton. The model is called TWSEAS (I think it stands for Tactical Warfare Simulation Evaluation and Analysis System). The other is SEES, which is a force-on-force small group conflict model that is more like a daughter of JANUS. It's basically a subroutine of JANUS. It is used for tactical offensive and defensive missions of very small groups. You can model fire teams; you can model an individual; you can model squads, up to platoons and even battalions.

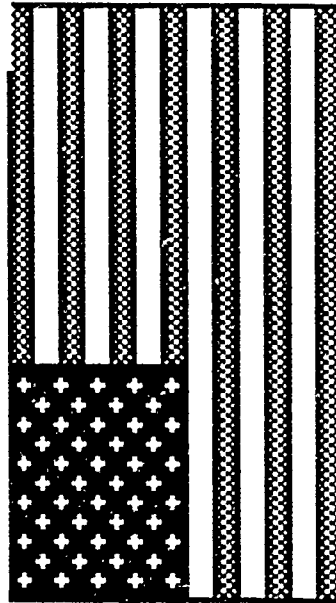
There is another model we looked at called SHIPDAM which was developed by the Navy at David Taylor Model Basin and which looks very promising and certainly very relevant to the Navy's operational problems concerning "on board" response to fires that might break out, damage control operations, and so forth.

The next thing we recommend to the Navy was that they form a multi-disciplinary team. This team should then become thoroughly familiar with the select sample of models you are going to examine, e.g., SEES or TWSEAS or SHIPDAM. It would be very important for these folks to work very closely together. You almost have to "force function" this to happen, making sure the physicists are understanding the medical terminology used by physiologists.

Livermore recommends that we identify human performance needs within the selected models, i.e., take a look at the models, find out what parts of human performance might enhance them, and give that an initial first effort. This effort should be based on very firm studies done in the fleet or in an operational setting to identify "critical tasks". Then prioritize the independent variables regarding the issue of expected impact. You only focus on the most significant variables which will have an impact on outcomes.

**LAWRENCE LIVERMORE NATIONAL LABORATORY  
RECOMMENDS THAT THE US NAVY:**

**\* START BY SELECTING & FUNDING TWO  
OR THREE SMALL GROUP  
CONFLICT SIMULATION MODELS  
(SEES, TWSEAS, ETC.) \***





**LAWRENCE LIVERMORE NATIONAL LABORATORY  
RECOMMENDS THAT THE US NAVY:**

**FORM A MULTIDISCIPLINARY TEAM  
TO BECOME THOROUGHLY FAMILIAR  
WITH THE SELECTED SIMULATION MODELS.**

**THIS TEAM WOULD INCLUDE THE FOLLOWING FIELDS:**

**MEDICAL/PHYSIOLOGY**

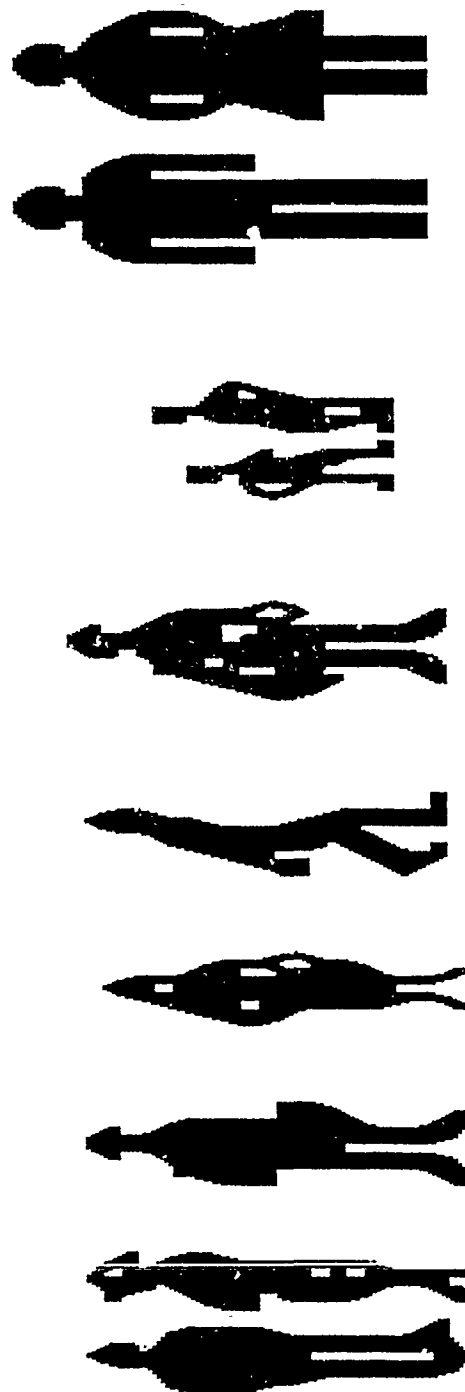
**PSYCHOLOGY**

**PHYSICS**

**OPERATIONS RESEARCH/STATISTICS**

**COMPUTER SCIENCE**

**ELECTRICAL ENGINEERING**



**LAWRENCE LIVERMORE NATIONAL LABORATORY  
RECOMMENDS THAT THE US NAVY:**

**IDENTIFY HUMAN PERFORMANCE NEEDS WITHIN  
THE SELECTED MODELS**

**THEN, PRIORITIZE THE INDEPENDENT VARIABLES  
REGARDING THE ISSUE OF EXPECTED IMPACT**

**INTEGRATE THE KNOWN RELATIONSHIPS BETWEEN  
PRIORTIZED INDEPENDENT VARIABLES WITH  
IDENTIFIED DEPENDENT (PERFORMANCE)  
VARIABLES**

**INDEPENDENT VARIABLES**


**DEPENDENT VARIABLES**

Next, integrate the known relationships between prioritized independent variables with identified dependent or performance variables. These are the things we suggest that you put into a matrix. Make it very traceable for the public to be able to see your rationale and thinking so that other people in different disciplines will understand.

Once you get this matrix of various dependent and independent measures, we would suggest that you take these network models and explore each critical task. I won't go into any detail, but a network model basically has people doing some type of detection (this would be target acquisition here), recognition, you arm something, you estimate the distance to the target, you follow the target, you fire the weapon, and this whole thing is repeated including reloading, aiming, communications, calculations, and adjusting things to optimize performance. You find out what happens if any of these components degrade or are not operational--what happens to this whole system--and those are the things you select to model.

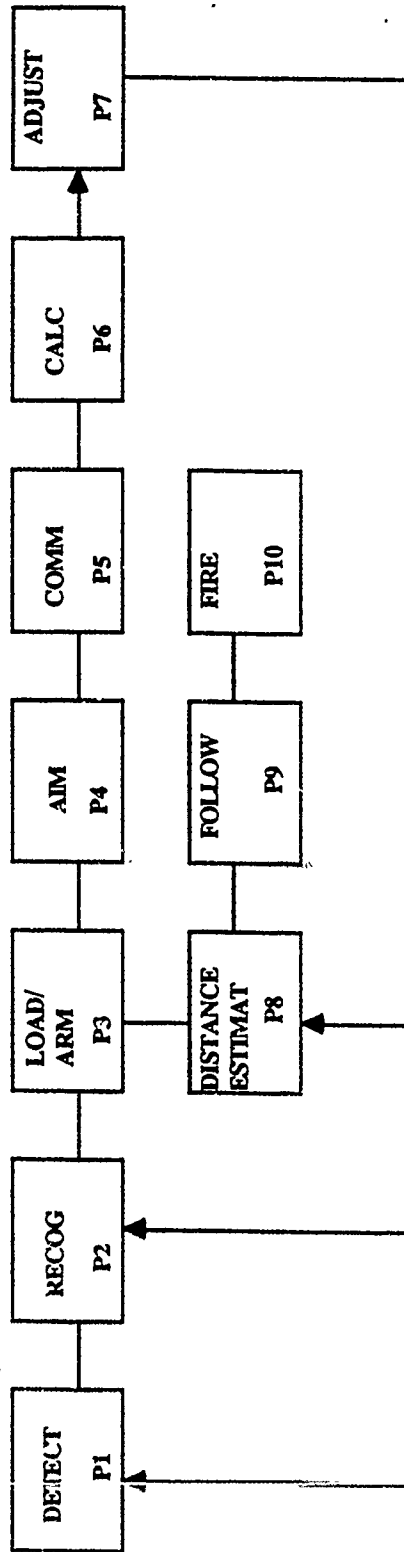
By the way, there is a good tool for that. I'm not plugging anybody's product, but there are a number of different tools on the market that make the task of networking very easy to do. I know that NHRC uses MicroSAINT. We have a copy of it up at the Lab.

All of the services have many types of combat models. The Navy has quite a few. Let's say I wanted to get a subroutine from the Air Force. Let's say they have a great logistics subroutine and I want to include that in TWSEAS to make it more realistic since now, when you play TWSEAS, you can have unlimited rounds of ammunition to fire. That's not very realistic. In fact, depending upon how you want to use TWSEAS, that could be negative. If I want to get this subroutine and incorporate it into TWSEAS, I cannot do it. Why? Because it's developed on a different system, written in a different command language, located in a different place in the United States. So I see this whole area of combat simulation modeling as needing some type of template or control organization imposed upon it from a high source, like OSD down, in order to better control software development.

Another thing we would suggest is that some type of oversight function be provided to make sure these models can be integrated in the future and reduce conversion costs. You might say we don't do that because that's not our particular mission. Well, apparently it's the mission of somebody in the Navy to provide oversight for these kinds

**LAWRENCE LIVERMORE NATIONAL LABORATORY  
RECOMMENDS THAT THE US NAVY:**

**DEVELOP TASK NETWORK MODELS FOR EACH  
CELL OF THE MATRIX**



of activities. That forces models to be developed in the future to become more compatible with each other, so that the researchers in the field may obtain greater utility out of these models. In looking at these kinds of things with regard to combat simulation models, [Bob, I know you will be interested in this], every time I ask modelers what are the validity coefficients they ran on a particular model I get strange looks. I ask them about the internal consistency of the model and I get strange looks. I ask them about compatibility with other models and I get strange looks. That tells me there is something amiss at a much higher level regarding combat simulation modeling. I wish Earl Alliusi was here.

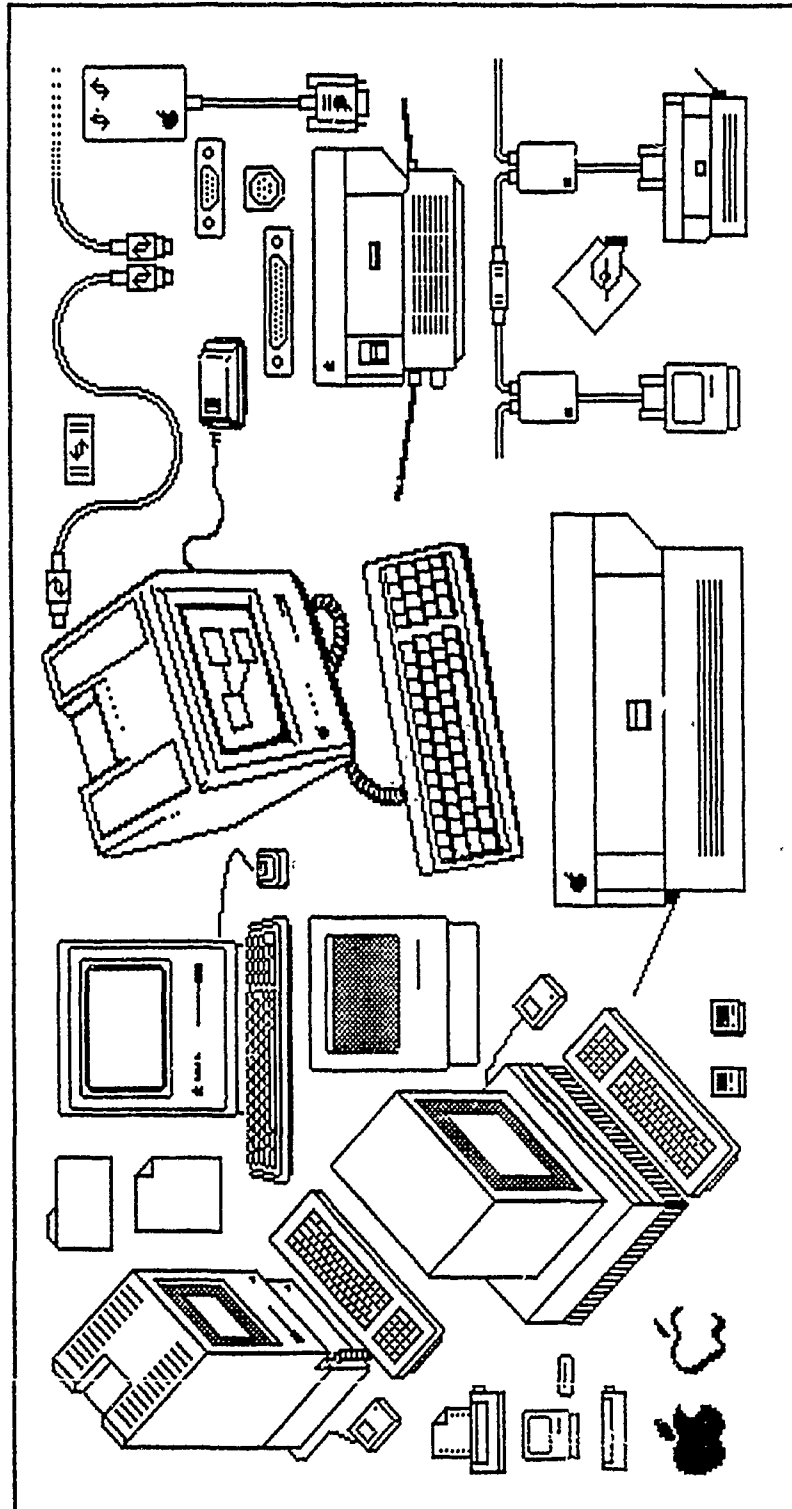
Communication of modeling activity is a problem that relates to the issue of integration. How many people do you know who are forming small, multidisciplinary teams attacking this issue? Anybody? I know they've got something going here at NHRC, but where else?

From my perspective as a third party reviewer, I don't have any ax to grind and I can tell you within the Navy labs there tends to be a degree of territoriality. In Army labs it's worse, so don't think I am picking on the Navy. This really is not productive. If you are going to develop combat simulation models, take into account human performance and make sure it goes to the Navy lab that knows something about human performance. Don't give it to a Navy lab that does electron studies or advanced laser beam weapon studies. The human performance variables are not going to get infused into those models. What they are going to do is concentrate more on models of lasers.

This was just an idea to show that it's possible to have some Navy lab take responsibility for that issue and then provide some kind of oversight function to force fit the model development so that models are more useful in the future. That's it, unless you have any other questions.

I'd like to thank you very much.

# DO WE HAVE AN INTEGRATION & COMPATIBILITY PROBLEM ?



**OVERSIGHT AND CENTRAL INTEGRATION  
FUNCTION IS REQUIRED TO MAKE  
OUR MODELING PRODUCTS MORE PORTABLE,  
USEFUL, COST EFFECTIVE, AND VALID**

**APPROPRIATE LEVEL OF HUMAN PERFORMANCE**

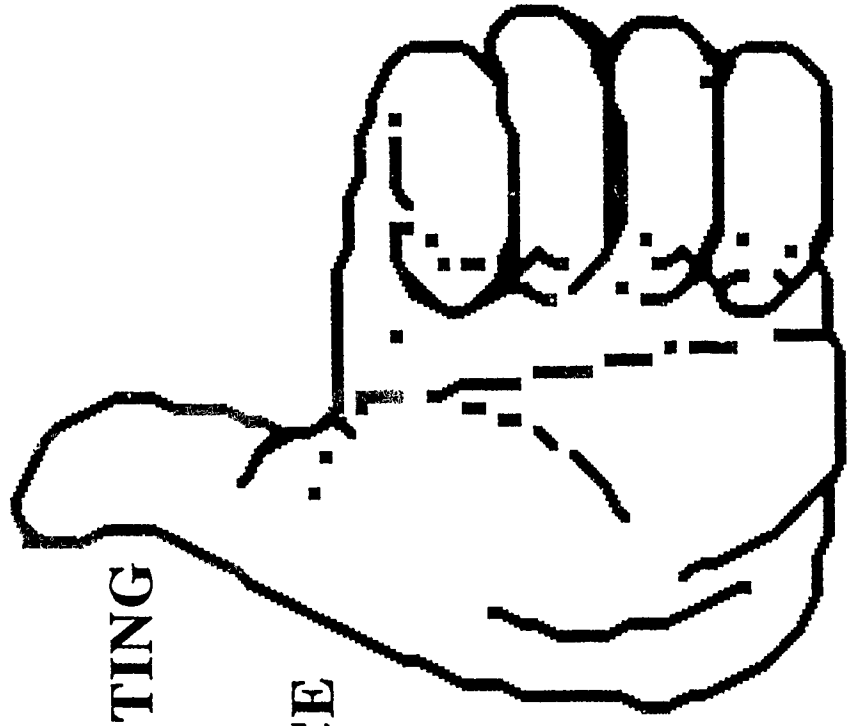
**VALIDITY REQUIREMENTS TESTING**

**FIDELITY**

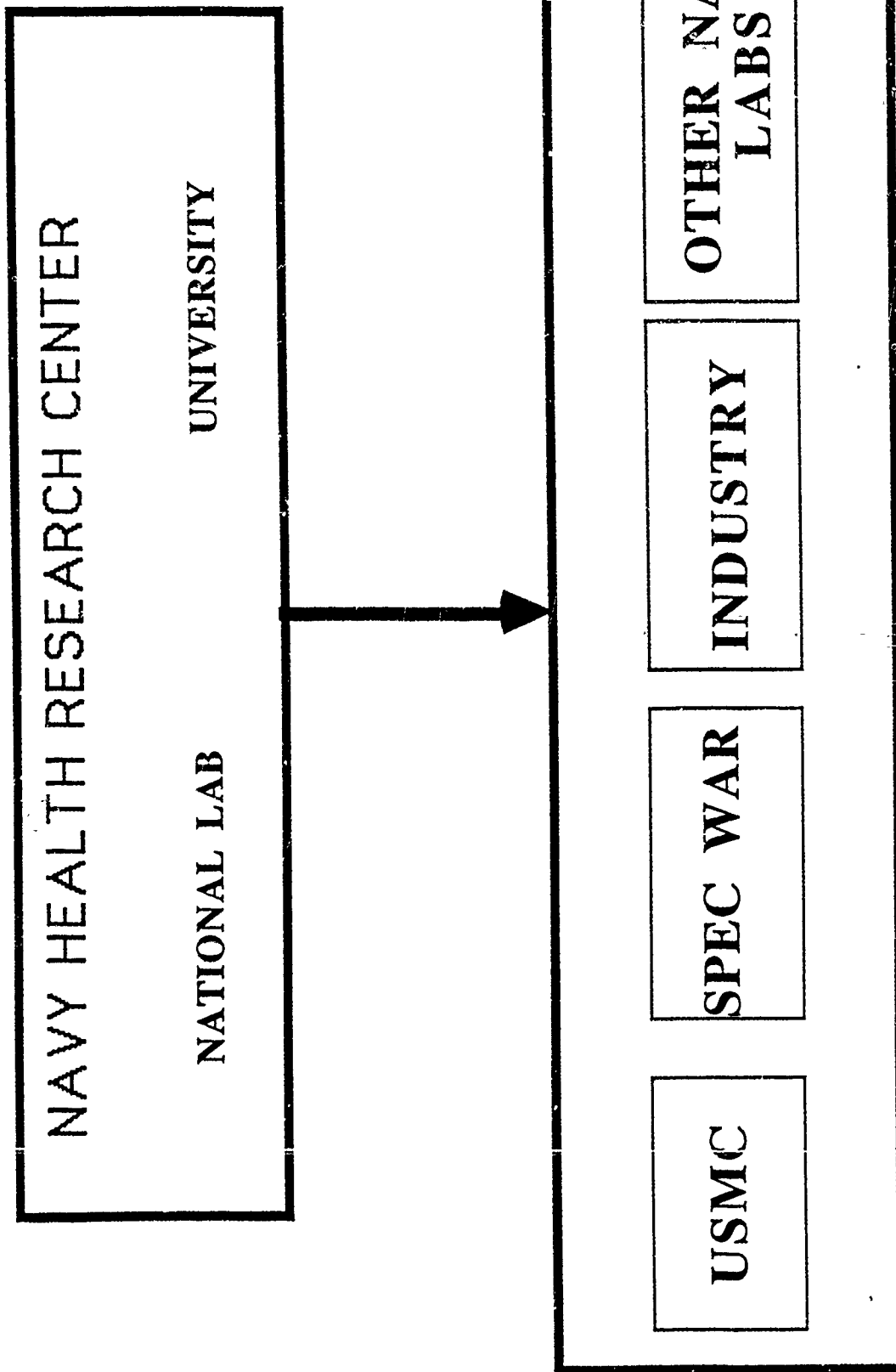
**COMPATIBILITY**

**FUNCTIONAL PERFORMANCE**

**CONNECTIVITY**



**MULTIDISCIPLINARY**





DR. GUNDERSON: Next, I'd like to introduce Dr. Bob Helmreich from the University of Texas, Department of Psychology. I first knew Bob when our laboratory gave his research group a little support for the Sea Lab project, so you can imagine how long we have known each other and, how far back we go. Sea Lab, if you don't know, and I'm sure you all do, was running a submerged chamber off the coast of La Jolla shores for several weeks. Bob has had a very distinguished career in social psychology, group psychology, and aviation psychology. I don't want to go on and on; I'd just like to say we've had an opportunity to interact on consultant panels from time to time, and it's a great pleasure to have Bob with us and to have him share this information today.

Robert L. Helmreich, Ph.D.  
University of Texas, Austin, Texas

DR. HELMREICH: Try to go from underwater to outer space. With characteristic modesty, Eric said he and the lab gave a little support. I firmly believe I wouldn't have gotten my Ph.D. if it hadn't have been for the kind of support he gave, when I showed up in La Jolla as a graduate student, pretty much lost. Eric was terrific in getting us research assistants, logistics, everything you can imagine. It was terrific. It's also really fun to be back in San Diego. In my earlier incarnation, I graduated from the Fleet Anti-Submarine Warfare School across the street and haven't seen the place in years. In fact, this hotel wasn't here, so it was fun at 1:00 A.M. this morning to figure out where I was.

What I'd like to do is say a bit about the project I'm directing that's sponsored by NASA and supported by the FAA, it deals with crew performance in demanding and stressful environments. If it sounds like there is an overlap between the purposes of this meeting and my project, I'd say it's about as close to 100% as you can get. I'm excited that you invited me to join you and that you are studying multiple stressors, because that's right where I am.

The NASA project I'm working with is looking at the issue of how we prepare crews to perform well in demanding situations, how we select and how we train them. So it's a three-pronged thing. I started out working with NASA and ONR on the Tektite projects which were undersea saturation diving projects. The goal was to see how small groups interact under stressful conditions. The main stress in NASA in the mid-seventies was that nothing was flying; so about 12 years ago it was recommended to

me that I expand my NASA work and look at air crews. It turned out that was probably the synergy that we really needed, because the aviation industry, both military and civilian is research oriented, and there are a lot more pilots than there are astronauts. It's possible to do more meaningful work.

Where we are now, is in a cooperative venture with the military, primarily the Air Force, and the major civilian airlines and the Germans at DVL R which is supporting some research with Lufthansa and the German Space Program, looking at issues of crew coordination and crew performance. The model that we have essentially says that when we look at what happens—what does work in aviation—planes don't fall out of the sky because they are badly built. They tend not to fall very often. Planes don't fall out of the air because crews don't know how to fly them. Technical competence tends not to be an issue. What our analysis of accidents suggests is that planes fall out of the air because crews don't work together effectively. It's team work. They screw up working with each other. So, the FAA as the regulatory agency says we have got to do something about this. What we need to do is to train crews how to work together more effectively. The generic name is Cockpit Resource Management; in other words team training, if you will, for crews. Strangely enough this seems to be relevant to space crews, too. They need to work together, so we found a common ground.

When we look at what's available in the data, and I really agree with the prior talks about the importance of data bases on human resource and human behavior, the data base is pretty close to zilch. Pilots are evaluated quite well in terms of how they work as solo individuals manipulating sticks and rudders. There is a vast data base in the DFAA and in the military. We can tell if a guy can shoot an ILS approach, if he's a dot off, how he maintains his air speed, but we don't have any meter for saying how well he works with fellow crew members in dealing with complex problems. So, the first task we were faced with was coming up with better evaluation tools for the crew level instead of the individual level. Once we do that, then perhaps we can look at training and see if it enhances crew performance. That being done, we can say what are the limits to training in improving crew performance. In other words, can we accept the trainer's model? Can we take a chimpanzee and make him into an effective airline pilot? A lot of people think so. Or do we need to pay more attention to selection factors? Are there limits on training?

What we are doing is trying to put all those pieces together, and it has been a fairly lengthy process. First off, we had to have the performance measures, and second we needed a data base on baseline performance in organizations; then we can start saying if training has any effect. This project has been going about five years now. It has suddenly gotten very intense. We are tracking over 15,000 active pilots right now in a longitudinal data base. I'm about to take the next couple of years off from the University of Texas to devote full time to the project. The data are starting to come in, and what I'd like to share with you is a bit of the data we have and where I think some of the holes are.

We have just finished drafting a white paper that says sort of where we are and what we have found, and I can make copies of that available. It summarizes a lot more than I can do in 10 or 15 minutes, so I'll make that available.

Let me hit a few high points. One of the things we have discovered is that personality factors--measurable personality traits--are critical determinants of performance in demanding environments. This is a fairly important finding because the data from pilot selection, both military and civilian, would argue the opposite, that personality is not a very critical issue. We have argued that the reason it was not seen as critical was that we were using the wrong criteria for performance; specifically, using training performance rather than line performance. I think the critical distinction is that clinical measures are designed to screen out the crazies. But, we are interested in selecting the most effective people and those are rather different tasks. Eric and I have been on a new committee to develop criteria for astronaut selection. We need to look at performance in operational settings. The bottom line in our research is not whether they get through training or not, but how do they actually perform in line settings, either simulator or operational. A critical factor in our research is training observers who actually observe crews flying the line. We have now over 3,000 crew members observed which involved about 27 observed variables on each crew flying in operational settings, both military and civilian.

Another area we are involved in is full scale simulations. We have just completed a study at NASA Ames where we used regular airline crews. They came in and flew a two-day simulation, five flights, including an overnight--everything except flying attendants. (We actually had simulated flight attendants. The crews don't think they are very satisfying but that's the best we could do.) We're doing the same study in

Germany starting next week where we are having German crews fly multi-leg missions. We're also using the personality factors in line performance.

Let me turn the corner a bit and say one thing about performance in training. We're looking at the various programs that are designed to enhance crew coordination. These include training in decision making, training in interpersonal communications, and training in personal reactions to stress. We have been measuring these factors with some survey instruments we designed to look at attitudes regarding crew coordination and personal characteristics. One finding that really fascinates me is relevant to this group. This is that flight crew members, both military and civilians, are unfamiliar with the effects of psychological stress on human behavior. They don't have the slightest notion what it does. The modal impression is that "I perform a hell of a lot better when there are rockets flying at me or when the wings fall off." I suggest the data go in the opposite direction. Most of the new training programs are now attempting to deal with stress effects, and I can show in our data that they are pretty effective in changing peoples' attitudes.

Another finding we are picking up from the data, which is intriguing and which we are able to do with pre-, post-measures, is that training in crew coordination and stress is not uniformly successful despite an overwhelming significant main effect for training. We can see a huge main effect in all of the programs, Air Force and civilian, that are training crews in coordination--overall, crews get better. But when you have a repeated measured design you can go back and look at individuals. The old saying that I learned when I was a brand new Ensign in the Navy, was that "there is always 10% who don't get the word." Well, it turns out 10% of the people who go through these training programs are getting worse. They are boomeranging. We are finding that somewhere between 10 and 12% of the people, at least using the attitude measures, come out of training more negative about the importance of interpersonal communications, more negative about crew decision making, and also more convinced that they are the Lone Ranger, that only a silver bullet will get them. This is kind of a disturbing finding when you think about it, especially if the guy is going to fly your plane back to Washington when you leave this conference.

We found that two factors lead people to boomerang or react negatively in training. One is personality. Certain personality types tend to react in the opposite direction. The other is simple group dynamics. This training is typically done in sma!

groups or seminars, and small groups and seminars sometimes go berserk—the whole group will go the opposite direction, which does not make the day for a trainer. We are trying to figure out how to deal with that.

In terms of our knowledge base on multiple stressors, almost all of the situations that we deal with in flight crew emergencies, are multiple stressor situations: typically, a high level of threat (the plane's going to crash), a work overload, and frequently, fatigue. Emergencies tend to happen at the end of long flights, unless the crew forgets to put the flaps out for take off in which case it's a very short emergency. So, we are typically dealing with multiple stressors, and our data base isn't very good on that. This is not the sort of thing we study effectively using bored freshmen in an introductory psychology laboratory. I think the data are generally worthless from that type of situation. You need real people in meaningful situations. So we don't have a lot of empirical data. The other thing we don't have much of is good data on the group processes involved. If we come to the point of saying these are group performance issues, as opposed to the sum of individual capabilities, what do we know about the analysis of group process data? I would argue, precious little. It's a tedious, miserable, type of analytic work to do, but it's very important to figure out exactly the patterns of intercommunications.

One of the components of our NASA project is doing just that. Doing microanalysis of group process data, both from simulations and from real accidents. What we typically do is take, say, our big NASA simulation where we had crews flying two-day missions; we are analyzing every utterance, using as our analytic unit, the thought unit, which is frequently smaller than a sentence, looking at all of those and how they interplay with one another.

The other source of data we are using is CVR data from accidents. I'm in the middle of analyzing several recent U.S. domestic accidents, which were considered coordination failures. Again, we are finding very meaningful data, but it's not a big enough base to model very well. About the most useful cases are the few accidents that involve very long duration, high emergency situations, i.e., where a crew is in extremis for a very long period. There you would have a really fascinating set of data on stress. There are few accidents like that where we have the recorders. I just finished one—a Saudi Airline accident that happened a few years ago when the aircraft caught on fire at 30,000 feet. The rumor spread was that a pilgrim on the way to Mecca was roasting a

goat in tourist class. That was not true. But anyway, the plane caught fire and the crew had a riot--330 pilgrims onboard who spoke polyglot languages. The fire started aft and burned forward. People were burning to death in the cabin. Fire was burning through wiring so the controls stopped working. The #2 engine jammed on and could not be controlled. Smoke was filling the cabin. Flight attendants wanted to know what to do. They lost hydraulic power. And, finally, the fire burned through the outflow valve so the aircraft was depressurizing, sort of like deep diving. It was the equivalent of about 200 feet under, which meant their eardrums had great pressure, and they're trying to land the plane. This was stress and multiple stressors.

You can see everything we know about the effects of stress on performance happening. They are having trouble multi-processing, communications are fractionating, everything is going down the tubes, and you can really model it with these data. They managed to get the plane on the ground and then everybody burned to death before they could get out.

A similar accident we are analyzing was an American jet out of Atlanta which was vectored by air control into a severe thunderstorm which broke the windshield. Both engines flamed out, so they were dead stick at 28,000 feet and tried to coast it in. In fact, they landed it on a road. Unfortunately, the road was narrower than the plane. But at any rate, in the process of landing, you could pick up the same pattern of performance under high multiple stressors. These are useful data, but we don't have very much.

There is a lot we need to know, that we need to start throwing into models. I truly applaud the idea of saying let's take imperfect data and start throwing them in and see how they work. It's a lot better, I really think, than having no data at all.

That's an overview of our project. I'd love to talk to anybody about it. As I say, we have this quite extraordinary developing data base now. It is a secured deidentified data base in the sense that I am protecting the guilty and innocent alike in terms of individuals and organizations. The data are there as a resource for research and I would suggest that they are pretty exciting data to work with. I don't know how much time I have. I'd love to answer any questions.

AUDIENCE QUESTION: Where do we gather data, in the simulator or in the actual cockpit in terms of the probability of stress effects?

DR. HELMREICH: I'm glad you asked that. I think we are not stressing crews enough in the simulator. There was an odd kind of knee jerk reaction about seven years ago. This training (which the Air Force calls Mission Oriented Simulator Training and the airlines call Line Oriented Flight Training) is basically full mission simulation. When it started becoming very popular in the 1970s when we started to get really good simulators, the model became: let's keep tossing problems at crews; if crews handle them well, let's toss them another problem and we can break any crew. They started doing that. The key researchers, one being a psychologist named John Lauber, who is now on the National Transportation Safety Board, got upset with this and said, "It is not very good training if you keep overloading crews until they crash. Let's back off." So now, the simulations tend to be relatively benign. I think they are too benign. You really want to generalize to that nasty situation when the wings fall off and I don't think we're stressing crews enough. That is one of the questions we are addressing in the research. I wish I had enough data to answer it correctly.

One of the nicer things about our aviation system is there aren't that many massive emergencies on the line, which is good. Last night was the first time I've had to make a missed approach in about three years. We couldn't get down in San Diego because somebody turned off the runway lights when we were 40 feet above the runway.

AUDIENCE QUESTION: Have you ever tried taking data from an actual incident, presenting the crew with the exact conditions?

DR. HELMREICH: Yes sir, that is our regular practice. Most of the airlines are doing exactly that. Every time you get a problem in the simulator, it's a real incident somebody has faced. There is high fidelity in that sense, but a lot of them really don't stress the crews, perhaps, as much as they might. That remains to be seen. I think it's very important. The simulator is certainly real enough to the crews.

AUDIENCE QUESTION: Can you ever make a simulator stressful enough, because people know it's a simulator?

DR. HELMREICH: I think so. I'm sorry if I was misanswering the question. I think you get so involved in it and if you take an airline crew, for example, it is their livelihood. The only thing that isn't going to happen is death, but to many crews something worse than death can happen. If they screw it up, they lose their ticket and can't fly anymore. The fidelity is high. It's a crude analogy, but in many cases, the seats are wet at the end of a really challenging simulation, and the crews genuinely don't know they are in a simulator. The truth of whether it's really real is unanswered and is the Heisenberg principle in effect.

AUDIENCE QUESTION: When you train a small group that learns to perform as a group and optimize it's performance, how interchangeable then are the parts? If you could train many small groups to the same level of performance and then start switching the component people around, how interchangeable are the small groups?

DR. HELMREICH: That is an excellent question. The model that has to be used in civilian aviation is training interchangeable groups. Because, thanks mostly to union rules, it is highly infrequent that crews fly together much. Thanks to the new computer bidding system, crews which used to fly together for maybe three days at a time may only fly together for one 50-minute leg. They are constantly shuffling, so you are reconstituting brand new groups. The focus in all of their training is generality of effects, learning to recognize and deal with strangers in a group situation. The contrast is SAC where they have hard crews and fly together for months at a time. The little bit we have from some other organizations, suggests there is a compromise. The hard crews tend to get complacent after a while. Crews that shuffle constantly are not as effective as crews that fly together. NASA has actually done some controlled research on that so there is a nice, intermediate point. I think Lufthansa flies their crews together for 60 days. That seems to be a nice number. That's an important question.

AUDIENCE COMMENT: Your comments on negative training effects and what you consider a negative result. I've had a couple hundred combat missions in Viet Nam. The term over there was "the golden biggie" that was going to get you, and I would suggest that to an experienced combat pilot that might be almost essential to surviving in a war zone—that outlook. The people that I ever heard express doubts or fears about being shot down or captured over there, were. And so, why not use the approach: nothing's going to get me. As far as crew coordination, any pilot worth his salt will tell you that you don't need more than one seat in an airplane anyhow.



DR. HELMREICH: I hear you. I hear you. Let me respond to that. That's an excellent point, and I'm sort of pressed for time and will oversimplify. I really was discussing noncombat situations. I think it's a fine line. You've got to know that when there is an external stressor out there that there are some degradations in your performance. But you also have to think that despite the risk, I'm not going to get hit.

The other data we have are that in our big samples we can track single fighter pilots into multicrew air flights and the answer is if you want to fly your 747 upside down, give me an ex-F18 pilot. If you want to keep it right side up with a crew, then give me a former nonfighter pilot. They tend to do better in a crew environment.

AUDIENCE COMMENT: One concern I have as far as workload stress and those stress effects, airline data are just one end of that performance vs. stress curve; all military flying situations tend to be on the other side. I suspect the problem we have right now is grossly inadequate cockpit design to support crew coordination. We design aircraft to make good ILS approaches. I'm sure the F18 or similar aircraft will do a wonderful job of shooting ILS approaches, but they won't do squat in combat.

DR. HELMREICH: One of the things developing in the project that I'm very excited about is tailoring the training to the flying environment rather than saying it's a generic thing. One of the things that makes me very happy is having the military in our data base. Because you're right, it's a very different situation. It's very different in that short haul civilian operations are much more stressful than long haul. We have, for example, Southwest Airlines as our short haul. They do 10-minute turns and it's very stressful flying. PanAm is the other extreme, they make two landings a month. Their problem is lack of practice. You do a turn from Los Angeles to Tokyo.

AUDIENCE QUESTION/COMMENT: How can you get the information about performance under circumstances such as people on fire and then compare that to performance of say your Army helicopter pilot in a battle area? What can your crew do about that? In one case you are invoking a set of rules, and in the other case it's reaction to circumstances. It's a different sort of thing. You actually have to do a certain amount of thinking. I have a lot of friends at NASA who have said you have to think when you are a military pilot and you don't have to when you're an airline pilot.

DR. HELMREICH: When we evaluate the scenarios used in simulation, it has a book solution, it's a bad simulation.

AUDIENCE QUESTION: Another question. When you assess the aviator's mistaken beliefs of effect of stress on performance, is that just your impression of the crews or is that based on something substantial?

DR. HELMREICH: I think the baseline effects about people being less effective at multiprocessing in high stress, rather than low stress, are pretty basic findings about high arousal, high stress situations. We're using a survey instrument that asks a whole series of factual questions about individual capabilities under high stress situations, so they are objective data.

AUDIENCE QUESTION: If you have a crew believing that their performance has improved, would we just measure the decrement?

DR. HELMREICH: In fact, yes. I haven't analyzed all that data, but we are collecting self-report evaluation about crew performance from every simulation. It's a little hard to believe after they crash that they did a great job. We just had this one little problem. Other than that, it was a great trip on the Titanic. I'd say we have pretty hard data on that.

DR. GUNDERSON: Our next speaker is Dr. Peter Cherry of Vector Research, Inc., who will give us an overview of the Army's research on models.

Dr. Peter Cherry  
Vector Research, Inc., Ann Arbor, Michigan

DR. CHERRY: I'm going to talk about some research that has been done under the sponsorship of the U.S. Army Institute for the Behavioral and Social Sciences (ARI). I'm going to give you my own opinions. They don't represent the Army's opinions nor ARI's. I'm willing to talk about what the Army is doing in combat modeling, and I can also talk about an initiative taking place in their assessment at the Office of the Secretary of Defense, all focusing on human factors. Since most of the color here is dark blue, I will say I have been doing Army research for 25 years now. My first experience was to design tactics for MED. Some of you will know what it is. They sent me an approval and an evaluation unit, put me in the back of a Neptune, and flew my tactic. I got very sick, the tactic did not work and I discovered what importance human factors have.

I'm going to talk about research on a conceptual framework for the representation of human factors in combat models. We have been concerned about it for a long time. Other people have become increasingly concerned, more in the last four to five years.

The research goals of the ARI project were to identify those human variables that influence combat performance, to develop or identify techniques for getting data that would be useful and including these in combat models, and to estimate the nature and level of these effects.

I'll talk to you about some of the things we did and the discoveries we made. In order to give you an indication of how we set out to do things, it corresponds to what Bill Banks said about small groups. It could pertain to joint warfare, but it actually pertains to the Army, and you will see we go all the way down from CONUS to what we call company and platoon level. This is where execution takes place. Very few tasks on the battlefield are performed by groups that are any larger than platoon or squad. The critical issue here is that the Army is organized into what we commonly refer to as stovepipe functions. The engineers do engineering, the infantry do the infantry tasks, the armor units do armor tasks, and so forth. Yet to really make it all work, it has to

be synchronized at horizontal levels as we go down. The key issue then is this executing element in command and control, vertical and horizontal.

Now, we set out to come up with a framework to try and examine human factors in combat, and we had to identify a number of things. First of all, we came up with a framework for describing combat. Combat consists of activities performed by these executing elements and the extent to which they deliver an increment of combat power in maintenance, fire, laying a barrier, removing a barrier, or whatever, is a function of how well they perform their tasks and also how well it is coordinated with the other small units on the battlefield.

We decided we would deal with two kinds of small units: executing elements and command control groups. These are battalion staffs, the company commander and his executive or teams or sections in a division command control organization. So we are dealing with small groups and we talked about kinds of tasks. Principle tasks are the tasks they are trained to do—the engineers laying a mine field or the infantrymen delivering fire. Secondary tasks are not the prime survival tasks or their primary training. For the infantrymen, you might think of it as digging a hole or cleaning his rifle. For the tanker it would be doing preventive maintenance. Then we talked about planning and execution for those small groups that are doing the command control, the battalion staff, division staff, and so forth.

What we came to grapple with, I guess, is what does stress do and what kind of human factors influence performance. We came up with these three things that we think are important. There are behaviors that take place on the battlefield, and I'll talk to you later about some of those. One is whether a task is initiated or not. Choose a task to perform. When the artillery fire starts to fall on you, do you take cover if that's the appropriate response? Do you take cover and then begin to maneuver? Do you call in fire to remove that source? Do you become suppressed? Do you initiate an inappropriate task? Consistent with tactics and training or inconsistent? That's the guy who takes cover and does not do what is appropriate in that particular situation. Finally, we have this failure or reluctance to initiate tasks. Notice we are not spending a great deal of time talking about time, accuracy, and completeness. I'm talking more about what task I pick to do and whether or not I do it. As I say, you can describe, as Bill Banks mentioned, the task networks with time, accuracy, and completeness. What is probably equally or more important is to talk about what behavior is adopted in a given

situation. What is the probability of that behavior being adopted, and if it is an adverse behavior, how long does it last?

We quickly got into things that change performance in combat and what we wanted to look at was the stress recovery cycle—physical, emotional and mental stress, the effect of the environment, and combat itself. We probably have good first order data to allow us to include things like thermal, mechanical and so forth, stressors in combat models. We know what happens when we put somebody in MOPP gear; we know how long they can perform, and we even have a conjecture as to how that performance degrades. We don't do as well with other issues.

What soldier attributes do we have to look at? Well, we certainly have the basic abilities. The soldier comes in to us with certain capabilities in all of those areas. They are influenced by training; we give him knowledge and, of course, we were confronted with the so-called intangible factors: motivation, morale, leadership and cohesion. Clearly, performance degrades and changes as I apply stress in these areas. I allow opportunities for recovery, but some of these changes may, in fact, be more important than others.

We have heard a couple of comments about the literature. I said just a moment ago, the key issue is the stress recovery process. We set out to try and look at the effect of sleep deprivation on combat performance at the National Training Center (NTC). We actually had instruments on participants, squad leaders, platoon leaders, company commanders, and the battalion staff. The idea was we would see their performance degrade as we deprived them of sleep. We didn't deprive them of enough sleep. Their performance really did not change. In looking at the issue, we discovered that most of the things we can get from the laboratory or field do not accommodate the sleep-rest cycles that are provided to the soldiers in combat. The soldier sneaking 40 winks, or 10 minutes, or whatever, is not reflected in the laboratory work, and as a consequence, we can't really take our literature, at least on sleep deprivation, and transfer it into combat settings. We think this is probably true for other stressors like fatigue as well as sleep deprivation. We can get some qualitative inferences but nothing quantitative at this time.

By the way, if anybody wishes to disagree and has data, I'd be delighted.

There is a sleep recovery curve for cognitive tasks. Using a logic task, from Haslam, we kept the person awake 96 hours and then allowed them partial opportunities for recovery; we get such a sleep recovery curve.

I looked at that and we were not completely delighted with it. What we were doing was administering a test immediately after the person awoke so to use this kind of thing in a combat model and talked about how performance deteriorates when we keep somebody awake, is not appropriate. It's good data, but it's not good combat data.

Now, it turns out if you want to find out about the effects of stressors in combat, and you go to the appropriate subject matter expert, you can find out fairly quickly he will produce testable hypotheses. They have a fairly consistent overall view of the importance of tasks and variables. Going to historical literature on the other hand, it's not sufficiently detailed to get human factors data out of it.

Let me give you some examples here. We talked with a retired Four Star General, whom I will not name, but who has experience in the Second World War as a company commander, battalion commander, and regimental S-3. We asked, "What is the effect of fatigue and sleep deprivation in combat?" He said, "Well, the thing you have to remember is your job as a platoon leader or company commander is to overcome that kind of thing." How do you do that? He recalled several instances, one of which he described as a river crossing, in which to get his troops across the river, he pointed a rifle at them and said, "I know you're tired, but you're gonna cross the river. You can stay here and take your chances, but if you don't cross, I'm going to shoot you here." That's an example of the kind of thing we very rarely find in the laboratory or the field experiment. But it points out a critical issue. It is the role of the small unit leader to manage the stress recovery process. It is the role of the small unit leader in the Army to make that small unit effective.

We got a chance to look at this hypothesis of fatigue and stress at the National Training Center. The comments I will make about what we saw there are general and, I think, fairly revealing. How many of you know about the National Training Center? One, two? The National Training Center is where the Army sends its battalions (actually they are going to start sending brigades) to operate in the field at Fort Irwin with Miles gear. They actually train against a very well trained outforce, equipped with Soviet or pseudo-Soviet equipment, fight Soviet doctrine and tactics. There is a lot of stress and

very few of them win against the outforce. They have to do in the field everything they would do in combat. It's not like the CPX; it's not like an FDX; they have to do things. We have hypothesized that in terms of getting human factors into our combat models at the squad, platoon, and battalion level, there were four things that were critical. The first thing is in terms of the outcome of a squad or platoon level engagement, and that's what a battalion battle is made up of; that initial conditions where the soldiers are on the ground as they encounter the threat, either in the offense or defense, pretty much determines the outcome of that fire fight or engagement. Those initial conditions are primarily determined by leadership and supervision--the company commander and his exec, the squad leader, and the platoon leader. The critical thing is the level of participation. I understand that SLA Marshall is now in disrepute, but he did say, I think, that only 10 to 15% of infantrymen fired in the Second World War; in Korea it was better. Strangely enough, you see basically that kind of thing happening at NTC, where there is no lethal threat. We don't know why, but it happens.

Finally, for those soldiers who choose to shoot and participate, there does not appear to be, in a fire fight at least, a major change in their performance levels. It doesn't deteriorate. Our subject matter experts made it quite clear to us that when the bullet flies by, you get very alert and you manage to shoot back fairly well. It's when the bullets are not flying that you fall asleep and forget to dig the foxhole or clean your rifle.

So, those four hypotheses are just to show you some of the things. Now, a tank has an effective range up to about 3,000 meters. If we describe the expected opening range we start with characteristics of their defensive positions, where they could open fire if they wanted to. The tankers pretty well exploited the capabilities of their system, and they chose defensive positions fairly well.

On the other hand, notice the following. We had 25 tanks, 12 integrated TOW vehicles (hammerhead vehicles), 20 or so Bradley fighting vehicles, an APC, and a bunch of M-13's. Ten of the 25 tanks, none of the Bradley fighting vehicles, and none of the M-13's were killed.

MALE VOICE: Of the ones that fired which were the ones that were killed? Is there a correlation?

DR. CHERRY: They both were, and yes, there is a correlation. There were the 12 tanks that fired no rounds. Several of them were killed before they chose to engage. Three tanks fired 2 to 3 rounds. Generally speaking, these are the ones that fired and got killed. Three tanks fired 31 and 46 rounds apiece. It looks good for the ace tankers. This is the company commander in a tank and his executive officer in another tank. He had a defensive position in which there were 14 vehicles sighted and the threat passed two battalions in front of him. He engaged, his exec engaged, and one other tank in the company engaged. He eventually got killed. He did some killing. He did not run his company. He never told the battalion commander what was going on. The battalion commander committed the reserve in the wrong axis, and the battalion got wiped. If you talk to me about human factors in combat and you want to talk to me about how well a guy fires the 120 or M-1 or how well he fires a TOW missile, I will tell you if I am going to use combat models to predict outcomes or use them to support training. I'm much more interested in this kind of behavior.

With regard to the ITV's, and the Long Range Antitank Weapons Systems, one guy got off two rounds, and two guys got off between 7 and 10 rounds. The rest of them didn't participate in the battle at all. It's not that the guys can't fire the TOW. They can. They're good. They know what range it has and their pretty good at gunnery. They have to be placed where they get a chance to fight.

Now I'll do some modeling and some operations research. Some of you will certainly be familiar with Fredrick Leinchester, who is the father of combat modeling. No one uses this anymore, but there are two important lessons there. The first is the alpha and beta which are typically the attrition rates. We model attrition in terms of how effective people are in delivering lethality with ground base weapons systems and how well they choose their routes of advance or defensive systems to reduce vulnerability. Those are prime tasks--acquire a target and pull the trigger--and there are some secondary tasks. I should point out that the attrition rate methodology used in the major Army models, the ones at Leavenworth and White Sands, and so forth, are in fact, based on task network analysis of the behavior of crewmen fighting the weapon system, and they have been that way for 20 years. Unfortunately, we have never been able to find the human factors data that describes deterioration or the effect of stress on those attrition rate coefficients. However, there is provision there to handle it if it is available. There is from the point of view of doing research on Army combat models something that is much more important--effectiveness in positioning forces. Do you ge



the platoon or the company in a position where it's going to engage? Do you lay them down on the ground where they are effective when they get a chance to fight? We need to know how many of them fight when they do get a chance. But the other thing that is important that comes out at the NTC is that what we are really talking about here is the number of people who get to fight in executing elements. These small groups that perform these tasks have a tremendous influence on who gets to fight at the platoon and company level. And, interestingly enough, you see at NTC tanks that don't go into battle because they don't have fuel; tanks that do go into battle but don't have any ammunition, and this is a training environment.

As far as stress and recovery goes, we did give some thought to how we would like to model it in combat models, and I think I can take back more from here than I can give in a sense. We think we need to look at baseline performance. We have to look at how deficits occur and capacity is restored. We think that a first cut at modeling is to deal with thresholds and levels of constant performance. We need to find out how our capacity to perform deteriorates and how it recovers; then we need to know about the role of the intangible factors, whether it's the leader who is good or the one who points a pistol at the guy and says, "I know you're tired, but you're going to cross the river now."

We think the performance levels can be reasonably modeled, and this is an abstract sort of thing. Under the impact of stress fairly constant performance levels deteriorate very sharply and eventually become non-performance. Here is where the soldier or the leader just refuses or cannot initiate the task that is necessary.

From the modeling point of view, we think we could treat the stress recovery process as one in which stress is applied and reserves deteriorate and when there is an opportunity to recover, get a recovery, and so forth. But this is purely and simply a modeling process. It has no real foundation, we think, in anything we have seen. We do think if you are going to talk about stress recovery in the Army combat situation that we will be dealing with points at which eventually somebody cannot perform and has to have a period in which they need not perform at all. It's not a question of deterioration; there has to be a period provided for them to restore their capability.

Based on what we saw at NTC in which the tankers who did fire, fired well, stress did not appear to have a major effect. For the combat model, we have to understand the behavior of the command control organizations at battalion and company level in planning preparation and execution. We need a baseline, and we really don't have it in the combat models. In our combat models almost everybody gets to fight. Everybody's topped up and everybody has done their preventive maintenance, and so forth. We need that baseline. NTC, it turns out in that sense, is a very valuable source of data for the Army, at least, as we observed things at NTC. The key issues are not the degree to which we are fatiguing people or stressing them; training and knowledge are key. The problem is whether or not the units know how to function and perform tactically in the situations in which they find themselves. We need to get a handle on stress recovery. I think once we get on with the baseline, stress recovery research exactly as this conference is addressing it has to be done. Until the literature provides a useful starting point, it does not provide us, as combat modelers at least, any answers.

MALE VOICE: What about cognition and memory?

DR. CHERRY: We wanted to look at an incoming soldier with capability and to assess memory capacity--short term, long term--and his ability to reason. There is a hidden agenda here which I did not mention. If you are familiar with the Army's MANPRINT Program, we were looking at what kind of command control equipment should be provided, and do we want to provide memory support or computer processing support. That's why that was done and perhaps it was somewhat artificial.

MALE VOICE: Especially at the unit level, I thought reconstituting stress recovery, or reorganizing implied reforming communications with the group and then doing the task we intended to do. This is a problem we have had in attempts to try to model continued combat.

DR. CHERRY: We haven't done a good job. Let me tell you what we asked if it would be possible. We can do what are called "focused rotations" at NTC. What we wanted to do was take tank crews and scramble them. If your tank crew becomes a casualty in mission segment #1, we'll let you participate in mission segment #2, but we will scramble the tank crew to see what happens with reconstitution. We wanted to look at not just rescrambling the tank crew, but also taking elements out of it, i.e., make them fight with only three and so forth. We haven't really got much data on that

reconstitution or reorganization process at all. I believe that it is very important. I think the effectiveness of these units and the ones that go to NTC, generally speaking, have been together for at least six to eight months by the time they get there. It is a function of that small group training and structure and stability. What's going to happen in combat, of course, somebody is going to get killed, and we are going to have shortages and reformed groups. The effectiveness of people after that first battle is probably going to be much reduced. But, I think I am as concerned about the small unit leaders as I am about the tank crews themselves. It's clear they have a very, very significant role in unit effectiveness.

MALE VOICE: You suggested in your remodeling of performance decrement and increased stress that there was a linear relationship between performance and increasing stress. I think conventional wisdom for 80 years or so is that this is an inverted U-shape function. Could you comment on that?

DR. CHERRY: First of all, the linear decline is not performance. It pertains to reservoirs, if you like, or capacity to perform. Our conjecture was that we could model stress. Now this is over the long term. It's not an instant in time when I am applying more and more stress; this is stress applied over a long term. We conjecture we could do a fairly good job of modeling it if we said that as stress accumulates and I force you to do a task over and over again, your performance stays fairly constant. Once I've exhausted a certain portion of your capacity, your performance drops down to another level, and then it drops down to another level. Now, from the point of view of combat modeling, if we really want to look at physical stress, lack of sleep, and so forth, our conjecture also is that what we really have to model is the failure of the guy to undertake a task. Not that his performance of a specific task deteriorates, rather than he fails to undertake that task, and then we get into a leadership sort of thing that says the leader, morale, etc., postpones the point at which his performance drops down like that. Such factors will enable him to operate under stress a little bit longer, but we're not saying there is a linear relationship in terms of instantaneous stress and performance as I add more and more. We really didn't address that. I may have misled you.

In looking at what happens at NTC and in talking to the subject matter experts, what we want to know is if the tank crew took two seconds longer to acquire a target; the tank crew went to the defensive position and coordinated with somebody to put a

berm out there; or that the tank crew did their preventive maintenance. Those are the things that appear to be more important. Once they see a target, they manage to engage fairly successfully.

MALE VOICE: How about the opposite of where under stress you do something you shouldn't? You say that sometimes they just don't perform; they don't do what they should. How about the opposite when they do something they shouldn't?

DR. CHERRY: You saw what happened with my company commander and my executive officer in that sort of thing. I would argue they did something they shouldn't. When we described that particular data and everything to General Glenn Otis, who is retired, his comment was, "Well, here's how I would handle it. I would give him a medal and I'd court martial him, but I'd give him the medal first." So why does that behavior take place? That guy is trained to fight his company. All of a sudden he is on his first rotation and here they come. He goes and engages and doesn't do the thing he was trained for and knows he should do. Typically--and this doesn't happen just once, it happens a lot--the comment you get from these guys is, "By the time I realized what I should be doing, the yellow light is on and that is the signal the outpour has hit them and they are dead." So that incorrect behavior is good and bad. We haven't worried about the Audie Murphys and the John Waynes yet, but I agree with you. We have to worry.

DR. GUNDERSON: Our next speaker will be Lieutenant Commander Frank Petho from OP-11B1. He will share with us some aspects of stress as seen from the top.

LCDR Frank C. Petho, MSC, USN  
Office of the Chief of Naval Operations, Washington, DC

LCDR PETHO: Good morning. I got a call about the middle of last week from Dr. Gunderson, and he asked if I'd share some informal comments with this group concerning the issue of stress, particularly its political dimensions. I'm here to tell you if you are looking for stressors, you take a mid-level OPNAV staffer and you ask him for some informal comments at a meeting like this--you're looking at stress.

To give you a little background on this issue, and to put it in proper context, back in late September, I got a call from Stan Collyer, ONT, who said, Frank, have you heard about this HASK thing and the APA thing? I said, No, I hadn't, but I would take a look, and we did and sure enough all the wormholes opened up. I called the APA and talked to their lobbyist about what was happening, and sure enough the APA was going to use the VINCENNES incident to highlight the requirement, need or desirability, depending on your camp, of more research in decision making stress and what have you. So the Navy pow-wowed, and we had our representatives there and the APA had their representatives. The meeting was a success from everything I heard. I was not there. But, once again, at the mid-level, action officer level, my interest was peaked a little bit later on when the task group came down to SECNAV and said "I want you to take a look at various aspects of stress, specifically in surface systems." To make a very long story short, it trickled down the chain of command and a VINCENNES review group panel was established and headed up by Vice Admiral Nyquist, who is OP-03 Surface Warfare. Part and parcel to that review group was a subgroup on training and stress factors which was headed up by Vice Admiral Boorda, who is OP-01. One afternoon, a Thursday afternoon, I was called in by someone and told what we need to do is develop a position for the upcoming review. What I want you to do is address human stress information processing, training and so on, and put together a pitch. I want you to brief me at 2300 on Monday. That was on a Thursday. So I said, 'Roger that' and he said, you're the staff psychologist, you should be able to do that. So, I ran (we're all collocated in the same area) down the passageway, and as those who have worked in Wing 8 will know, I ran down to the clinical types and asked for help and they provided solace. I talked to everybody I could talk to about this. Luckily, Jim McGrath was in

town a couple days early; Jim McMichael and a whole bunch of other resources, and then Thursday afternoon I figured I better talk to the people that count. I walked down, and as you know the Chief of Chaplains is also on that deck, and I walked down there and I'm here to tell you they do have some insight in how people go about dealing with stress.

To make a very long story short, I worked that weekend on putting together this pitch. I decided after all the input had come in I would go to the horse's mouth, if you will, and get the HASK testimony that the APA psychologist gave. I looked at that, studied it, and pulled out stuff I thought I could convey to a flag level group and a series of recommendations that would prevail.

I briefed. By the way, that weekend I was so preoccupied trying to figure out what I could say about stress, how do people respond to stress in terms of information processing, etc., my short-term memory went. I was focusing on peripheral tasks, and it was terrible. In fact, I had to deal with that Sunday in church. I was the only one singing: "What a Friend We Have in AEGIS."

Monday night we gave the brief to what is called the murder board. It's the Navy equivalent of a dissertation defense, and it went over rather well. In fact, it generated a lot of discussion and a lot of sea stories emanated.

The next day, it was "murder boarded" by Admiral Boorda's admirals, which include subsurface and surface as well as air. He wanted to get input from everyone. That was successful as well and the response I got was that you don't have to make any changes, give it as is.

That Friday, the brief was given to the flag level group, the review group itself, which consisted of five vice admirals, a lot of rear admirals, who effectively represented the surface and their interests in this particular issue.

Let me tell you a little bit of what I said to these people. Basically, our task which came down from Sect F was to take a look at this whole VINCENNES situation and recommend what kind of research we need in order to understand what went on or what were the stressors. Right out of the box, we basically said we really don't have to

look for much more research on this issue. We tried to highlight what was going on there, and these are the bullets that appeared on the slide.

A team of 30 to 35 highly trained men, operating a complex and sophisticated system make sense of sometimes confusing, competing and complex audio and visual systems; facing a series of decisions on those systems while under the press of time; engaged in hostilities and the changing threat scenario under exposure to injury, disfigurement and death. I'm not sure we need to go too much further into what precipitated the stress.

After that, we talked about certain instances. I went to the aviation literature, the nuclear literature as well as the industrial literature to look at things that had happened out there that we could use to highlight the effects of stress on human information processing in this particular group. We talked about the China Air 747 that lost 30,000 feet over the Pacific because of certain things; we talked about the L1011 that crashed in the Everglades in Florida for human-related error. We talked, and by the way Westinghouse came through with some excellent data from France and their own data, that showed that roughly 50% of the incidents were related to human factor issues. We talked about Chernobyl; we talked about Three Mile Island, and we talked about the industrial complex, BoFall. Basically, we said you can design a system that is fully linear. The engineers do that and I was talking to a group of engineers, but when you introduce the human into it, I used the term when you start using meat servos, things go down hill. The bottom line in talking about these different areas, is that for the first time, the surface Navy has fielded a platform that rivals all others in the terms of demands placed on the operator in that particular system. We're talking about AEGIS. AEGIS is the future. AEGIS is here now, but it's going to go out into a lot of other platforms. The point is, that these people, 30 to 35 people, operating in concert in that system, represent a platform that heretofore has not been looked at in terms of human factors.

Then I talked about how stress impacts decision making. I went through it very rapidly, and we talked about what we are going to do about it. because the bottom line of the briefing was that we had to come up with a series of recommendations. The first thing we said was regarding testing. We were asked to specifically address testing, and we said it would be better to put our assets somewhere other than in testing. Quite frankly, we can test all the OSs, radio men and sonar men on personality correlates, but the bottom line is the Navy is facing a terrible manpower shortage and a lot of trouble

with training. Pre-selection or classification works well with adequate manpower pools, but not in today's environment. We talked about training as a second alternative, and we said we could help the situation with a training dimension. We talked about drill and the requirement for discipline, adherence to pre-established procedures, checklists, and what have you.

We also talked about pre-conditioning. The aviation community, for example, preconditions a lot of the community with controlled exposures to stress. Anybody who has gone through the Universal Underwater Egress System, where you are turned upside down underwater, blindfolded, and you have to escape, has an idea of what you are going to do in that particular environment. We talked about the fire fighting trainers. We talked about escape in invasion, cold water training, altitude training, damage control and flooded compartments. There are a lot of examples out there of how we go about preconditioning our crews. The point led up to why aren't we doing this with stress training. We talked about compensation, and our bottom line here was that you can tell people how they are probably going to behave under stressful situations. If you can tell them that, why don't we? We recommended developing a stand up lecture to be given in various classrooms across the Navy that actually talks of the effects of stress on human information processing.

On another dimension, we highlighted the requirement for more human engineering factors in design. Right now, OP-01 has taken for action that particular cause. My billet is new. I was brought on to do precisely that. I have been there for about 18 to 20 months, and we're making inroads in the acquisition community to ensure that human engineering is incorporated in design as early as possible. Where we are coming from in the OP-01 arena is that if you don't have proper design up front, it's going to cost you later in manpower and training. That was the pitch we made to the VINCENNES group as well.

**MALE VOICE:** Isn't that already a requirement?

**LCDR PETHO:** Sure. It's covered by paperwork all over the place. In fact, we've got a new DOD directive right now. But, the fact is, there is a chasm between all the things that tell you to do it and whether or not you are going to do it.



Finally, we recommend an increase in human factors R&D; specifically 6.3. Status: Right now we have tasked NOSC and NPRDC to begin working on a lecture that addresses the effects of stress on information processing. We originally focused or intended to give this to the Prospective CO-XO (PCO,PXO) School at Newport this month. There has been a change. What we are doing now is incorporating those findings, those lessons learned, into the Operations Specialist A (OSA) School at Norfolk and out here, and we hope to have that on line by September. They are due to give us a plan of action of milestones in a couple of weeks, but we are hopefully going to have that on line by the end of September. We also are going to step it out into PCOPXO school at Newport. The next class is the middle of April and we will be there for that. Step it out into Department Head school at Surface Warfare Officer School (SWOS) as well as the first level of SWOS training and then on out from there. Our problem now is taking what we know about it and tailoring it to specific audiences. For instance, I got a call from the OiC at A school, the OSA school at Norfolk. They said "Doc, this is great, this is wonderful, but how are you going to do it?" I said "we have tailored this lecture to PCOPXO School." There was a long pause on the line, and they said "but doc, these people I've got in my classroom are still processing civilian chow. What are you going to talk about in the PCOPXO?" The bottom line is we are going to have a lot of tailoring to do. We want to tailor it by work station as well as individual ratings.

Lastly, there was a comment earlier about can you use a simulation to induce levels of stress that approach the criteria and environment of combat. I guess we talked about this at length at the review group, and there are professional sanctions in highly motivated organizations that can really induce an awful lot of stress, to the extent that there are some pretty nasty levels of stress that can be induced and that is being looked at. I'm going to end with that. Are there any questions? I'd be more than happy to answer them.

MALE VOICE: Particularly in the VINCENNES case, where the system design breaks down, we don't seem to have much stuff in it for preliminary classification problems, particularly three-way classifications. Has anybody thought about that?

LCDR PETHO: Yes sir, as a matter of fact, one of our tasks out of OP-01 and CNET is to specifically upgrade Identify Friend or Foe training in the OS continuum. The lessons learned, stuff I've talked about here in terms of cognitive impact of stress

are going to be folded into that particular segment of the OS curriculum. We're working on it.

MALE VOICE: We take these complex systems and then adapt the people to them. I think maybe sooner or later, we have to worry about developing systems that are designed to enhance capabilities rather than the other way around.

LCDR PETHO: Sir, in that regard, 29 December, Sect F directive came out on Manpower, Personnel and Training, and Safety in Acquisition Systems. It's basically forcing MANPRINT on everybody. Okay? OP-11 has for action to write the SECNAV instructions. We have two drafts of it already. The OPNAV instructions are being written, and we're looking at a drop dead of probably a month to have both instructions out and that will specifically address those issues.

MALE VOICE: I'm surprised with the response to this. One question: Was there any plan to build an experimental component into this lecture or any training in coping with stress?

LCDR PETHO: No, we're going to evolve to that. This is a new ball game. There are people at very high levels talking about introducing this type of stuff in a lot of different places. What I have heard here this morning substantiates the Army literature for small group performance and aviation high tech. The point is the AEGIS system in the surface community has developed and deployed this particular system that really is a hybrid of both of those research thrusts. We're groping around and I think we are going to learn an awful lot as we do it. In point of fact, when I give this to PCOPXO, they're going to send an 07 with me just to cover me because they said if they just saw a psychologist standing up there and start talking about it, there is no telling what would happen to you.

DR. ZORNETZER: As the lucky fellow who had to represent the DOD for HASC, one of the things they were very concerned about was what is the Navy doing and what kinds of resources are we putting into all these areas. You mentioned before in your comments that one of the recommendations of your committee was to increase human factors R&D for 6.3 levels. What about other levels? I'm thinking very fundamental. Have you addressed any of those issues as well?

LCDR PETHO: That was my program. I couldn't let that audience go. No, I think that is part of the plan. Given the budget environment today it's going to be a hard row, but Stan and I have been talking about that and we will go in together on it when we go. That's it. Thank you.

DR. GUNDERSON: Incidentally we have with us at least two members who were on the APA panel testifying before the Armed Services Committee. I'm going to ask them to comment on LCDR Petho's presentation.

DR. HELMREICH: Well, I'm impressed with the response. It's very nicely put together. I feel good because we were trying to make some constructive comments on the issue and somebody was listening. It never happens to psychologists.

DR. DOBIE: Just a couple of observations. Going back over the years when I was involved in British Air Force studies, I noticed that instrument flying training as it evolved went the opposite way. I think wrongly. In other words, people were put under the hood to learn basic instruments. I'm quite sure although they may have gotten some reinforcement in training effectiveness, we were sadly lacking in the ability to handle the other stressors, because they were put in this little cocoon. It would have been much better had they been given the maximum stressors and taught how to selectively address the things that were important and things that weren't important and allow them to deal with that. The other observation is that I believe that training should finish up in a positive way so you can teach the guy if he does the right thing he can come out of it. I think the idea, for example, of getting disorientation experiences and then when the guy throws up the hood, the instructor says, there, you see what I mean. You were upside down and descending on fire. I think it's much more important to finish up teaching by helping him get out of this and not just demolishing him at the end of his training session.

LCDR PETHO: I agree wholeheartedly. The only thing would be selection that would put him there and once again it is going to be a series. Basically a laboratory experience within the classroom. Now, how we are going to do that and put it together remains to be seen. We have some video footage back from CIC operations where you could stop and say, see, this is what I'm talking about. Also, we have a lot of interesting interactive video where a Tactical Action Officer (TAO) would be part of it. By the way we got this idea from the Medical Department which is using it for combat surgery.

One of the people came over to our place and said I just saw one of the greatest things over in MEDCOM. Why don't we do it for TAO training? So, we are looking at that as well. It's got to be a good experience in the classroom to highlight these effects; otherwise, it's just going to pass.

MALE VOICE: It's a single piece of knowledge you get in one episode and retrieve during a much later drill or real circumstance, which has got reinforcing effects such as the engage and fire, engage and fire. Would you expect somebody to say, oh, I remember 18 months ago they said you've got to worry about what you're shooting at?

LCDR PETHO: To the extent we systematically implement this whole range of effort, throughout all these various course and at all levels of command.

MALE VOICE: You think it will become part of the drill?

LCDR PETHO: Yes sir.

MALE VOICE: Okay.

LCDR PETHO: At both forums, the murder board and OP-01, as well as the actual briefing, the amount of sea stories generated was incredible. It cannot be a sterile, stand up lecture. We have to get at those sea stories, because we're talking at the battle group and command levels. We want them to say, "Hey, that happened to me." So, it happens at all different levels and it has to be an integrated approach; where it is just another lecture, it's lost.

MALE VOICE: My impression has been that the RAF has probably got the best training program. I'd like to plug a conference coming up in May, in San Antonio. The National Security Industrial Association (NSIA) is having a conference on environmental and safety in the acquisition process. Keynote speaker will be Captain Bob Chaney here from the Naval Health Research Center, but also from the Navy, we will have CNET Vice Admiral Fisher, Admiral Secrest, and the Commanding Officer of the AEGIS Training Center, Captain Margolis. It should be a lively conference, so you might want to consider that in San Antonio, May 9-11.

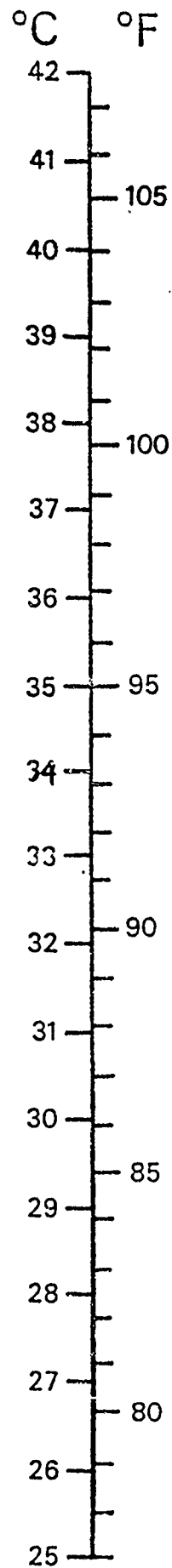
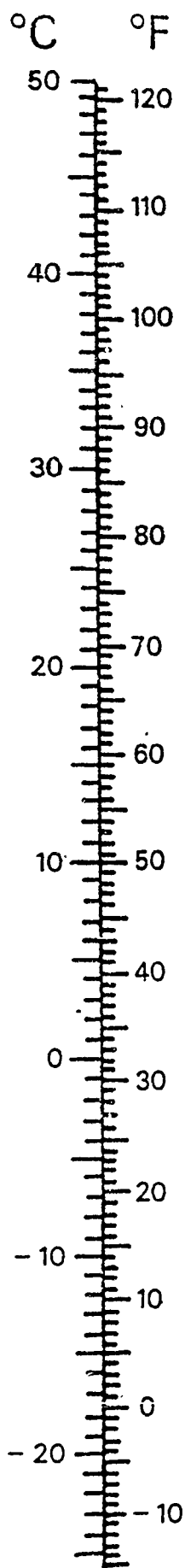
DR. GUNDERSON: Dr. Hal Goforth will be the first NHRC investigator to review work in his area of expertise. He will discuss the effects of cold stress upon Special Warfare personnel. Hal's combined field and simulation approach appears compatible with model development.

Harold W. Goforth, Jr., Ph.D.  
Operational Performance Department, NHRC

DR. GOFORTH: I have the pleasure of being the first in a series of researchers from NHRC who will address various thermal stress issues. My topic involves cold water stress experienced by a subgroup of SEAL personnel from the Naval Special Warfare Command. These SEALs are operators of the SEAL Delivery Vehicle (SDV). I can't discuss the technical aspects of an SDV because its mission-related performance capabilities and many of its components are classified. However, I can describe the SDV as a wet submarine operated by a pilot and a navigator which transports a classified number of passengers. The SDV pilot and navigator function much like the cockpit crew of an aircraft, communicating critical information as they fly the craft, while the passengers remain relatively passive. The water temperatures they will be exposed to at the contingency targets are quite low (0-2° C).

It's appropriate at this point to view figure 1, the nomogram for converting temperatures from degrees Centigrade to Fahrenheit. Since other thermal stress speakers will refer to degrees in Centigrade, I suggest you memorize this chart. The conversion equation is:  $\text{degrees C} \times 1.8 + 32 = \text{degrees F}$ . Later today I plan to test your memory after a six-hour exposure to a combination of stressors (e.g., high ambient temperature, inactivity, elevated levels of caffeine, and fluctuating blood glucose levels) by asking you to repeat this equation.

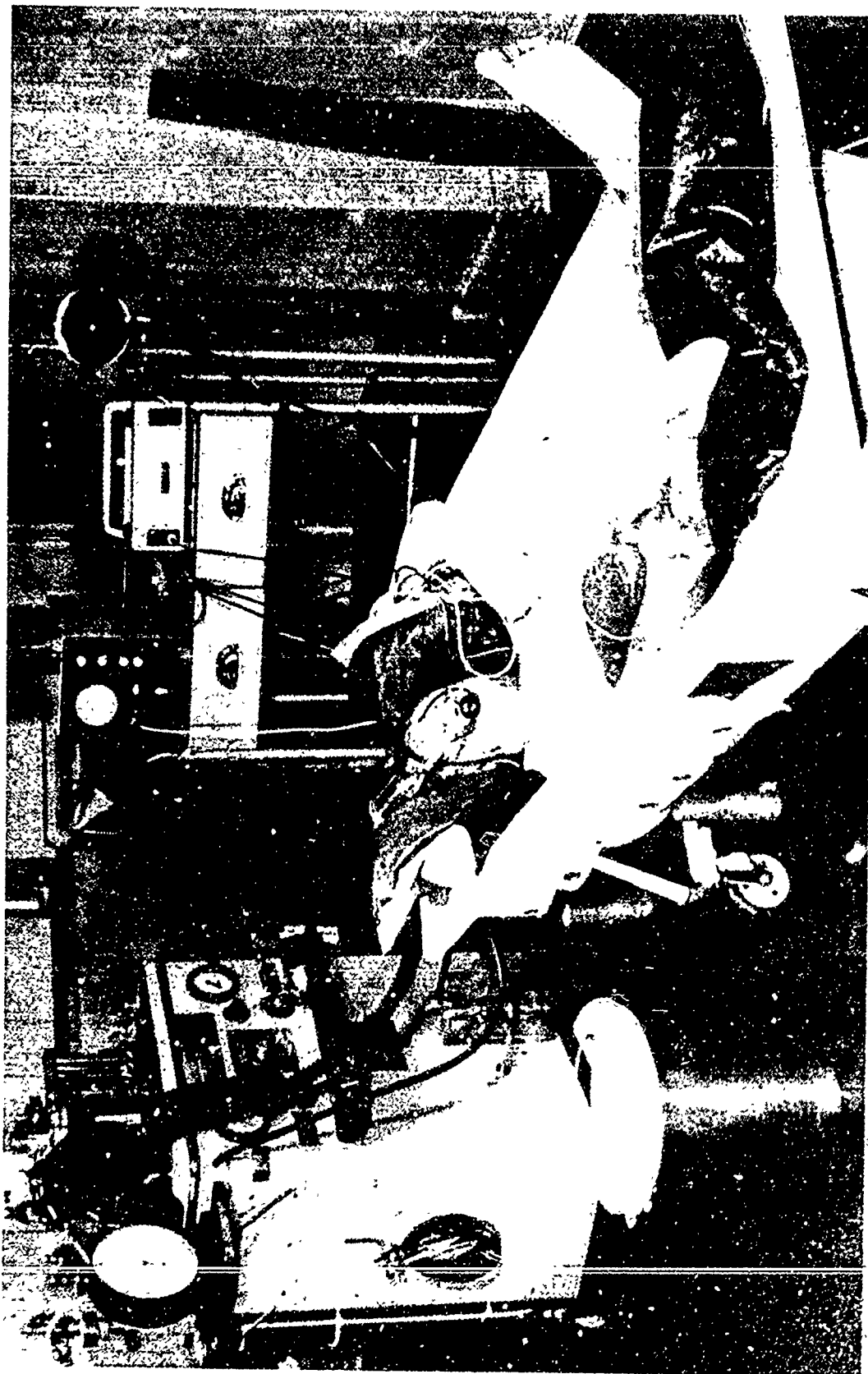
Unlike the majority of cold water studies conducted with animals or humans, suspended/sitting in a hammock clad only in a bathing suit, our subjects (SEALs) wear thermal undergarments and dry suits. Furthermore, our laboratory has determined the profile of an average SEAL (figure 2) which differs from most previous cold study volunteers. An average SEAL is 26 years old, 176 lbs., 70 inches, 14/5 body fat, quite compact and muscular, with a VO2 max of 57 ml/kgX min. Note the difference between a SEAL (figures 3 & 4) and the typical cold study subject (figure 5).



Fahrenheit/Centigrade temperature conversion chart

# SDVT-ONE PERSONNEL PROFILE SUMMARY

<u>CHARATERISTIC</u>	<u>N</u>	<u>MEAN</u>	<u>SD</u>	<u>RANGE</u>
AGE (YR)	22	26.5	4.4	20-36
HT. (IN)	22	69.5	2.0	64.0-72.3
WT. (LBS)	22	175.5	22.7	121.5-227.5
BODY FAT (%)	22	13.9	3.5	8.57-25.98
HEART RATE REST	16	60.9	7.2	53-80
HEART RATE MAX	16	194	15.8	182-205
SBP REST	16	116	16.0	100-162
DBP REST	16	81	11.8	64-116
VO2 MAX (ML/KG*MIN)	16	57	7.8	36-66
<u>BLOOD PROFILE</u>				
GLU	13	86.4	9.1	72-104
CHOL	13	209.2	36.9	170-285
HDL	14	48.2	9.2	32-66
TOTAL/HDL	13	4.2	1.4	2.7-7.5
TRIG	13	93.3	26.9	55-161
HCT	14	43.7	1.6	42.4-45.5
HBT	14	15.1	.50	14.6-15.6
TP	13	7.2	.39	6.6-7.9
ALBU	13	4.9	.23	4.5-5.1



An early method for inducing hypothermia for surgical operations by surface cooling with the patient immersed in ice-water. It was said that, with correct management, the risk of frostbite was negligible. (Reproduced by courtesy of Mr. Charles Drew, published in *British Medical Bulletin* 17, 32 (1961).)







Since Fleet commanders are not constrained by the regulations and guidelines of a Committee for the Protection of Human Subjects (CPHS), they can require SEALs to perform prolonged cold exposure dives during field exercises. Monitoring SDV operators during field exercises allows us to obtain data that would be impossible to replicate in the laboratory. For this reason much of our data has been collected during field exercises. An added advantage of field studies is that they contain an element of uncertainty and risk because failures of critical equipment and subsystems can create real emergencies which add to the overall mission stress.

It's impossible in the time allowed to review in detail the full range of physiological responses of divers during prolonged cold exposure; therefore, I have chosen to address only the more important effects of acute and chronic exposure. During our studies divers have achieved core (rectal) temperatures of 35-36° C which is considered to be mild hypothermia. The dominant acute physiologic response to these exposures is peripheral vasoconstriction, accompanied by diuresis and dehydration. Other responses (figure 6) include: decreased muscle function, shivering, increased oxygen consumption at rest and a decrease in maximum oxygen uptake capacity. Additionally, there are metabolic effects including shifts in normal levels and substrate utilization. Pain and discomfort also occur and contribute to decrements in performance of a variety of psychomotor and cognitive tasks.

Following chronic cold exposure (weeks-months) subjects are reported to exhibit several physiological modifications considered by most researchers to represent habituation, rather than true acclimation. These adaptations merely allow the individual to tolerate a colder core temperature. Because they do not represent an increased capacity to generate heat and delay or prevent the drop in core temperature, such adaptations are considered habituation.

Before proceeding I should point out that figures 6 & 7 contain a summary of findings from studies of subjects (i.e., medical students, physical education students and/or white rats) exposed to cold water without the benefit of thermal protection (insulated dry suits). The physiological responses of these subjects occur under a commonly used set of experimental laboratory conditions quite different from the diver in the field. One must keep in mind that the rate of temperature drop, intensity of shivering, temperature and humidity of breathing medium, etc., differed significantly

# **EFFECTS OF COLD ON DIVERS**

## **ACUTE:**

1. Vasoconstriction - decreased peripheral blood flow, w/ CVD.
2. Diuresis - increased urine flow, electrolyte and body water (plasma volume) losses.
3. Decreased muscle function - decreased manual dexterity and muscular power.
4. Shivering - early onset and intense
5. Increased Oxygen Consumption - 1-2X from shivering & Decreased VO<sub>2</sub>max
6. Metabolic - decreased glycogen, increased lactate accumulation rate & fat metabolism.
7. Discomfort and pain.
8. Decreased cognitive performance

# **EFFECTS OF COLD ON DIVERS**

## **CHRONIC:**

1. Increased effectiveness of vasoconstriction (thicker layer of shell insulation).
2. Increased Shivering threshold & decreased intensity.
3. Decreased Oxygen Consumption - due to decreased shivering intensity.
4. Metabolic changes - glycogen sparing due to enhanced fat metabolism.
5. Decreased discomfort and pain - increased tolerance of a lower core temperature (i.e., Habituation to cold).
6. Improved cardiovascular & CIVD response.

from divers breathing dry, compressed air and wearing insulated dry suits. Therefore, the direct relevance of these studies to SEAL/SDV operators may be limited.

Figure 7 is a summary of the chronic adaptations to cold: an increased thickness of the insulative shell surrounding the body, increased shivering threshold coupled with decreased shivering intensity. As a result of the decrease in shivering intensity, the resting oxygen consumption decreases accordingly. Perceived pain and discomfort decrease and interfere less with performance of psychomotor and cognitive tasks. The cardiovascular response to cold improves with more effective cold-induced vasodilation (CIVD).

Figure 8 lists the critical factors (or model variables) which affect the diver's response to cold. One may wonder why a physiologist places equipment at the top of such a list? You may recall the earlier presenter who stressed the importance of proper performance and maintenance of the tank equipment in determining tank crew performance. The same relationship exists between the performance of the SDV, its subsystems, dry suits and related diving equipment and SDV operator's performance. Equipment performance, therefore, represents a critical variable to include in a model to predict SDV operator/diver performance. The other factors in this list are not necessarily listed in order of priority. Body type or linearity (surface to mass ratio), body fat, and muscle mass are important variables affecting body cooling rate, insulation and heat production.

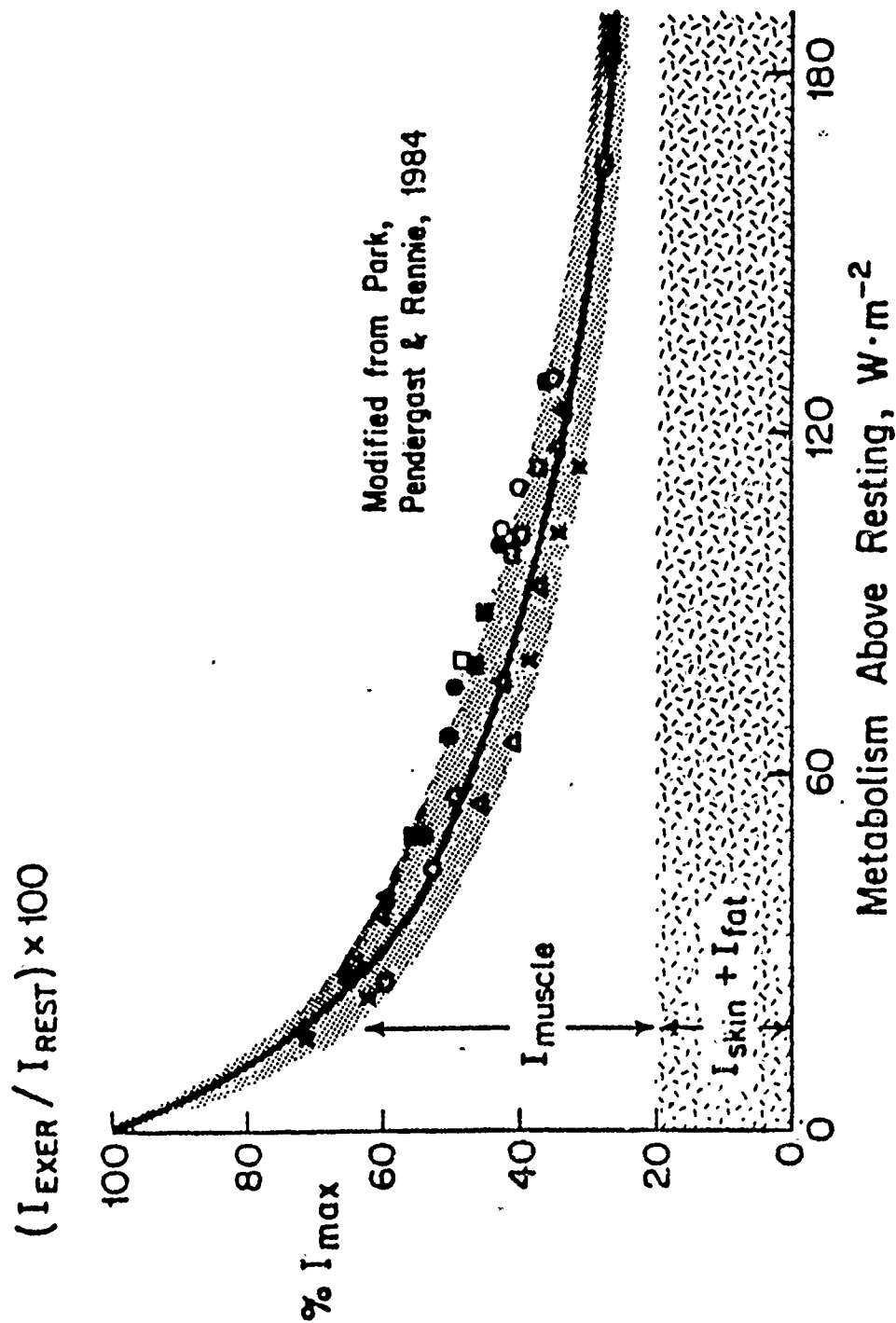
Activity level and work-rest cycles are very important because of their effect on skin and muscle blood flow and metabolic heat production. SDV operators are required to remain passive for several hours then become relatively active for a couple of hours and return to a passive state again for several hours. Currently our understanding of the effects of intermittent low and high intensity exercise upon the thermal status of divers wearing insulated dry suit systems is quite limited. A number of work-rest cycles could be modeled to predict the thermal responses of divers to a variety of selected mission scenarios.

The characteristics of the breathing medium can be a very important variable because of its effect on body heat loss and dehydration. Cold, low density, dry gas mixtures will cool and dehydrate the diver significantly faster than warm, moist air. The initial hydration status and rehydration during the mission affects the diver's

# **FACTORS AFFECTING DIVER RESPONSE TO COLD**

## **Potential Model Variables**

1. Equipment type and performance
2. Body type - (linearity = surface:volume ratio)
3. Body fat and muscle mass - insulation
4. Activity level - metabolic heat & blood flow
5. Breathing medium - it's temperature & humidity
6. Hydration status - body fluid levels (PV)
7. Nutritional status - liver & muscle glycogen
8. Drug intake - caffeine, nicotine, alcohol, etc.
9. Level and type of physical fitness - aerobic
10. Degree and recency of cold exposure
11. Degree of fatigue and sleep deprivation
12. Rate of cooling - peripheral and central
13. Experience with manual tasks in cold water



Normalized overall tissue insulation (as percent  $I_{max}$ ) as a function of metabolism above resting. Data are from seven male subjects.



## **INPUT DATA FOR MODEL DEVELOPMENT**

### **Environmental:**

- 1. Water temp.**
- 2. Exposure duration**
- 3. Thermal protection system (CLO values)**
- 4. Breathing medium (temp., humidity & density)**

### **Physiological:**

- 1. Activity level (Watts)**
- 2. Body mass (surface area:mass ratio)**
- 3. Subcutaneous fat (mean skinfold thickness)**
- 4. Nutritional status (36hr dietary history)**
- 5. Hydration status (total body H<sub>2</sub>O & PV level)**
- 6. Deep body & mean skin temps (core/extremity)**
- 7. Drug intake history**
- 8. Cold habituation**
- 9. Physical conditioning**

## **INPUT DATA FOR MODEL DEVELOPMENT**

### **Mission Requirements:**

- 1. Load carried or towed while swimming**
- 2. Rate of Transport**
- 3. Cold-wet and cold-dry durations & transitions**
- 4. Clandestine/ tactical requirements**
- 5. Work-rest cycle**
- 6. Additional mission specific data**

plasma volume levels and circulatory capacity. Nutritional status affects energy substrate utilization and liver and muscle glycogen levels which in turn affect physical and cognitive performance. The pre-mission nutritional status of SEALs and its effect on diver performance received command attention in 1986 following a hypothermic drowning incident. This event involved poor judgment by an SDV operator exposed to a complex set of stressors including hypothermia, hypoxia, lack of sleep and inadequate nutrition.

This incident initiated a tasking letter from NAVSPECWARCOM to the Office of Naval Technology (ONT) requesting Medical Research and Development Command (MED R&D) to conduct research to determine the effects of these stressors upon SEAL mission performance.

Other factors to consider include the diver's level and type of physical fitness, degree and recency of cold exposure, level of fatigue, drug intake (nicotine, caffeine), rate and degree of central and peripheral cooling, and last but not least, the level of experience or practice performing manual tasks under cold conditions.

Figure 9 demonstrates the drastic loss of muscle insulation during exercise at work loads 0-180 Watts/M<sup>2</sup>. A tragic example of this occurred recently when a highly motivated SEAL trainee died of hypothermia at the end of a five-hour open ocean swim in 12° C water. All attempts to revive him in the field and hospital were unsuccessful. Hypothermia during SEAL training represents a real world problem for SPECWAR since prolonged intense exercise in cold water creates high muscle blood flow, loss of muscle insulation, high heat flux and ultimately hypothermia.

Figures 10 & 11 contain recommended input factors for developing a model which would address performance of SPECWAR personnel in thermal stress environments. These inputs are grouped as environmental, physiological or mission related.

Environmental/equipment inputs are: water and air temperatures, exposure duration, thermal protection equipment, breathing apparatus and medium. Other mission specific inputs should also be included in this category.

Physiological inputs should include: subcutaneous fat, muscle mass, body type, nutritional status (pre-mission diet), hydration status, deep and skin temperatures, and intake of legal (caffeine, nicotine and OTC) drugs. From our mission analysis studies we have determined that a number of SEALs are using over-the-counter (OTC) drugs which are contraindicated for diving and cold tolerance. NHRC is concluding data collection to document the physical training schedules of individual SEALs and platoons. Preliminary results indicate that once SEAL trainees graduate from BUD/S, most of their physical training occurs as a result of their own initiative rather than platoon leaders.

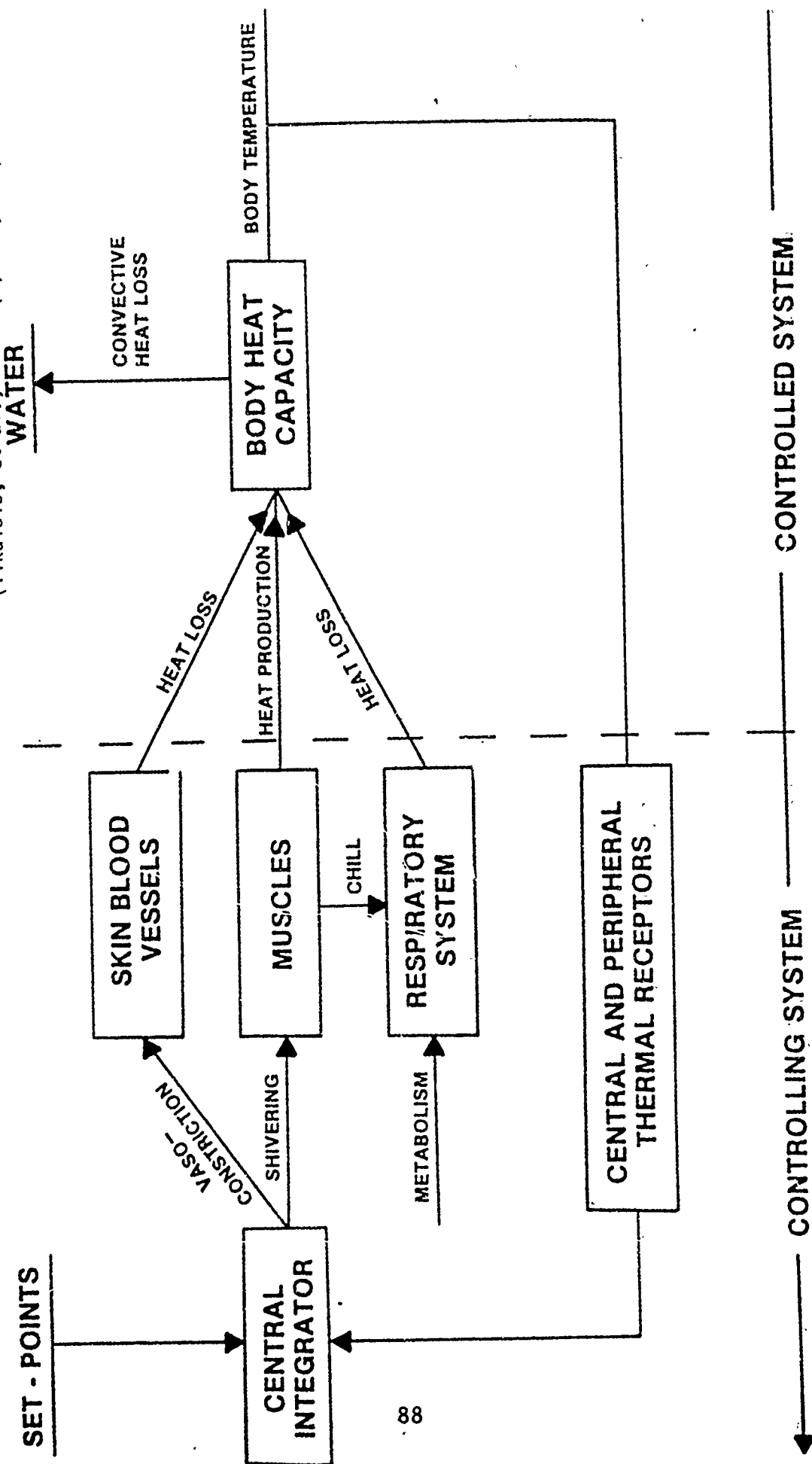
Mission descriptions and their physical demands have been more difficult to obtain partially because of the classified nature of the missions and the reluctance of SEALs to discuss details until they develop trust with the researcher. However, once the proper relationship is established it's possible to go on mission exercises and collect the required data. Such data include loads carried, rate and distance transported, exposure durations, transitions, work/rest cycles, and additional mission specific information that is required for any working model.

Figure 12 shows an existing model for thermoregulation during cold water immersion of "RESTING NUDE HUMAN". This diagram demonstrates that useful models already exist and provides a basic framework on which to begin. However, the majority of primary data used to run existing models are, to a large degree, inappropriate for an equivalent thermoregulatory model for SEAL divers. To emphasize this point, figure 13 shows the estimated survival times of humans during varying periods of cold water immersion. The shaded area (well into the lethal zone) represents the combinations of temperatures (0-5° C) and durations (6-10 hrs) experienced during SEAL mission exercises. Obviously such charts do not apply to SEALs wearing insulated dry suits; nevertheless, there are medical and tactical reasons to establish operating limits for SEALs.

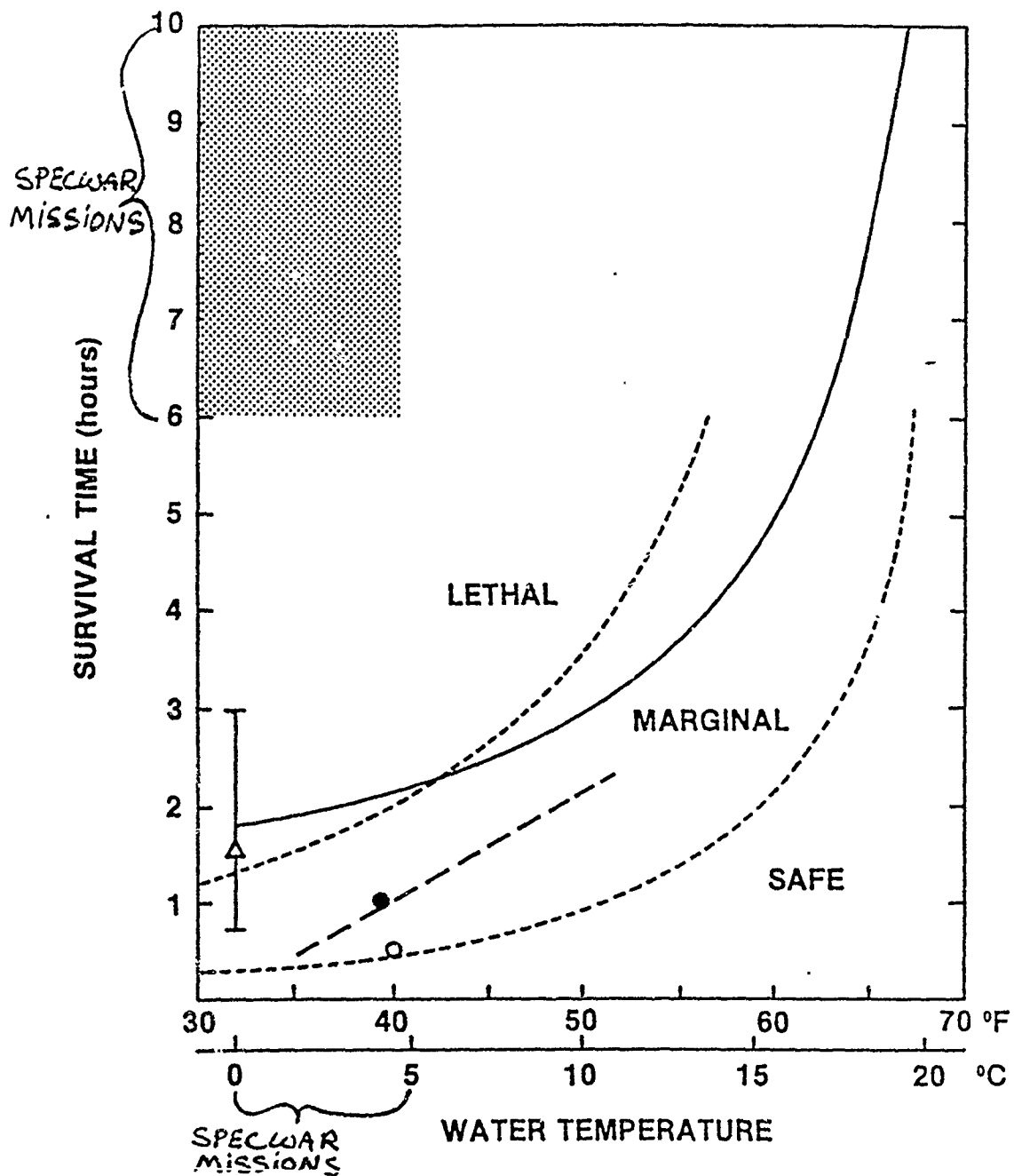
Figure 14 is a summary of the NHRC databases, their sources and measures taken of SEALs during various exercises. To date we have been on 16 SDV cold water (3-5° C) mission exercises and instrumented quite a few operators/divers. The measures taken were designed to quantify the divers' physiological responses to the environmental and physical demands of these mission exercises. We have also obtained control and pre-mission dietary records in conjunction with pre- and post-mission biomedical/mission description questionnaires. Using a battery of tests and measures in our laboratory

# THERMOREGULATORY MODEL FOR WATER IMMERSION

(Tikuissis, et al., JAP 64(2):719, 1988)



Simplified block diagram of thermoregulation of resting, nude humans totally immersed in cold water. CHILL, is metabolic output in response to the cold stress.



Estimated survival time during immersion in water of varying temperatures.  
(Modified from Hayward (68)).

# **Current Database**

## **Sources:**

- 16 SDV/DDS Field Battle Problems (52 Operators)
- 8 SEAL Exercise Missions (39 SEAL Operators)
- 3 SDV Trainer Studies (16 SDV Operators)
- 2 Cold Water Tank Studies (4 EOD Divers)

## **Measures:**

Questionnaires - Biomedical, Pre- and Post-mission  
                                - Psychological

Diet Records

Thermal + ECG Sensors

Body Weight Changes

Blood and Urine samples

Muscle Function Tests

Laboratory Tests and Measures

we've attempted to establish the physical, hematological and psychological profile of a SEAL based on a sample size of 48. In all we have collected over five liters of blood and 100 liters of urine, including selected physical and hematological parameters for 22 SDV operators, a representative subgroup of SEALs. The complete database includes similar data on BUD/S trainees and other SEAL team members. These data are currently available for use in model development, testing and validation. In a later presentation, Dr. Hodgdon will demonstrate the potential use of these data with an existing load carriage model.

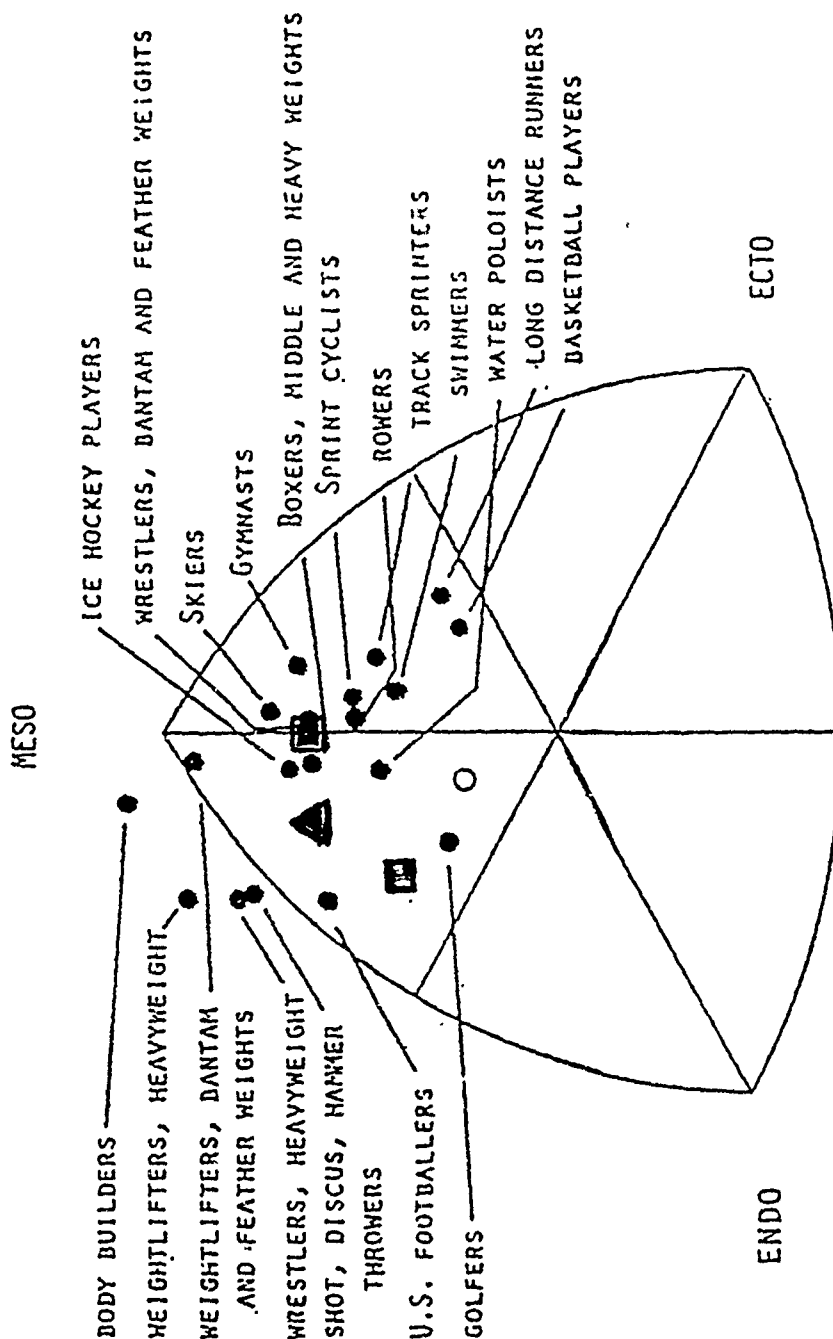
Figure 15 is a somatochart showing the body type of SEALs, SEAL trainees, and outstanding competitive athletes (Olympians). This plot has three axes representing: linearity (height: weight ratio), adiposity (percent body fat), and muscularity. The somatochart was developed by Drs. Carter and Heath who have characterized large numbers of Olympic and other top athletes. One can see from the SEALs' position on the somatochart that they are quite muscular, have moderate adiposity (body fat=14%) and are short and stocky (low linearity). The lack of linearity and high muscularity are advantageous for cold water tolerance. Figure 16 shows the rate and degree of cooling experience by SEALs wearing insulated dry suits, which is unlike that experienced by the typical lightly-clad, cold water subject.

Earlier I stressed the importance of equipment performance and its effect on SEAL mission performance. In figure 17 one can see that six of 16 missions were aborted due to flooding of dry suits. An additional two of 16 were aborted due to diving equipment problems, resulting in a total of eight of 16 mission exercises aborted due to equipment failures. With clearly 50% of the missions unable to be completed, equipment performance is a major concern of the SDV Team's Commanding Officer. These data have provided fleet commanders with the necessary documentation to effect changes in the design, development, testing and support of critical SDV mission equipment coming from contractors and R&D laboratories.

Improperly functioning thermal protection systems affect researchers ability to monitor the true effects of prolonged cold dives. We would like to document the thermal profile of divers during a full mission profile without dry suit leaks or flooding. The problems associated with the urinary collection device and overboard discharge system have caused divers to develop novel and inappropriate solutions. Malfunctioning urine systems leave the diver with the dilemma of avoiding fluids and



# SOMATOCHART WITH SELECTED SOMATOPLOTS



● Mean somatoplots of selected groups of outstanding male athletes (Carter, 1978)

○ Mean somatoplot of non-athlete males (Carter, 1981)     3.5 - 4.6 - 2.8

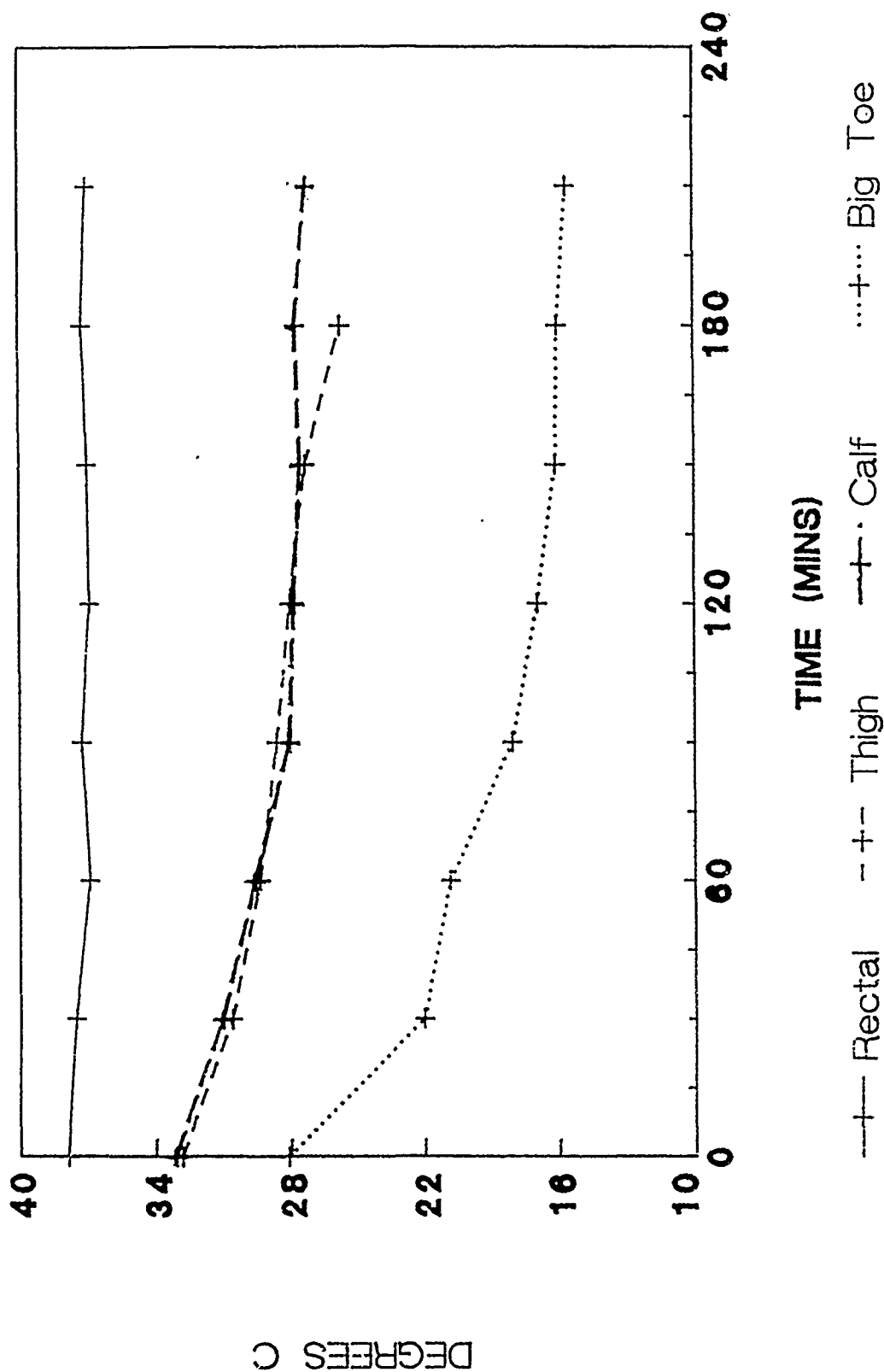
▲ Mean somatoplot of SEAL/SDV sample (n = 48)     2.7 - 5.9 - 1.8

■ Mean somatoplot of HUD/S sample (n = 20)     2.1 - 5.9 - 2.0

□ YOUR SOMATOPLOT     **OTHER NAVY**     4.0 - 5.3 - 1.7

Name.     Endo     Meso     Ecto

# BODY TEMPERATURE DURING COLD WATER SDV MISSIONS (DRY SUIT, FIELD COND.)



## EQUIPMENT / PERFORMANCE

- Dry Suit Integrity

14 of 52 flooded { 27% }

9 of 52 Leaked { 15% }

Total 42%

- MK- 15 Problems

10 of 32 Malfunctioned { 31% }

2 of 10 Completed Mission

W / Back-up System

- UCD / Overboard Discharge

Kinked Tubes

Back Pressure

Incorrect Use

- Gloves

Inadequate Thermal Protection

## EFFECT

6 Aborted  
Mission  
Cold Divers

2 Aborted  
Missions

Urine In Suit  
or  
Dehydration

Loss of  
Dexterity  
etc.

purposely dehydrating himself before the dive or urinating inside the dry suit. Proper education and training in the use and maintenance of equipment appear to be partially responsible for some equipment problems. This past year I had the opportunity to observe and exchange information with the British Special Boat Squadron. Even though their operating environment and tactical use of the SDV differs from that of the U.S., they have been successful in solving many common problems associated with cold water SDV missions. The knowledge and information acquired while working with the Brits was quite valuable and allowed me to suggest several beneficial changes in thermal protection and urinary systems currently in use by SDV Team-ONE. Cold, numb hands continue to plague all cold water divers, some worse than others. A number of laboratories are now pursuing several parallel lines of research in search for a tactically useful solution. The Brits have constructed a dry glove system that appears to work well for them; however, it has not been tested and evaluated by U.S. SEALs.

Figure 18 lists several interventions already tested by various Navy laboratories, including NHRC. Others, with potential payoffs are still under study (figure 19), and it is hoped they will maintain body heat and decrease dehydration. NHRC has located a U.S. garment company to design and produce thermal undergarments, combining radiant barrier and Thinsulate properties, similar to those used by the Brits (made in Switzerland). NMRI is testing novel suit inflation gases with superior insulation properties. Several laboratories are developing and testing active warming systems. Various hydration and exercise regimes to decrease water and heat loss have been tested by NHRC and NMRI. Cold habituation has been studied in several laboratories and offers potential but still needs additional testing using parameters that relate more to SEALs. Special nutritional manipulations (e.g., carbohydrate-loading) have been attempted but more study is required before recommendations can be made in this area. NHRC studies indicate that basic nutritional guidelines are greatly needed for shipboard deployed SEALs. The use of thermogenic drugs (theophylline and caffeine) have been effective in cold air but do not appear to be useful under the severe stress of cold water.

The SDV simulator located at NAVSPECWARCEN at NAB, Coronado provides researchers a platform to replicate all aspects of the SDV field mission except the uncertainty and fear components. NHRC has developed a quantitative data capture and analysis system to document performance decrements of pilot and navigator during mission simulations in 3-4° C water. Figures 20 & 21 show the generic harbor and job

## **Interventions Previously Studied**

- 1. Improved Thermal Protection Systems
  - a. Active warming**
  - b. Undergarment insulation materials**
  - c. Dry gloves (and suits)**
  - d. Overboard urine discharge systems**
  - e. Dry suit inflation gases****
- 2. Euhydration and Rehydration with water**
- 3. Cold Habituation**
- 4. Nutritional Manipulations (CHO loading & Suppl)**
- 5. Drugs (Theophylline, Caffeine)**

## **Interventions with Potential Payoffs**

- 1. Improved Thermal Protection Systems**
- 2. Personnel Selection Guidelines (Body Type)**
- 3. Hyperhydration with Glycerol Solution**
- 4. Nutritional Guidelines (High CHO diets)**
- 5. Cold Habituation & Practice in the Cold**
- 6. Selected Drugs (Diapid=Vasopressin, Stimulants)**



descriptions/tasks which are monitored and quantified during SDV mission simulations. We now have the capability to monitor pilot and navigator performance under various levels of loading. This is accomplished by changing the nature of outside distractions and evaluating the operators' responses to novel and emergency situations. Once a baseline level of performance can be established we can next test the efficacy of selected interventions to offset a particular performance decrement.

I thank you very much for your attention. If you have any questions I'll attempt to answer them.

MALE VOICE: Do you monitor their carbon dioxide levels and are these naive subjects?

DR. GOFORTH: We don't have the capability to analyze gases at this point. As for the use of naive subjects, all of these SEALs have been around the SDV community for some time and would not be considered naive. We use only SEALs for our studies. This has both good and bad aspects, because sometimes we lack control over our subjects living habits (the bad), but on the other hand we are getting the data directly from the actual person under consideration (SEALs).



## Partial Job Description\*

### SDV Pilot and Navigator

#### NAVIGATOR

1. Excellent picture of total mission.
2. Know exact position of SDV in mission at all times.
3. Plan strategy ahead -- with contingencies.
4. Direct pilot regarding the present situation and immediate future situation.
5. Use OAS to help navigate.
6. Decide whether to reset on DNS or \_\_\_\_.
7. Monitor propulsion battery and air status.
8. Monitor OAS for unexpected targets.
9. Listen for unexpected targets.
10. Prevent detection: Be aware of areas patrolled by sentries; areas monitored by listening devices (& EM signature); active sonar surveillance areas. Assure appropriate counter action.
11. Assist SEAL patrol ingress & egress
12. Coordinate RECON
13. Mission Commander -- sometimes
14. Check MK-15 Displays -- Crew & Passengers
15. Monitor personnel status
16. Take land fixes (re. navigation)

#### PILOT

1. Picture of mission (with contingencies).
2. Know current task and cue for next task.
3. Know next task -- (and cue for following task).
4. Execute immediate task.
  - Fly straight and level.
  - Reset at \_\_\_\_.
  - Reprogram DNS. with various sea states
  - Ascend/Dive. varying salinity
  - Sneak and Peak various currents
  - Etc.
5. Monitor stick feel for SDV performance -- especially ballast.
6. Listen for unexpected targets.
7. Monitor ET voltage and DNS self-test.

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\*Note: Only those portions of pilot and navigator job related to potential training or experimentation via Device 2103 are included in partial job description.

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DR. GUNDERSON: The next presenter will be Lieutenant Commander Dennis Kelleher who will review aspects of dry cold as stressors.

LCDR Dennis L. Kelleher, MSC, USN  
Operational Performance Department, NHRC

LCDR KELLEHER: In contrast to the presentation you just heard from Hal in which, because of the operational environment the SEALs are in, they are at risk of suffering a traditional hypothermia exposure, our program generally addresses the amphibious warfare issue.

So, we take a different view of what the operational environment is. It could be physiologically stressful if they do not adhere to guidelines, do not adhere to their training regime or do not use their equipment appropriately. They could conceivably suffer the physiological consequences of wet or dry cold. The idea of the Marine Corps training program is, in fact, to reinforce the proper use of equipment and the proper use of training such that these physiologically stressful conditions don't occur. One thing that is different about operations in the cold not adequately taken care of by equipment training is the fact that there are different terrain features and with amphibious operations at sea, the problems of ship motion and icy decks. These are not normally trained for very effectively, but also you could have the imposition of untrained, physically demanding tasks imposed on what would normally be routine operations. What we would like as researchers is to have predictive models of combat performance that basically meet these six criteria; i.e., we would like them to be reasonably good at predicting combat task performance. We also would like them to be able to enhance operational awareness of the degree to which human factors will impact operations in an adverse environment. We certainly would like them to identify technology shortfalls that not only would aid us in developing research efforts but would also be able to identify them to the operators so there could be, again, an increased awareness in terms of the technology shortfalls. We would like them to be able to provide a mechanism for analysis and evaluation; i.e., we would like the model to be able to drive exercises that would give us assistance in evaluation of intervention strategies. Without an operational means of assessing the effectiveness of intervention in an organized fashion, we are left basically at ground zero again due to the fact we don't have an operational definition of what is going to be good or what has been an effective intervention. Eventually predictive models may drive R&D efforts.

# COLD WEATHER COMBAT PERFORMANCE

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NAVY AND MARINE CORPS COLD WEATHER OPERATIONS

MISSION

OPERATIONAL ENVIRONMENTS

DOCTRINE, TRAINING, EQUIPMENT

---

# COLD WEATHER COMBAT PERFORMANCE

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THE OPERATIONAL ENVIRONMENT - NAVY/MARINE CORPS

DRY AND WET COLD

SNOW COVER?

MOUNTAINOUS?

ROUGH SEAS

ICE COVERED DECKS

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The operational research types deal with things like measures of effectiveness. That is their term for whether what they are doing is good enough or not. We should, however, also have a very clear understanding in our minds as to what measures of effectiveness are in relation to any inputs we are presenting for their models. We are looking at this in clearly operational terms so they will see the relevance in what we are doing and so they can input results correctly into their models. Any measure of effectiveness must be specific to the operational requirement at hand, and therefore, we try to link all of our measures of effectiveness to combat performance. Also, if the measure of effectiveness is not measurable--and both independent and dependent variables must be measurable--then we are not able to put together functional relationships that will relate the two; so, there must be a measurable quantity linked to combat performance that is identified with a specific requirement for it to be a good measure of effectiveness for our model.

In contrast to the question of what is an appropriate or essential criterion in combat performance, if we look to those things that are measurable, correctness of behavior is measurable as accuracy. Whether one has selected the appropriate thing to do and whether one has done it, there should be some measure of correctness of the behavior. There should be some measure of time limits to the behavior--time with respect to decision making--and the degree to which the decision has been executed.

There are going to be some reference points against which that behavior is judged--identifiable reference points for the appropriateness and timeliness of that behavior. I use two Army terms here: SQTs (Skilled Qualifying Tests) and ARTEP (unit level performance measures); whereas SQT is an individual performance measure, an ARTEP is a unit performance measure. These references are threat based, or at least are supposed to be. They are supposed to be based upon real training performance.

MALE VOICE: What is our name for Navy ARTEP?

LCDR KELLEHER: Training standards. The Marine Corps calls them training objectives, but they are not as clearly defined as an SQT and ARTEP. Go to the Army Field manuals and there will be specific combat tasks that are specifically trained with specific tests along the way in terms of step by step performance of a task. I will go through what those tasks are in just a moment.

# COLD WEATHER COMBAT PERFORMANCE

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MEASURES OF EFFECTIVENESS - PERFORMANCE MODELS

SPECIFIC TO THE REQUIREMENT  
QUANTIFIABLE

LINKED TO COMBAT TASK PERFORMANCE

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We are looking at some Marine Corps tasks and we do, in our study, address some Marine Corps infantry problems. These are skill level I type tasks except for issue and communicate an order which is skill level III and IV type tasks; these are tasks that an individual within a group must perform to be able to accomplish an infantry mission. There are just a certain number that first level infantryman must perform. From these tasks, one can supposedly construct all of the special tasks that an infantry squad must perform to accomplish its mission.

The problem we run into is that those tasks, while they have identifiable reference standards, have no scaling capability for the x-axis. When we talk about the operational stress that is imposed, there has to be some way of measuring an operational stress. So, how does one operationally scale the stress of cold weather operations. You can look at the duration of the exposure, i.e., how long is the operation being conducted? What is the intensity of the exposure? You can go to casualty tables, and you can scale the type of operation, whether an offensive operation against an in place position or a defensive operation, as to intensity of exposure. I don't think these are very well defined, but they are basically going to be defined by tactical situation, the weather, the terrain and a variety of other situations/factors.

The question arises, can you develop a dose equivalency, if you will, for infantry operations? An example of the type of thing you would like to be able to construct, if you wanted to look at the performance of an individual infantry task, is some sort of dose equivalency for continuous small unit operations. This example looks rather trumped up, and it is. It's completely trumped up on the computer, and I have used some thermal terms just because this is a cold lecture. I've looked at  $-10^{\circ}\text{C}$ ,  $0^{\circ}\text{C}$ , and  $10^{\circ}\text{C}$ . We are looking at a measured performance, and again, I select time as our measured element for this combat task--time to build a defensive fighting position. A measured phenomenon, based upon the actual combat task performance, with some sort of dependency on operations--totally trumped up.

Theoretically, we'd like to get some better idea about the functional relationships for an individual infantryman fighting under these conditions and how well he is able to perform a given combat task. We can look to the individual components that potentially define that performance decrement, and we know during cold weather operations there are going to be unique physical performance demands imposed by the operation. Normally, there should not be the types of laboratory-based effects of cold weather



# COLD WEATHER COMBAT PERFORMANCE

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SCALING OF COLD WEATHER OPERATIONS AS A STRESSOR

DURATION OF EXPOSURE

INTENSITY OF EXPOSURE

TACTICAL SITUATION

WEATHER

TERRAIN

IS A DOSE EQUIVILANCY POSSIBLE?

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exposure, e.g., body temperature changes. And, in fact, depending on the pace of operations and whether the infantryman is doing what he is supposed to be doing or not, he is probably going to have an elevation of body temperature in contrast to a fall in body temperature. But, the burden of the task in rough terrain, particularly, will be increased in the cold. Again, depending on the elements of the operation, whether it actually did snow the previous night, or whether it's raining right now, the burden of the task in this terrain can shift with time, so the actual operational exposure to the stressful condition is a time-dependent phenomenon as well.

The question of hypothermia, again, becomes more of a casualty issue than it does an operational issue. Whereas there are certainly elements of peripheral cold exposure that have to do with manual dexterity and the like, the degree to which hypothermia is going to be a relevant issue for the analysis of cold weather operations I think is quite low.

Hydration and nutrition, however, are significant problems that still are not addressed. It has traditionally been looked at as an equipment, training, leadership issue, with respect to performance in cold weather. However, we have seen in our studies already that Marine Corps units that know we are testing hydration status are following Marine Corps guidances about what they should be doing in terms of hydration. Those individuals are still dehydrating and they are dehydrating for operational reasons, not necessarily lack of training or guidance. The operation simply has not allowed them to take time to make water, so they have had an operational burden imposed upon them by the nature of the cold weather operation.

The cognitive performance decrements that could occur could relate to sensory deficits and mental processing deficits. One particular problem we are addressing in our program is trying to link performance assessment batteries that have been developed over the years, with actual combat task performance. We are trying to do that in a simultaneous simulation of combat task performance with administration of imbedded laboratory tests within the context of the task.

We also have an overlay of personality and individual psychological differences in responses to the cold weather operation itself--mood alterations, affect changes, and successful coping. The cold weather operation itself imposes a stressful situation, and the degree to which the individual and the group will respond to cold probably is

# COLD WEATHER COMBAT PERFORMANCE

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## PHYSICAL PERFORMANCE DEMANDS OF COLD OPERATIONS

BODY TEMPERATURE MAINTAINENCE

ADDITIONAL BURDEN OF TASKS AND TERRAIN

RELAUVANCE OF HYPOTHERMIA RESEARCH

HYDRATION AND NUTRITION

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primarily defined by the degree to which they will cope with that operation. Developing an inventory of successful coping strategies that could be imported into the training for individuals in cold weather operations is one of our principle objectives of this program. Illness symptom incidence is another component we have been particularly concerned about, because morbidity and mortality questions in cold weather operations have come up consistently. These issues have principally been concerned with casualty production, the degree to which an individual is no longer performing because they are a casualty. We are not so much concerned with casualty production per se but with the marginal performance who are not casualties. So, we want accurate illness and symptom data to be imported into some of these models, but we also want to measure marginal performance decrement that is not casualty producing.

Again, I'm a physiologist so I know very little about the psychology of groups. We'll put the same slide up that everybody else does that shows when in a group you could conceivably have communication deficits and changes in the unit integrity.

Now what is the relevance of existing data bases. Again, to get back to Hal's earlier point that most of the physiology data base we have, relative to cold exposure, does not relate to the operational situation we are concerned with most; i.e., most of the research is dependent upon imposing a hypothermic stress when, in fact, the stress we are talking about is a whole complex of stressors related to the cold weather operation itself and probably does not relate to being specifically cold, other than in terms of the manual dexterity issues and the like and casualty production. Unfortunately, they are not at all correlated to the operation; thus, we are not able to directly make functional relationship links between the laboratory data bases and cold weather operations. We hope with our program, which is field measurement based, we'll be able to link directly large laboratory data bases to combat task performance. We will do that within the context of a simulated battery of combat tasks among performing Marine infantry units in the field, conducting training exercises. It is equivalent to the simulated type tasks you heard about from Hal Goforth in terms of SDV drivers. It's a multidisciplinary program.

It is actually done in the field. We take our measurements in the field. Right now we don't have the simulated task course built, but we do have our laboratory up at Bridgeport, California at the Mountain Warfare Training Center to support our operations. We also have the capability to take our laboratory--and what I mean by the

# COLD WEATHER COMBAT PERFORMANCE

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COGNITIVE PERFORMANCE EFFECTS OF COLD OPERATIONS

SENSORY DECREMENTS

COGNITIVE DECREMENTS

VALIDATION OF PERFORMANCE ASSESSMENT

BATTERIES

---

# COLD WEATHER COMBAT PERFORMANCE

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PSYCHOLOGY OF COLD OPERATIONS - INDIVIDUAL

MOOD ALTERATION

AFFECT

SUCCESSFUL COPING

ILLNESS/SYMPTOM INCIDENCE

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# COLD WEATHER COMBAT PERFORMANCE

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PSYCHOLOGICAL RESPONSE TO COLD OPERATIONS - GROUP

COMMUNICATION DECREMENTS

UNIT INTEGRITY

'MORALE'

'MOTIVATION'

'LEADERSHIP'

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# COLD WEATHER COMBAT PERFORMANCE

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RELEVANCE OF EXISTING DATABASES TO MODELS

CORRELATED TO COMBAT TASK PERFORMANCE?

CORRELATED TO OPERATIONAL EXPOSURES?

ARE FUNCTIONAL RELATIONSHIPS AVAILABLE?

CAN FURTHER RESEARCH DEVELOP THEM?

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laboratory is all traditional laboratory measures you would expect to be able to do in physiological research--we can mount in AMAL cans and load on a pallet and take to the laboratory; the laboratory being in the field. The types of measures we can do in the field are anaerobic power, aerobic capacity, and a whole host of biochemical procedures. We can take a biochemistry lab to the field with us, and we can also do surveys in the field.

This year we have done three studies at Bridgeport, one study at Fort McCoy, Wisconsin, and next year we will be taking our test battery to Norway in a joint collaborative study with the Norwegians to assess their combat operations. We can assess cognitive performance in the field using traditional performance assessment batteries, in new computerized versions. We can actually take them out in the snow and do our cognitive performance tests within the context of the actual performance of the combat task itself, so that we can eventually provide the essential linkage between these performance assessment batteries which are laboratory based and the performance assessment based upon actual combat task performance. Again, I showed you the anaerobic power test and right now; this is an indication of the way we will develop those relationships. A couple of striking things can be noted here. The test as it has been defined so far has been one in which we have not had the ability to control exposure to the performing troops; i.e., we can only have them at discrete periods of time, because they are conducting an actual operation. So, instead of having a continuous monitoring of their performance capability, we have only discrete data points. In some way, we then have to relate those discrete data points to a larger data base. In this particular case we are looking at four days of continuous small unit operations up at Bridgeport, California. Only two temperatures are represented. At 25° C we did some control studies in the summer, and then followed it up with a winter study. We were able to show, using our laboratory-based measures of anaerobic power; i.e., maximal peak power output in the Wingate Test, that there was a measurable, laboratory-based decrement in physiological performance. No linkage whatsoever to the ability to dig a defensive fighting position yet. That will come when we construct, using computer models, a simulated combat task force.

Now, can it be done and will people believe us? This isn't my data and, in fact, it is not real data at all, but it is doctrine. This is a slide from the only field manual that has been published by all four services simultaneously. The FM101-31 series, which is the

# COLD WEATHER COMBAT PERFORMANCE

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NHRC COLD WEATHER OPERATIONS RESEARCH PROGRAM

FIELD MEASUREMENT BASED

LINKED TO COMBAT TASK PERFORMANCE

CORRELATED TO LABORATORY DATABASES

MULTIDISCIPLINARY

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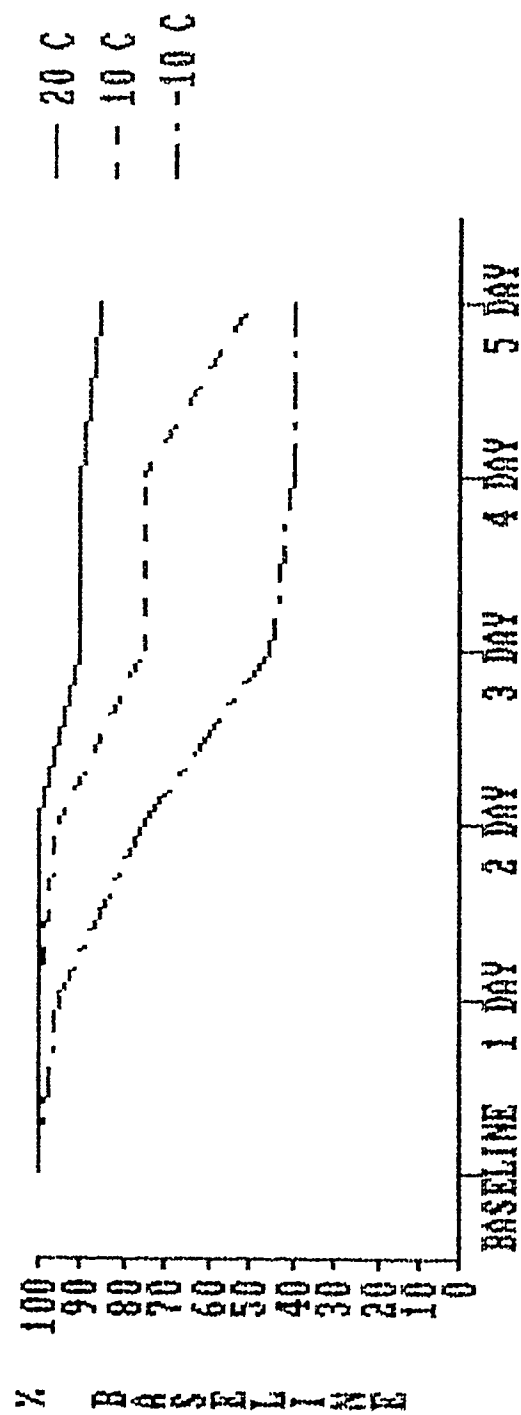
Commanders Guidance of Employment of Tactical Nuclear Weapons. We have finally taken physiological data and put it in totally operational terms and incorporated that data into operational guidance. The operational guidance we are talking about here are actually targeting criteria for tactical nuclear weapons.

Let me very quickly show you what's been done here. Minutes after exposure, and the exposure is a single pulsed exposure to a tactical nuclear weapons burst, is our operational x-variable. We have a secondary variable and that is the exposure size, or the dose that was administered, and three classes of combat effectiveness-performance degradation. Combat effectiveness is an individual's ability to perform his combat task. This was individually based but has now been structured to crew performance as well. What was done before was that there was just a split: they are able to do their task or they are not able to do their task; i.e., they're a casualty. This individual is on the battlefield. He is supposedly performing a task. He is not a casualty in the old casualty-based decision paradigms; he is there performing his duties. Well, in fact, he wasn't. He was combat ineffective, but he was there on the battlefield. Performance degraded is a situation in which he is performing something but probably not performing up to the commander's expectations of what his combat performance should be. So, you can, in fact, construct out of data based on only 100 human exposures to ionizing radiation a fairly good case for importing human performance data directly into operational guidelines, and we certainly would like to be able to do this kind of importing of data using cold weather operations as well.

**MALE VOICE:** Concerning the Marines in cold weather operations, what the commanders are chiefly concerned with would be the extent they taught the troops how to deal with extreme cold. If it became a preoccupation with survival, there would be a resulting loss of combat effectiveness. They view their problem as one of how to teach the troops to fight in arctic conditions and that was a matter of attitude more than anything else.

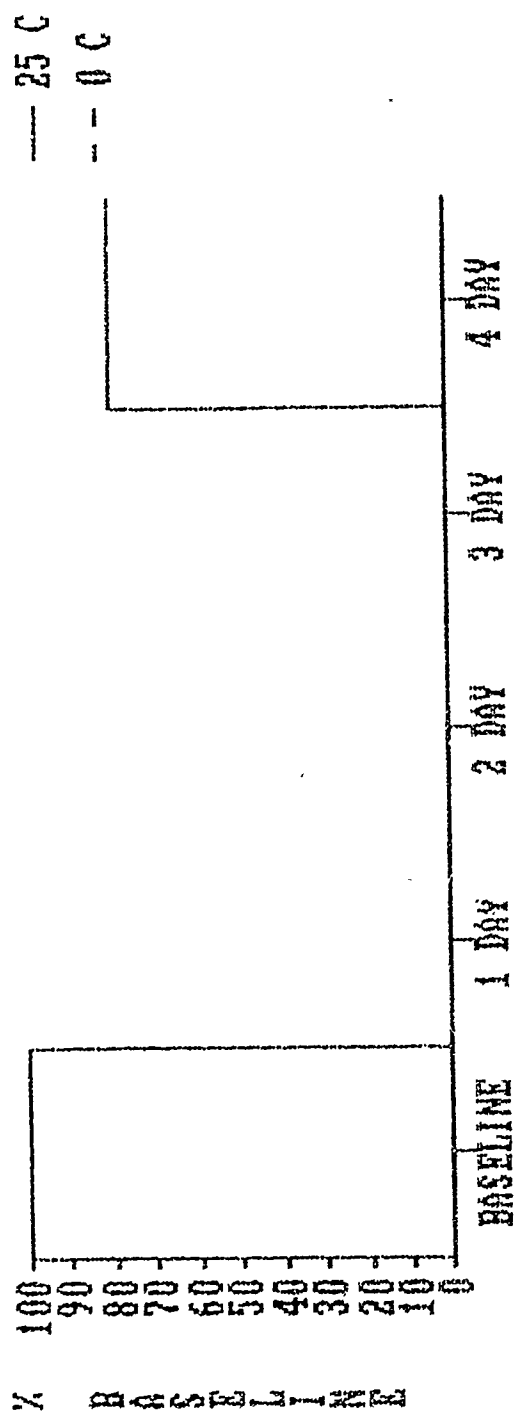
**LCDR KELLEHER:** Actually, when you are out there with them, you can see two prevailing attitudes; i.e. cold, the boogie man, is going to get them and make them a casualty irrespective of what they do, or cold is just another condition under which they have to operate, and there are certain things one can do to keep your performance from being degraded. Obviously Marine Corps training is directed toward the idea of showing that there are very good interventions one could make to be able to keep cold from

# TARGET ACQUISITION - PERCENT OF BASELINE



## CONTINUOUS SMALL UNIT OPERATIONS

# ANEROBIC POWER - WINGATE BICYCLE ERGOMETER



CONTINUOUS SMALL UNIT OPERATIONS

Figure 49 shows that typical group members will be temporarily effective until about 50 minutes after the exposure. This group will become performance-degraded until about 4 hours, after which people in the group will have declined sufficiently to be categorized as CI. The group will remain CI for about 2 days, after which typical group members will recover enough to be placed in the PD category. They will remain PD for approximately 2 days. At approximately 4-5 days after exposure, they will become CI and remain so until they die. Death can be expected about 12 days after exposure for the entire group. Similar information can be derived from Figure 50 for physically undemanding tasks.

Figure 49. Expected Response to Radiation for Physically Demanding Tasks.

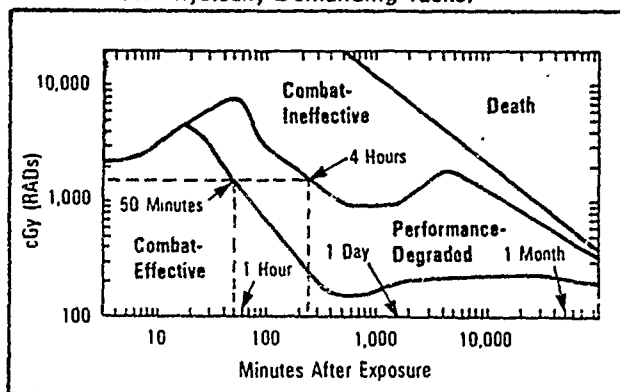
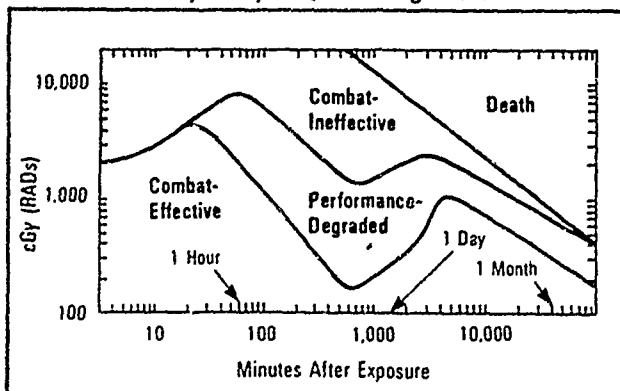


Figure 50. Expected Response to Radiation for Physically Undemanding Tasks.



#### REPEATED EXPOSURE

On a nuclear battlefield, units may be exposed several times to some levels of radiation from friendly as well as enemy nuclear weapons. In view of these multiple exposures and the slow overall recovery, commanders must consider the consequences of using personnel previously

exposed to doses of radiation that may not have caused the symptoms of acute radiation sickness.

To assist commanders, operations officers maintain the radiation status of units assigned. Friendly units are placed in one of four radiation exposure states based on previous exposure history: RES 0 through RES 3.

#### Categories of Radiation Exposure

- |              |  |
|--------------|--|
| <b>RES 0</b> | A unit that has never been exposed to nuclear radiation, a unit which has received no dose.  |
| <b>RES 1</b> | A unit that has received a dose greater than 0 but less than or equal to 70 cGy(RADs).   |
| <b>RES 2</b> | A unit that has received a significant but not dangerous dose of radiation, a dose greater than 70 cGy(RADs) but less than or equal to 150 cGy(RADs). If the situation permits, units in this category should be exposed less frequently and to smaller doses than the units in RES 1 or RES 0 categories. |
| <b>RES 3</b> | A unit that has already received a dose of radiation greater than 150 cGy(RADs); consequently, further exposure is dangerous. This unit should be exposed only if unavoidable because additional exposure in the immediate future will result in sickness and the probability of some deaths.              |

Additional information on this subject may be found in FM 3-12.

#### RECOVERY AND LATE EFFECTS

Persons surviving exposures of 450 cGy(RADs) and below can be expected to regain their combat effectiveness in about 8 weeks after exposure.

Late effects of radiation injury, which can occur many months or years after the exposure, include leukemia, cataracts, and cancer. Late effects can develop in those who have recovered from the initial radiation injuries or even in those who have never been sick, despite repeated exposures.

itself being the enemy in contrast to the enemy they are supposed to be fighting. We'd certainly like with our coping strategies to get back to them as quickly as possible because there is no organized part of the curriculum that now incorporates psychological coping strategies in terms of being able to deal with the cold weather operations.

MALE VOICE: If you put people into repetitive emotional environments and give them no formal training, you find they don't make any significant improvement. You give them a confidence program and counseling, then they make significant improvement.

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CAPT CHANEY: LCDR Banta is Head of the Sustained Operations Program. He will be on twice today. This presentation has to do with heat stress and military performance.

LCDR Guy R. Banta, MSC, USN  
Sustained Operations Department, NHRC

LCDR BANTA: Good afternoon. The first speaker after lunch usually says, hopefully we can keep you awake. If not, Dr. Naitoh will be along a little bit later to tell you how to stay awake.

We talked a little this morning about the impact of cold on human performance in the Navy operational setting. With modeling in mind, what is the impact on human performance of heat in the Navy operational setting? Unlike any other service, the Navy is very diverse, with varied communities, each with unique job tasks that can involve exposures to heat which can result in altered performance. He must consider and evaluate any possible altered performance when we try to model individual or group attempts to accomplish a given task. So, let me go through a few of the Navy communities for you and briefly outline where heat exposures might occur.

My colleagues in the audience in the aviation community know the difficulties associated with solar heat. It goes back to the days of the Wright brothers. The aircraft cockpit area is nothing more than a bubble conducive to a greenhouse effect situation, especially when sitting on a carrier deck in a closed cockpit, and where ventilation is either nonexistent or slight.

In-flight heat strain during helicopter operations. We saw a good example of this when we were in the Persian Gulf recently, which I will talk about in my next presentation. During hover over the rear of a moving ship attempting to drop off supplies or pick up mail by hoist or other things of this sort, a sudden increase in heat load within the aircraft's fuselage may occur. This is due to the ambient temperature as well as the hot engine exhaust forced into the cabin by the wind vortex developed by the down-wash of the aircraft's rotor blades. With the presence of stack gas from the engine exhaust and everything else that is occurring, higher workload for some aircrew, you can have a very sudden high incidence of heat strain or heat injury. In fact, the support helicopter detachment assigned to the Gulf area last summer, reported to us that they had four hospitalized cases of heat strain two months before our arrival.



The flight clothing that an aviator has to wear varies depending on the type of aircraft--helicopter or fixed wings--that he or she flies in. A full complement of flight gear can get up in the range of 65 pounds. Unfortunately, this flight clothing is not designed for proper ventilation. When in a tight cockpit environment with a continuing solar heat buildup, even though metabolic work rate may be low, the actual heat buildup is pretty quick.

**Land based operations.** We talked about Special Warfare a little earlier. Another community which must often conduct land based operations, the United States Marine Corps, can wear a variety of combat gear, packloads up to 50 to 75% of their body weight, and can frequently be exposed to hot wet or hot dry environments.

**Chemical defense ensemble.** Fortunately, this country has not been involved in chemical warfare during actual combat, but we are constantly trying to prepare. I think we've all heard of the limits on performance capability when wearing this kind of equipment.

Even in the cold, to take some of the cold information discussed this morning, we can have a heat problem. When a lot of external clothing is provided to an individual to assist in protection against the cold environment, and that individual had an increase in metabolic work rate for example, shoveling snow off a runway, he quickly builds up a substantial heat load. We have had incidences in the past of heat strain during cold environment Navy operations.

**Shipboard.** A variety of ship types exist in the navy. Many of them steam or diesel driven and thereby heat produces. Additionally, a variety of job tasks occur within the heat load areas, particularly engine rooms. In the Persian Gulf which again I will talk about this afternoon, I personally was able to record ambient temperature in a steam driven engine room, during the fall of the year of up to 169° F. In fact, these guys work in these areas for a number of hours. Top side observers aboard ship, especially when wearing, aboard ship, general quarters equipment--helmets, flak jackets and things of this sort--suffer tremendous heat from solar exposure.

**The flight deck.** Different types of equipment, but again exposed to a lot of solar heat.













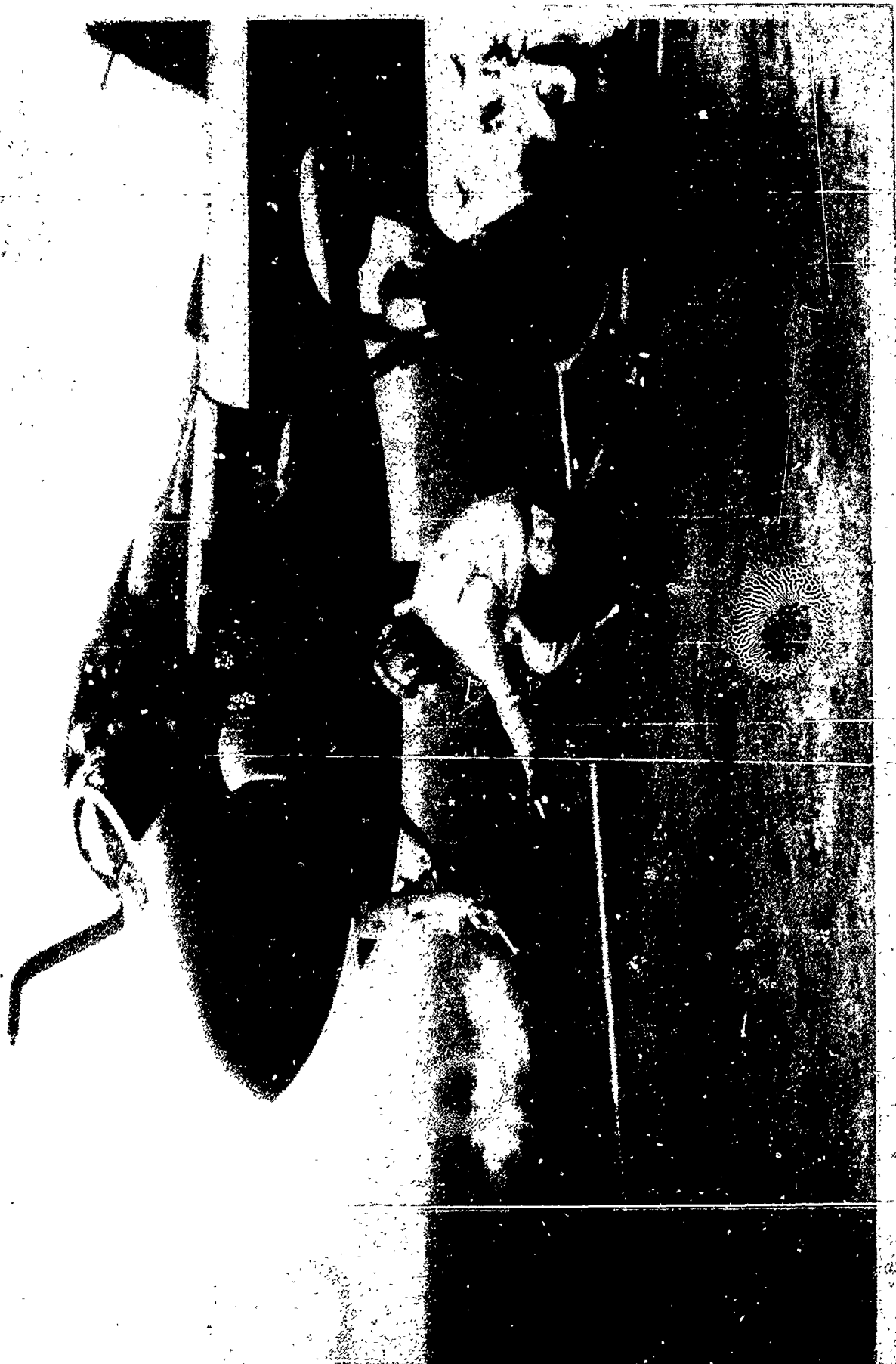


Fire fighting. Now we have, in addition to the ambient heat load, what might be man made or accidental extreme heat load when we have to battle fires. Of course, the equipment we have to wear is the "Silver Suit," which is impervious to proper heat dissipation, and we can't take time out for lunch and cooling off in this situation. We have to work in this condition until the battle is won.

We have looked at the incidence of heat stress or heat strain for the U.S. Navy for the first part of the last decade, and it doesn't look very impressive when you look at the total numbers. The reason for this is because these incidence rates reflect only hospitalized cases of hyperthermia. In the real operational world quite often an individual succumbing to heat strain or heat exhaustion doesn't get put in the hospital. He may have nausea. He may, in fact, collapse and have an episode of syncope, but actually not be hospitalized, so the incident does not get into the data base that we can tap. It is interesting, however, when we look at a breakdown of incidence according to job task. If we look at the rates by job tasks, we see that flight deck personnel, the seamen who work on deck, enginemen, and a real surprise health care personnel have higher incidence of hospitalizations due to hyperthermia. The health care personnel that are the most likely are the hospital corpsmen with the Marines working in hot dry or hot wet environments. So, we can see that across varied navy job tasks the rate of heat exposure is pretty diverse.

Maintenance of thermal balance within a body is a pretty efficient system within a small thermal range. The body, physiologically is capable of taking solar heat increased metabolic work rate due to external workload, and the radiant heat it may be exposed to and through appropriate radiation, conduction, and evaporation of sweat, maintain a thermal balance pretty comfortably.

An increase in workload is measured by oxygen consumption over time, but as work continues heat is stored and total body heat begins to increase. Core temperature measured, in this case by rectal temperature, increases and we have to have greater physiological heat dissipation response to get rid of that stored heat. Therefore, we begin to shunt blood to the periphery and we begin to show a decrease in the total peripheral resistance to that blood flow. This allows delivery of core heat to the outside of the body so that it can be evaporated or conducted off. By virtue of this sudden increase in peripheral blood flow, we have a decrease in internal organ and muscle blood flow. As this cardiovascular shift is occurring, the cardiac output that is responsible for





## INCIDENCE OF HEAT STRESS

1980 - 1984

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HYPERTHERMIA				
VARIABLE	CASES	CRUDE RATE	AGE ADJUSTED RATE	95% C.I.
TOTAL	120	-	4.95	( 4.12, 5.94)
OCCUPATIONAL CATEGORY				
LOGISTICS	0	-	-	-
SHIP OPERATIONS	3	3.63	3.81	( 1.23, 8.88)
AVIATION MAINTENANCE AND WEAPONS	14	6.01	6.66	( 3.64, 11.19)
SHIP MAINTENANCE	3	4.23	5.05	( 1.04, 14.75)
ADMINISTRATION	1	1.04	0.78	( 0.02, 4.34)
HEALTHCARE	14	10.81	11.18	( 6.10, 18.78)
MARINE ENGINEER	12	4.93	4.73	( 2.45, 8.28)
SEAMAN	21	7.97	6.88	( 4.26, 10.53)
AIRMAN	9	8.20	6.96	( 3.19, 13.22)
ENGINEERMAN	7	6.84	4.73	( 1.90, 9.74)
OTHER	36	3.67	4.20	( 2.93, 5.84)

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RATES PER 100,000 PERSON-YEARS

maintaining our dynamic blood flow throughout the system is going to be compromised because we are shunting all this blood flow to the periphery in order to dissipate heat. As stroke volume is beginning to reduce, which makes up part of the cardiac output  $CO = HR \times SV$ , we have to have an increase in the heart rate to maintain the cardiac output. Therefore, we will see an increase in cardiac strain.

All in all, as we increase heat exposure by work rate or environment, we see an increase in temperature, an increase in cardiovascular response, and an increase in sweat rate. After we have reached this zone, zone C as indicated in this graph, we begin to develop dehydration, temperature storage increases faster than heat dissipates, and we begin to experience heat strain and heat exhaustion. Once this occurs, we go through a number of symptoms that probably a number of us have had at one time or another--neuromuscular disturbances, fatigue, psychomotor problems, and cognitive problems--begin to present themselves as we are further exposed to the high heat strain.

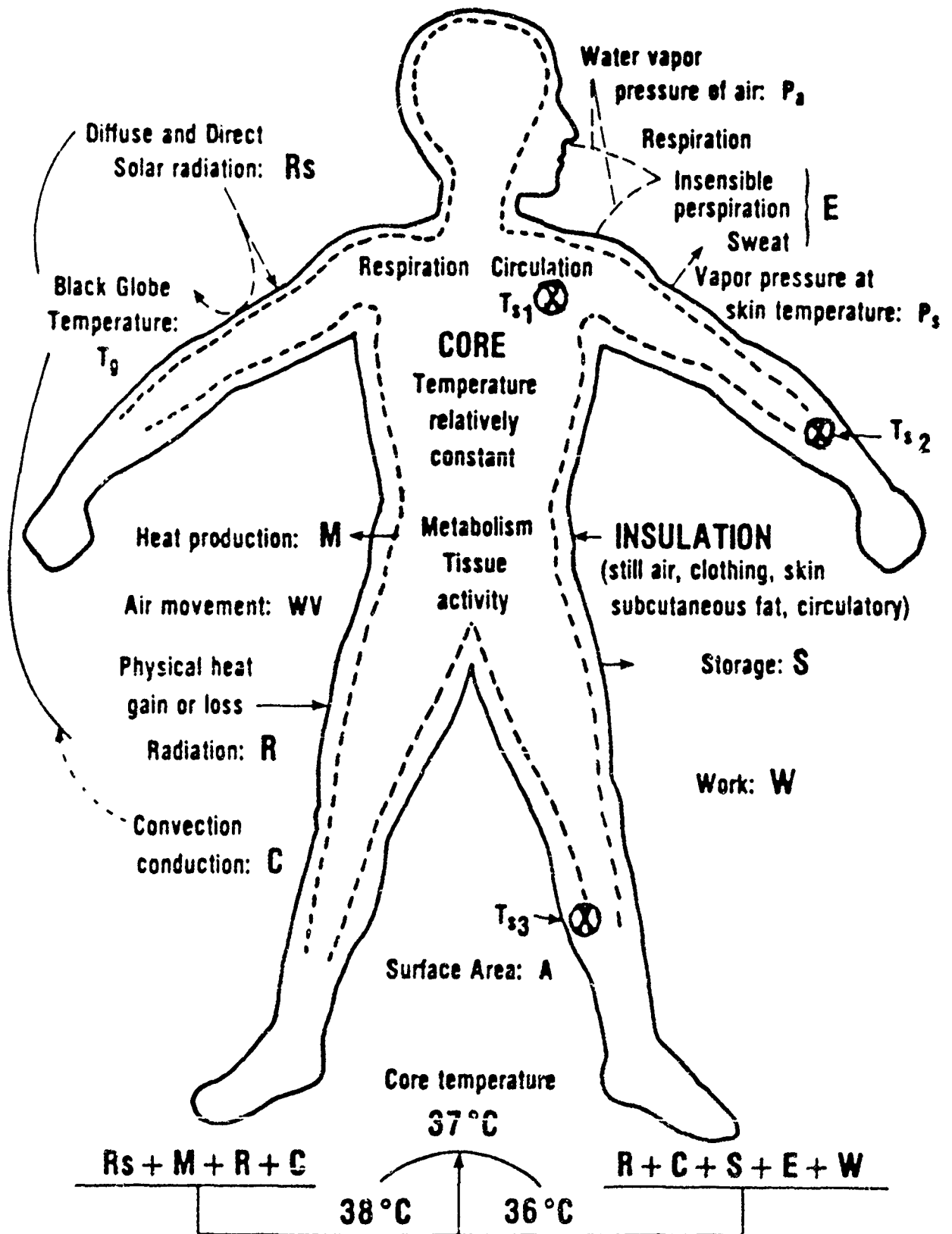
In fact, speaking of mental performance, it is pretty well appreciated in the literature that across time as temperature increases mental performance decreases.

Finally, that which we started out with, the reportable hospitalized heat stroke or heat casualty, begins to present dramatic symptoms and, of course death.

What has been the effect of heat stress on military performance? Based on laboratory and field studies, we have a few good pieces of information. We know in the aviation community, because the competition for blood flow, in an air combat maneuver situation in which we must maintain good cerebral blood flow, as temperature increases within that environment, our tolerance for acceleration decreases. At various work loads, which some of our speakers yet to follow are going to talk about at great length, there is a dramatic drop in work capacity as we increase environmental temperature above normal physiological capabilities to maintain the thermal balance I spoke of.

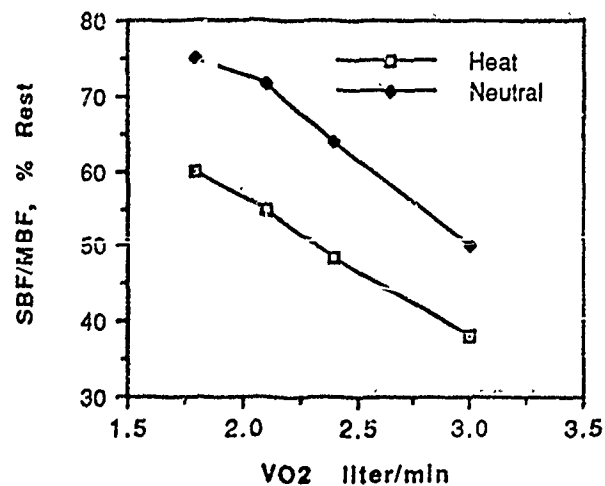
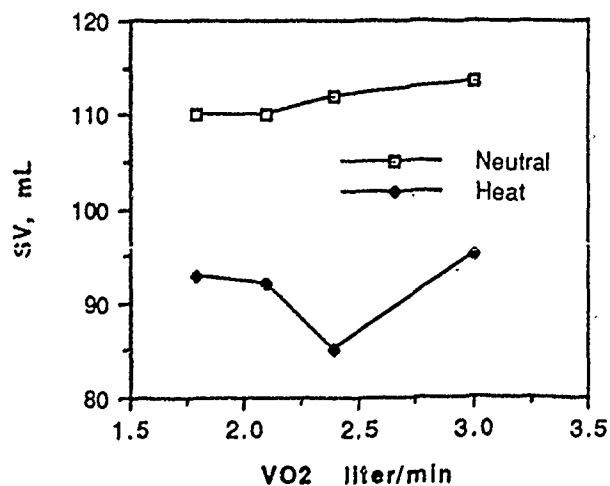
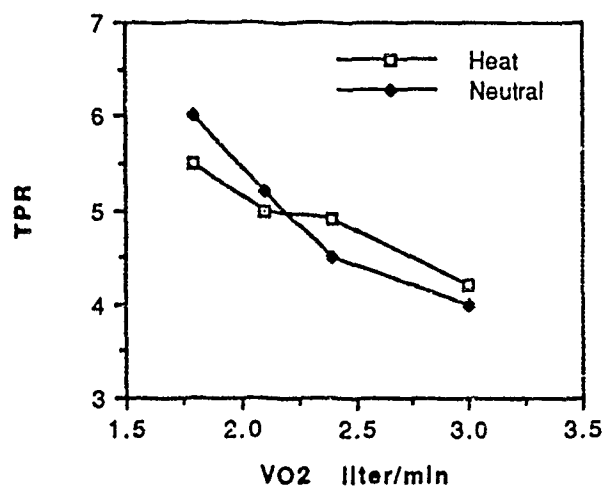
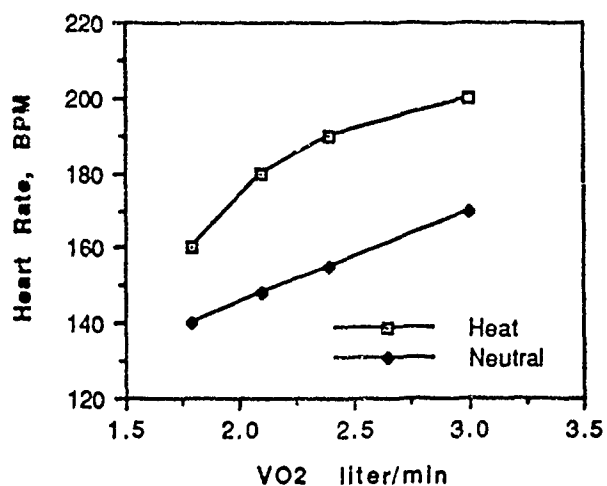
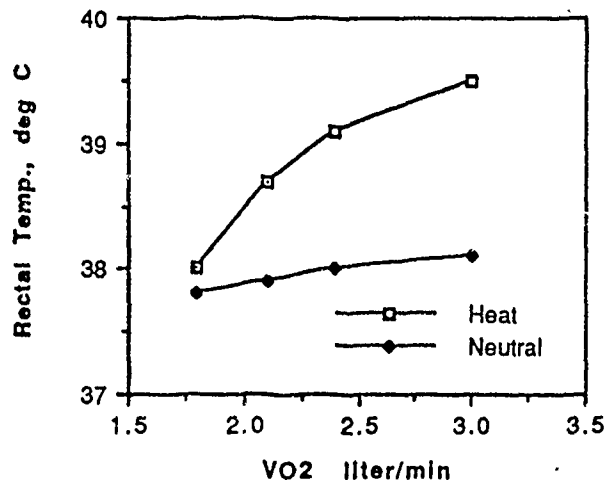
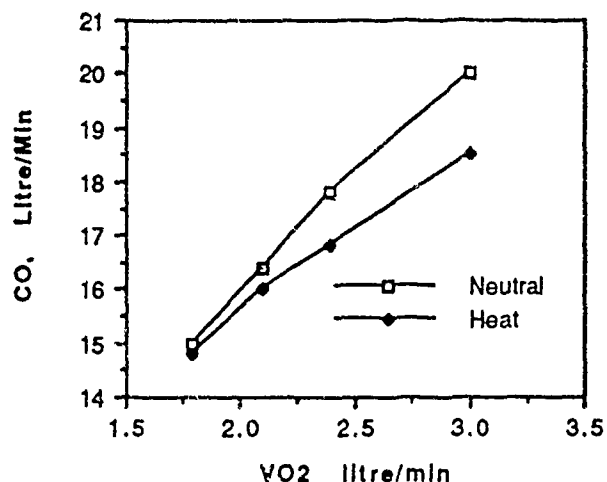
As to cognitive performance decrements, there have been a number of studies by all services, e.g., forced marches within chemical defense ensembles--we have a major project in this area right now--tank drivers, and helicopter in-flight personnel. I mentioned to you already about an in-flight heat strain situation still a problem today for aircrew flying in the Persian Gulf.

# SUMMARY OF FACTORS IN ENERGY BALANCE



Taken from presentation by R. Goldman, USUHS Medical School, 1981.

# Physiological Response to Thermal Stress During Work





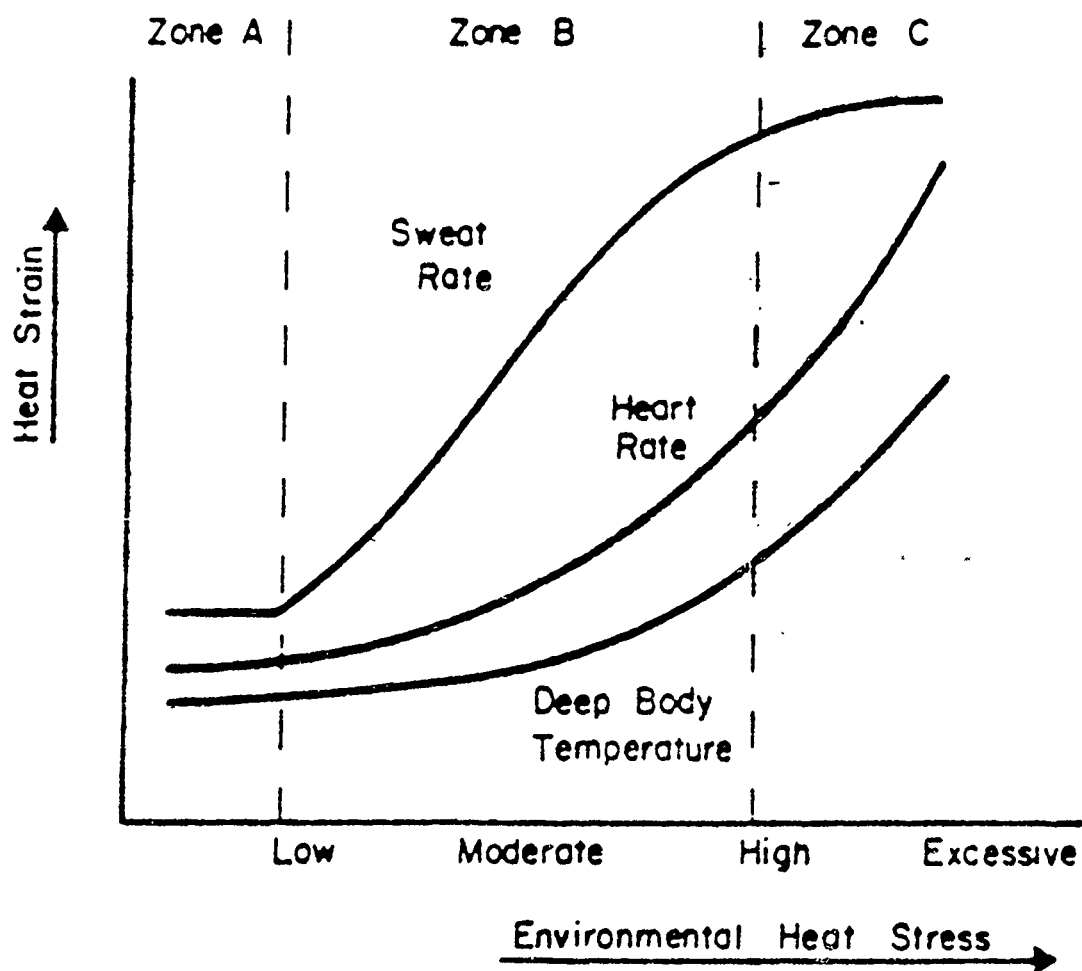


Fig 5 Changes in sweat loss, heart rate, and deep body temperature with increasing climatic heat stress (Zone A —no heat strain, Zone B —increasing heat strain, Zone C —high heat strain. From Lind, WHO Tech. Report 412, 1969.)

HEAT EXHAUSTION      PERIPHERAL VASCULAR COLLAPSE DUE TO  
EXCESSIVE SALT AND WATER DEPLETION

SYMPTOMS              PROFUSE SWEATING

HEADACHE

TINGLING SENSATIONS

PALLOR

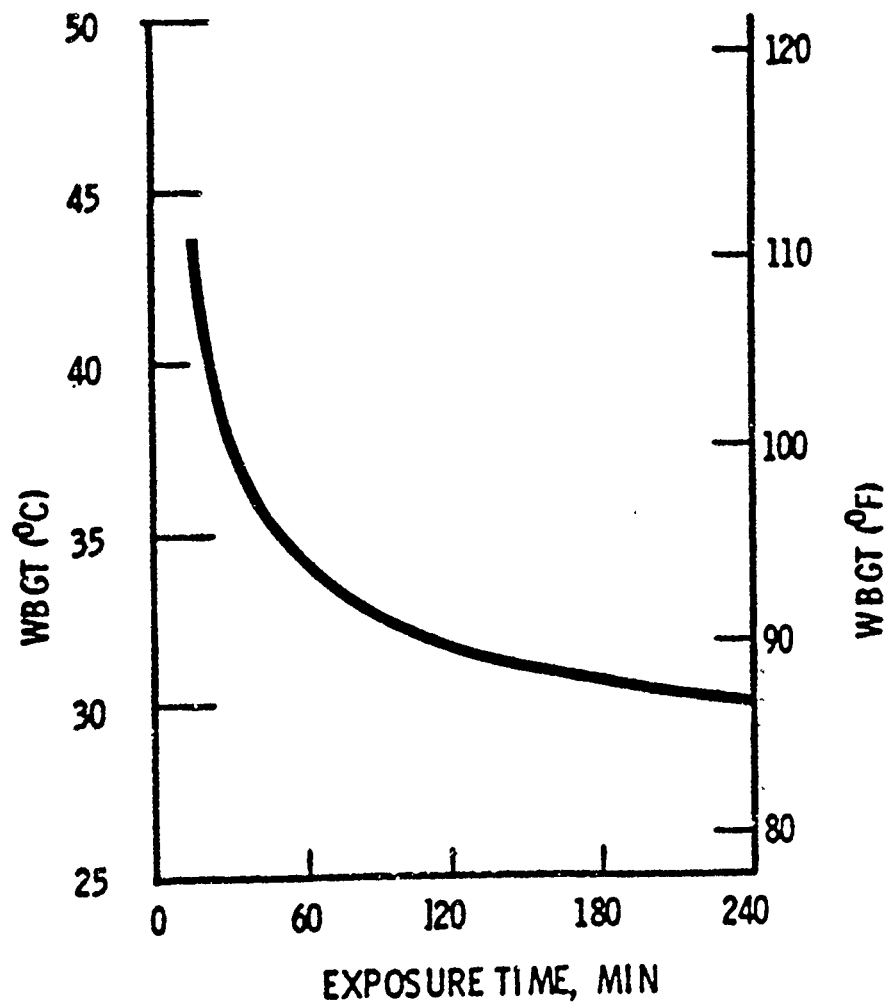
DYSPNEA

PALPITATIONS

NAUSEA

NEUROMUSCULAR DISTURBANCES

CLOUDY SENSORIUM



UPPER LIMITS OF EXPOSURE FOR UNIMPAIRED  
MENTAL PERFORMANCE

HEAT STROKE    FAILURE OF SWEATING/THERMOREGULATORY MECHANISMS

A MEDICAL EMERGENCY

SYMPTOMS        PRODROME OF HEAT EXHAUSTION

SIGNS            ABRUPT ONSET OF LOSS OF CONSCIOUSNESS  
                  CONVULSIONS OR DELIRIUM

SKIN HOT, FLUSHED AND PERHAPS DRY

RECTAL TEMPERATURE MAY EXCEED 41°C (106°F)

PULSE FULL AND RAPID

ELEVATED OR NORMAL SYSTOLIC PRESSURE

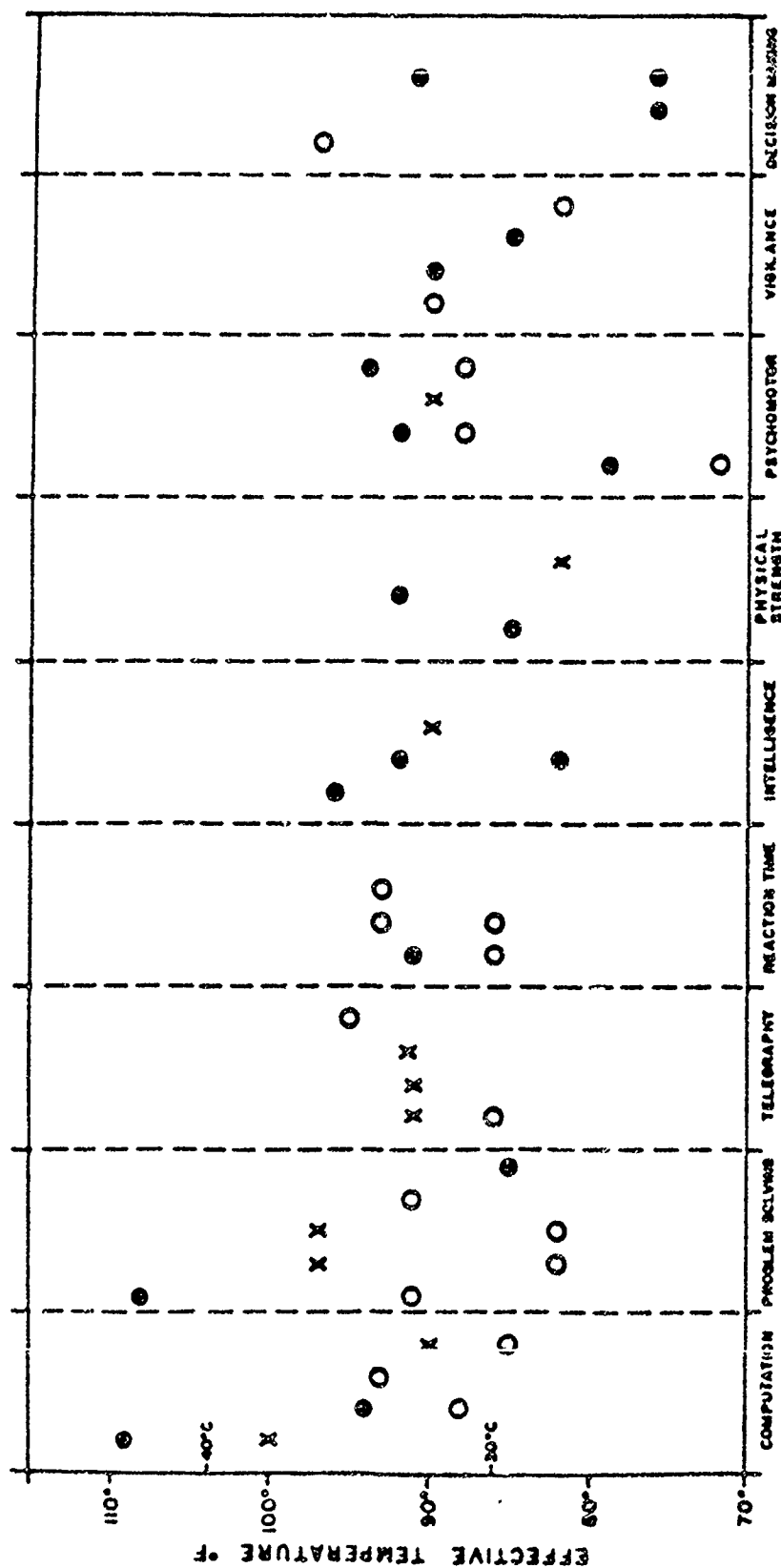
WIDE PULSE PRESSURE

RESPIRATIONS RAPID AND DEEP

HEAT STRESS  
EFFECT ON MILITARY PERFORMANCE

- \* DIMINISHED ACCELERATION TOLERANCE  
AT  $T_{re} > 38^{\circ} \text{ C}$
- \* 50 % DROP IN MODERATE WORK CAPACITY  
IN TWO HRS AT WBGT OF  $33^{\circ} \text{ C}$
- \* ALTERED LEARNING CURVE FOLLOWING  
HOT WEATHER FLIGHTS (WBGT =  $31^{\circ} \text{ C}$ )
- \* COGNITIVE PERFORMANCE DECREMENTS
  - FORCED MARCH
  - CHEMICAL DEFENSE ENSEMBLE
  - TANK DRIVERS
  - HELICOPTER FLIGHT OPERATIONS

USARIELA (R. Goldman)



When we look at some of the Army data from a few years back in a temperature range in which the Persian Gulf is pretty much within the upper level of this chart, and draw a line across the black circles that represent decrement in various cognitive areas, and in physical strength, we begin to appreciate the number of cases documented both in the laboratory as well as in the field, in which environmental heat stress has been identified as having an impact on an individual's or group's performance.

What have we done and how is it working today?

Hydration/Dehydration plays a major part in the difficulty of maintenance of performance and thermal balance. We have had a strong educational effort about hydration for a number of years, trying to get across to sailors and Marines that the thirst mechanism is not a good indicator of when it is time to drink. Once again, I would like to reflect on the Persian Gulf situation since that is the latest thing we had the opportunity to see. Proper hydration education may be there, but the availability of hydration may not be there. Water coolers may not be available or operating within the steam engine space because of water shortage or shut down of the total ship's system.

**Salt Supplementation.** When I was in Viet Nam many years ago, they fed this stuff to us like candy, and we ended up having as many heat casualties, I think, because of the increase in salt intake as it was to the heat itself. We have learned by trial and error that kind of salt supplementation was not necessary even in a field environment. We have now gotten more into the practices of proper dietary education, looking at our field rations more effectively, and things of this nature.

**Monitoring.** I mentioned earlier the Wet Globe Bulb Temperature Index (WGBT). The Air Force has one called the FITS (Fighter Index Thermal Stress). In a field environment during high temperatures, generally job tasks are monitored. By looking at the environmental exercise periods and temperature of a given day and/or the amount of exercise periods, the amount of time an individual spends in that temperature within a given day, we can properly advise troops and troop commanders as to the amount of individual exposure time that they should be limited to within that environment. These heat indexes are generally used to represent the total heat exposure and are related to time of exposure. In the combat scenario we can't say "stop the war while we check these indexes" or "we can only do this for an hour because it's too hot". So, whether or not, use of these indexes is operationally feasible is always at issue.

## HEAT STRESS INTERVENTION

- \* HYDRATION
- \* SALT SUPPLEMENTATION
- \* WBGT/FITS MONITORING
- \* PHEL CURVES
- \* LHA HEAT CHAMBERS
- \* FITNESS ACCLIMATIZATION



We have now developed what are called PHEL Curves (Physiological Heat Exposure Limit Curves) which are used most often aboard ship. Here's an example:

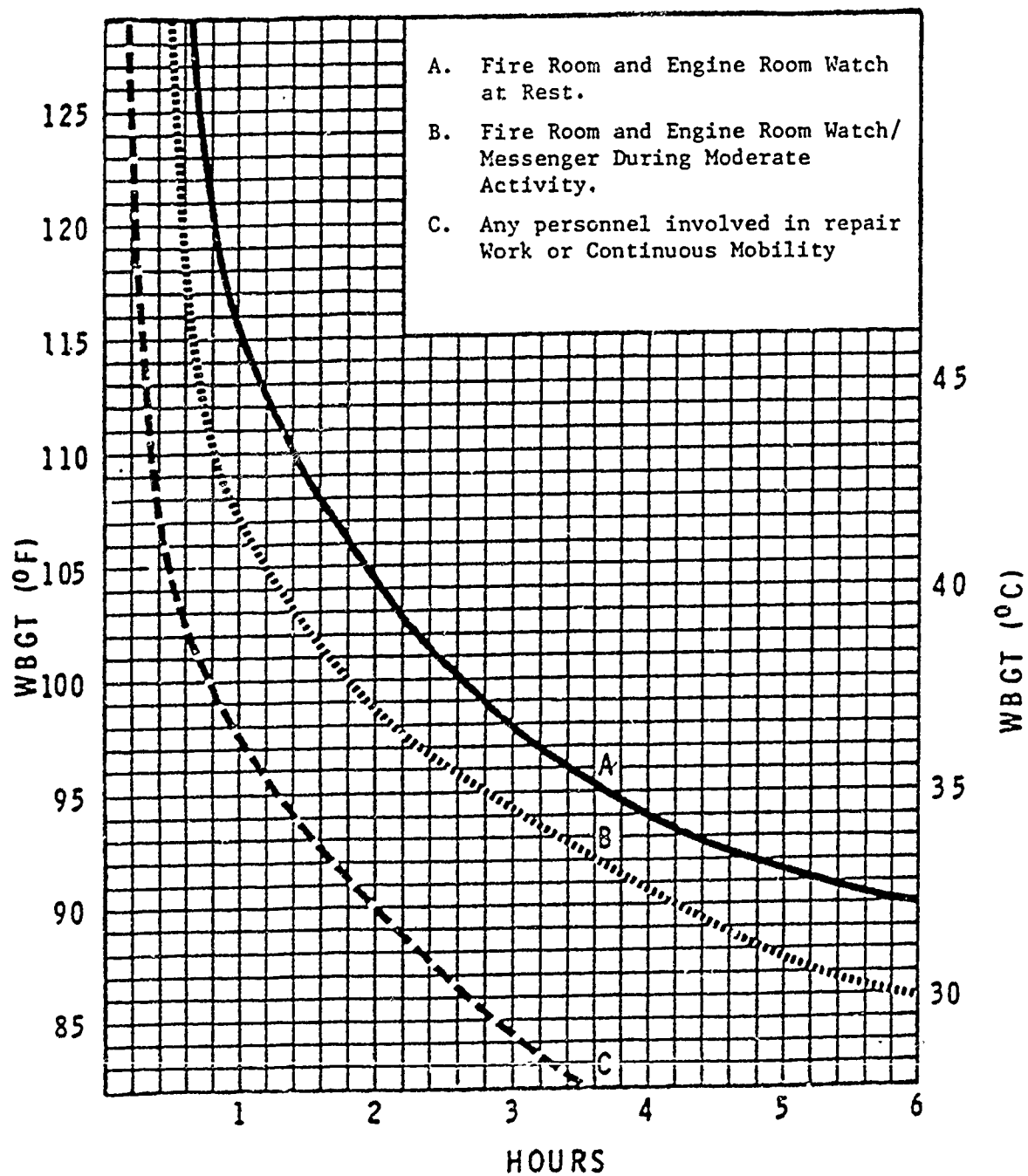
We will use the engine room watch which is at rest (curve A) or has moderate activities such as checking a few gauges (curve B), and here is anyone who is working very extensively (curve C). Using the same WGBT level, let's pick the middle curve (curve B) just to show no bias either way. Again, I'll use the WGBT level which was pretty common in the Persian Gulf last fall, which was around 95, 96, 98° F. Let's come across here and see that at 96° F we're talking somewhere about 2-1/2 hour maximum exposure recommended at this level, and at that time you would be required to leave that space. Additionally, instructions say that twice the amount of time worked is required for rest. So, if you are in there 2-1/2 hours you get 5 hours off and then you go back to work. But what if you are standing "port" and "starboard" (two section watch). In other words only two of you can stand that duty, or perhaps you are in a three section watch, and you have to go around the clock 24 hours.

What happens when there is a mechanical breakdown? The engine has to be fixed. The PHEL curves do not understand operational commitments and operational readiness. The individual is not going to be able to comply with the PHEL curves and may have to stay in the hot environment three or four hours before he can be properly relieved. He must repair the maintenance difficulty that has occurred and then do his collateral duties before he gets time to sleep.

The previous slide back listed heat chambers and fitness as means of heat stress intervention. We have known for quite a few years that as an individual becomes exposed over time to high environmental temperature and improves physical fitness, he can develop acclimatization to the heat load by improved heat dissipation mechanisms. Our body storage of heat is reduced, we sweat more, and our cardiac strain is less. Many years ago, in fact I bet it has been close to 20 years now, the Navy developed heat chambers aboard some of their ships in order to give Marine troops an opportunity to sit in hot chambers for extended periods of time while transiting in oceanic trips to wherever they might be deployed so that they would become acclimated to the new hot environment they soon were to be exposed to. They would spend several hours a day in those chambers. Well, I'll tell you it's not very easy to get a Marine to sit in a hot

# PHYSIOLOGICAL HEAT EXPOSURE

## LIMIT (PHEL) CURVES



chamber when it's about 100° F outside already and just sit there to become heat acclimated, like going to the sauna at the fitness club. It doesn't work very well. It was not operationally feasible, and it didn't work. Unfortunately, those heat chambers have now become nothing more than storage rooms and things of that sort on many of the ships; therefore they are no longer being used.

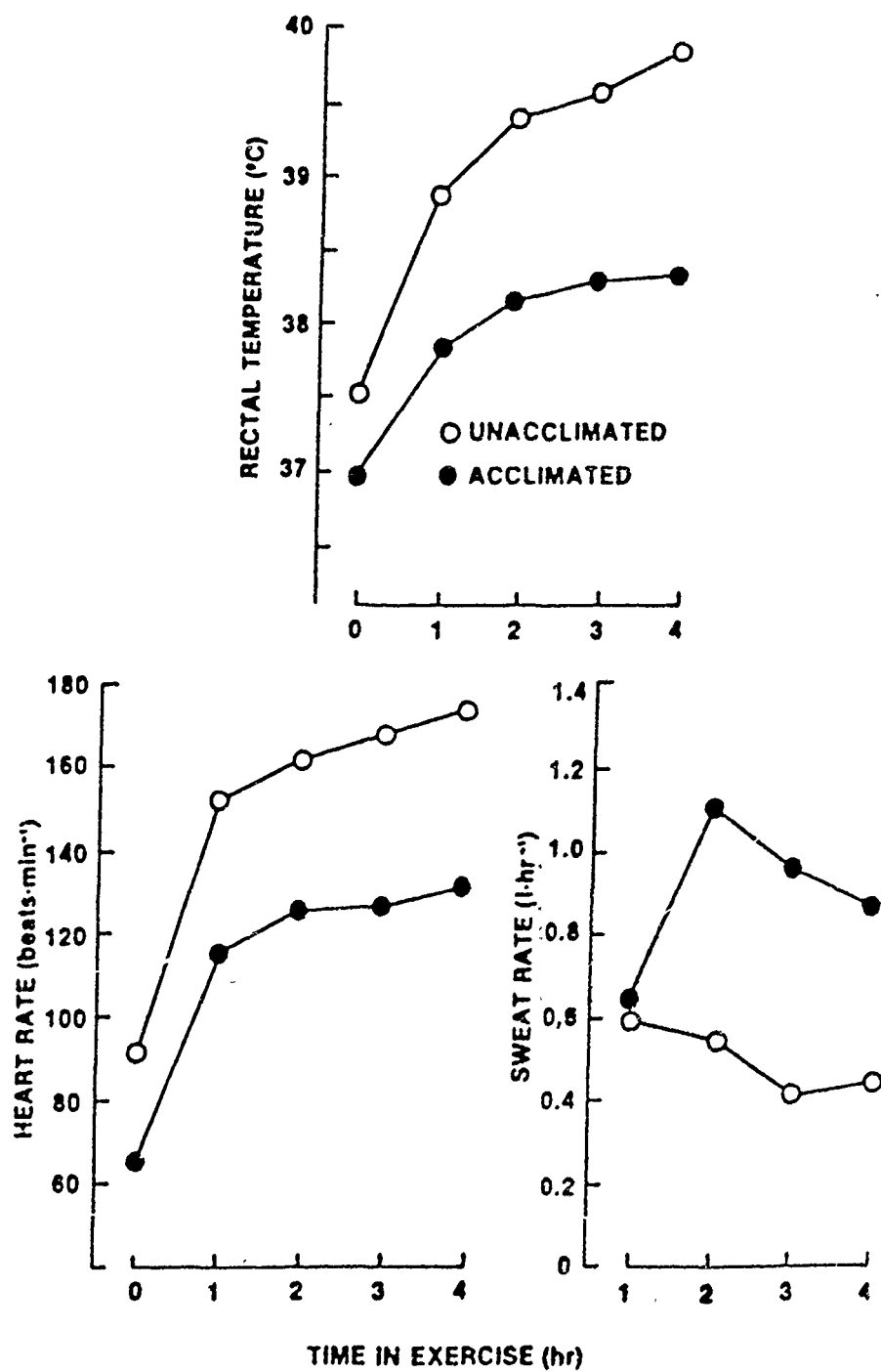
As far as fitness acclimatization, we practice fitness. We have physical fitness tests that dictate our physical fitness training activities in shore base environments but when you get aboard a ship such as a mine sweeper or a destroyer in which you have very little room to even sit down or lay down to sleep, you have no place to do exercise, and no place to run, so you begin to decompensate.

The point here is that one does what one has to do to win the battle.

What still needs to be done. I haven't put these in any order of priority. They are all of interest. Some of these will be mentioned later. Sleep loss interaction with thermal regulation, mechanisms of hydration and dehydration, trying to provide supplemental fluids that may act differently as far as enhancing heat dissipation, cross application between hot wet and hot dry as far as being operationally relevant to where the troops have to go, and medication and prophylactics. Here's an issue of concern in the area of chemical defense. Atropine, pyridostigmine, things of this sort--what impact do they have as prophylactic drugs on thermal response? Motion sickness medication, and other general medications, hygiene, "Prickly Heat" for lack of a proper clinical term. What impact does that have on thermal response? We are doing a lot of work in microclimate cooling these days--air fed, water fed, and ice. The operational feasibility of these devices are of issue. In a closed environment such as an aircraft or tank, we might be able to have a hard wire, tethered system to provide cooling for the individual, but in the field, that's not possible. Aboard ship, that's not possible, so we use ice. Ice melts quickly. What's the period of time we can use it? How long will it last? When and how can he replace it?

**Modeling.** Probably in the heat environment, we have seen the greatest success with modeling. This is Wissler's model from about 1961 where he divided the body into six components to express mathematically the blood flow dynamics I previously described.

## EFFECT OF HEAT ACCLIMATIZATION



HEAT STRESS RESEARCH  
WHAT'S STILL NEEDED

- \* SLEEP LOSS AND THERMAL REGULATION
- \* HYDRATION / DEHYDRATION MECHANISMS OF ACTION
- \* CROSS ACCLIMATIZATION
  - HOT / WET
  - HOT / DRY
- \* EFFECT OF MEDICATION / PROPHYLACTIC DRUGS ON THERMAL RESPONSE
- \* HYGIENE
- \* MICROCLIMATE COOLING

In 1972, Givoni and Goldman developed and reported mathematical weighings of core temperature response for modeling, taking components of metabolism, dry heat, and evaporative heat exchange. In fact, I'll show you an example of just what went into one segment of that model.

Looking at only the metabolic portion of the equation, we can derive the metabolic rate from the workload, the amount of clothing, the terrain, the grade, etc., all to develop a mathematical model that allows us to predict performance outcome.

Finally, the state-of-the-art has allowed taking this kind of modeling and provide it in a lap top computer that can be usable in the field by an operational commander. You could specify if its hot wet, dry, wind speed, water requirements, etc., and be able to calculate outcome of performance over time.

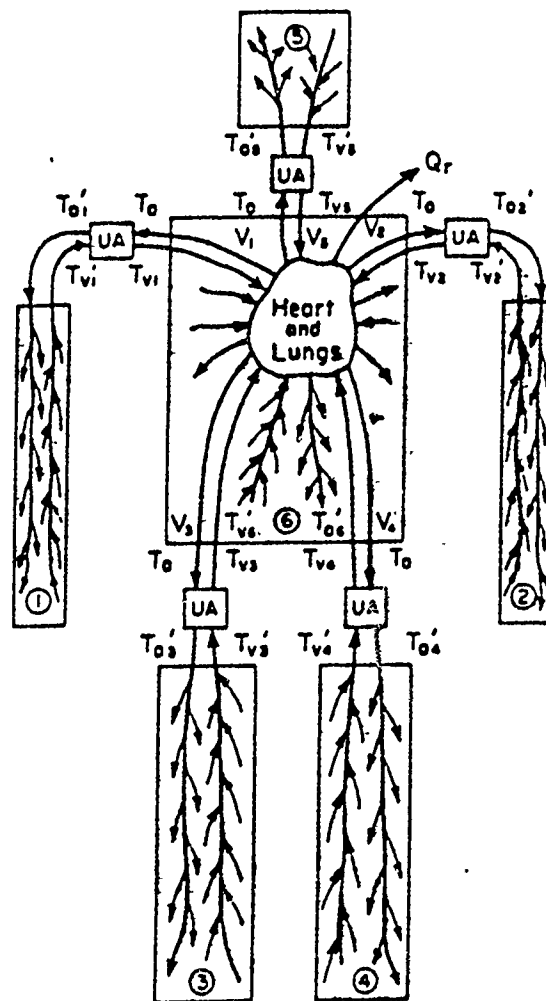
The difficulty with these models, as we go further into the concepts of developing predictive models, especially as we look at varied environments, is that there are other things that need to go in there. Some are listed here already and others I have just brought up today--like difficulties with medication, age of the individual, and impact of fitness levels. All of these should be considered and need to be part of those predictive models in order for us to predict the individual response as well as the mission response outcome. Thank you.

MALE VOICE: With the lap top what would you expect the field commander to gain from its use in the field?

LCDR BANTA: If I were a commander and I was handed a computer of some sort that allowed me to plug in my tactics, my environmental constraints, my number of personnel, the physiological response, the time limit involved, and the ambient temperature, I would use it to determine what was the percentage outcome of success in performance for my troops or an individual. Then, I could make a decision as to whether I wanted to accept a 10% decrement, a 50% decrement or whatever in performance as well as success of the mission.

MALE VOICE: I suspect the biggest problem, assuming of course you are able to perfect your model, is acceptability. Before that Marine unit commander accepts it, he will need to be assured he is getting results he can use.

# WISSLER'S MODEL OF TEMPERATURE DISTRIBUTION IN MAN



Components used in thermal system of the six-element man.

# PREDICTION MODELING OF PHYSIOLOGICAL RESPONSES IN THE HEAT

$$T_{ref} (^{\circ}C) = \underbrace{36.75 + 0.004 (M - W_{ex})}_{\text{METABOLIC}} + \underbrace{0.0011 H(r + c)}_{\text{DRY HEAT EXCHANGE}} + \underbrace{0.8e \exp [0.0047 (E_{req} - E_{max})]}_{\text{EVAPORATIVE HEAT EXCHANGE}}$$

Givoni and Goldman. J. Appl. Physiol. 1972.



## METABOLIC COMPONENT

$$36.75 + 0.004 (M - W_{\text{ex}})$$

$$M = 1.5 W + 2(W + L)(L/W)^2 + \eta(W + L) [1.5(V_w)^2 + 0.35 G V_w]$$

$$W_{\text{ex}} = 0.098 G(W + L) V_w$$

$M$  = metabolic rate, (watt)

$W_{\text{ex}}$  = external work, (watt)

$W$  = nude weight, (kg)


$L$  = clothing and equipment weight, (kg)

$\eta$  = terrain factor

$V_w$  = walking velocity, (m/s)

$G$  = grade, (%)

Pondolf, Givoni, and Goldman. J. Appl. Physiol. 1977.

**** DISPLAY ****				
on/off	user	program		alpha
WOPP I	WOPP II	WOPP III	WOPP IV	CLOTH WDRU
WORK LIGHT	WORK MOO	WORK HWY	METAB.RATE	FUNC 0
	CASLT LIGHT	CASLT MOO	CASLT HWY	NON-ACCL ACCL
SELECT	DISP	COMP	DISP UNITS	
Ta	% RH	HOT WET	HOT DRY	
WIND SPEED	CALM	BREEZY	WINDY	
CLOUDY	PARTLY CLOUDY	CLEAR SKY	INDOORS	
WRK CYCLE	WATER REQ		RUN	

The redesigned touch pad of the Hewlett-Packard 41CV which encompasses the input parameters of our heat stress prediction model

HEAT STRESS  
MODELING VARIABLES

1. AMBIENT TEMPERATURE / HUMIDITY / WIND
2. HYDRATION STATE
3. BODY COMPOSITION
4. AMOUNT OF SLEEP
5. FITNESS LEVEL
6. ACTIVITY LEVEL
7. AMOUNT AND TYPE OF CLOTHING
8. TYPE OF EXERCISE
9. MEDICATION
10. PRIOR HEAT ILLNESS
11. AGE

LCDR BANTA: Yes, I agree. In a laboratory setting, a controlled environment, you generally know what is going to happen physiologically to an individual when a given event occurs, and put those type of variables in our models. They are easy to quantify.

I am not a psychologist. As a physiologist, it's easy for me to speak of performance in physical terms compared to the psychologist who frequently talks about performance as cognitive function. Generally, long before the physical collapse occurs, most often it is the cognitive, psychomotor, vigilance, attention span, and short-term memory that go first, and those we have to be able to address too. As I will discuss later this afternoon, the job tasks are of issue here. What is most important for one job task as compared to another job task?

MALE VOICE: I'm trying to put this in a more operational mode. If I were a company commander and I went to the physiologist and said, I'm going to take my troops on a 20-mile forced march for this type of operation and give you the weight and so forth, can you give me an estimate of how many people are going to be able to make it? If you could say "well, Bill, you are probably going to be at 50% fighting strength when you get to your objective," that would be very valuable to me in an operational setting.

LCDR BANTA: I think, as I mentioned earlier, we're probably the furthest along on heat modeling and those capabilities are in existence today. We do need to stay, however, within a confined framework as far as workload, terrain, ambient temperature, and things of that order. I have to filter out still whether he's on a medication, whether or not he's fit, and some of the other synergistic issues that may not be there. But, those models are available today and being expanded to provide information to the modeler as well as the company commander.

CAPT CHANEY: The next speaker is Dr. Carl Englund.

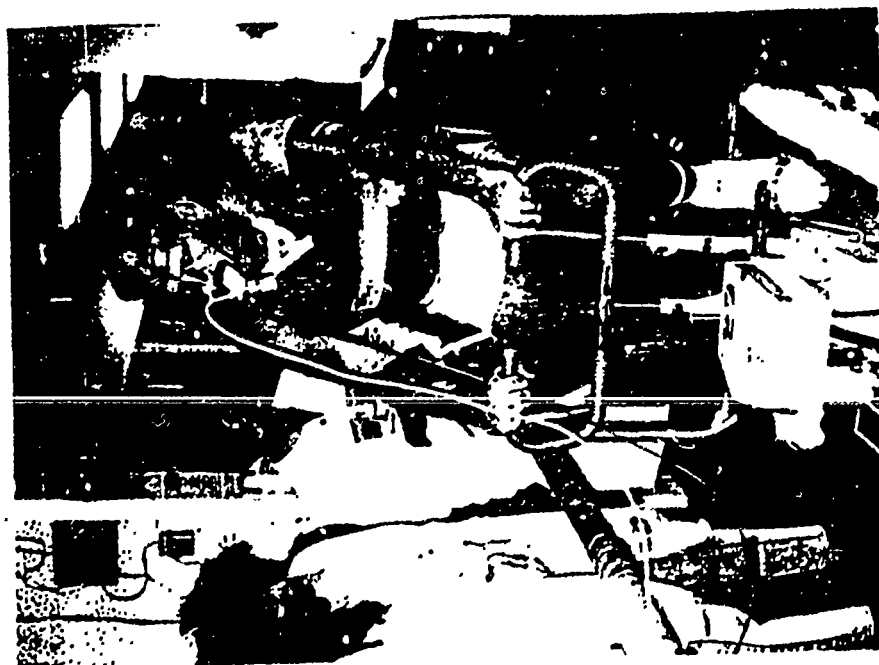
Carl E. Englund, Ph.D.  
Sustained Operations Department, NHRC

DR. ENGLUND: Good afternoon. Thank you for this opportunity to speak with you today about the relationship of physical work effects to cognitive performance. As an introduction to the problem, I should first explain that what we know of this relationship is very limited. The data were scattered among a few diverse journals and studies, and usually were not the primary objective of the research. I have organized the known information in the following way: Studies performed in a laboratory and data gathered in a more naturalistic environment such as a field training exercise. Within each of those categories I will discuss the relationship between these two factors on the basis of either methodological formats or as a function of some intervening variable. First, by way of an introduction, let's become acquainted with the construct of physical work.

The products of physical work, besides the objective of the work and a sense of accomplishment, are fatigue, muscle strain, sleepiness, and decrements in work efficiency. These factors depend upon the context, i.e., the time and place in which the work is accomplished, and whether work is performed alone or in a group. Other influencing contextual factors are temperature, humidity and noise levels, the length of time on the task, the work load, the quality of rest breaks, the quality and length of previous rest or sleep, fitness and training for the task, type of task or job, and caloric availability. Intrinsic variables of concern are circadian variations and the degree of recovery from fatigue, emotional capacity for stress management, and perhaps some inherited physical characteristics such as the ratio of fast to slow twitch muscles. Long term physical work capacity is a function of one's aerobic threshold and is influenced by fitness level and degree of training. The study of the relationship of these two factors, as can be seen, is a multi-disciplinary matter.

Work load is described as a function of work rate; i.e., work accomplished per unit of time and the length of time one works. Work rate constantly decreases with increases in fatigue. Figure 1 indicates that energy sources and cost change as a function of work rate and duration.

# PHYSIOLOGICAL LIMITATIONS TO PHYSICAL PERFORMANCE



<u>WORK RATE</u>	<u>CAUSE OF FATIGUE</u>
< 15 mins	<ul style="list-style-type: none"><li>• DEPLETES SHORT-TERM ENERGY STORES</li><li>• BUILDUP OF LACTIC ACID</li></ul>
1-6 hours	<ul style="list-style-type: none"><li>• MUSCLE GLYCOGEN DEPLETION</li><li>• MAYBE DEHYDRATION</li><li>• DEPLETION OF LIVER GLUCOSE</li></ul>
> 5-6 hours	<ul style="list-style-type: none"><li>• RUNOUT OF CARBOHYDRATE FUELS</li><li>• FAT &amp; PROTEIN BECOME FUEL SOURCE</li><li>• SHIFTS IN METABOLIC HORMONE LEVELS</li><li>• POSSIBLE MUSCLE DAMAGE</li></ul>

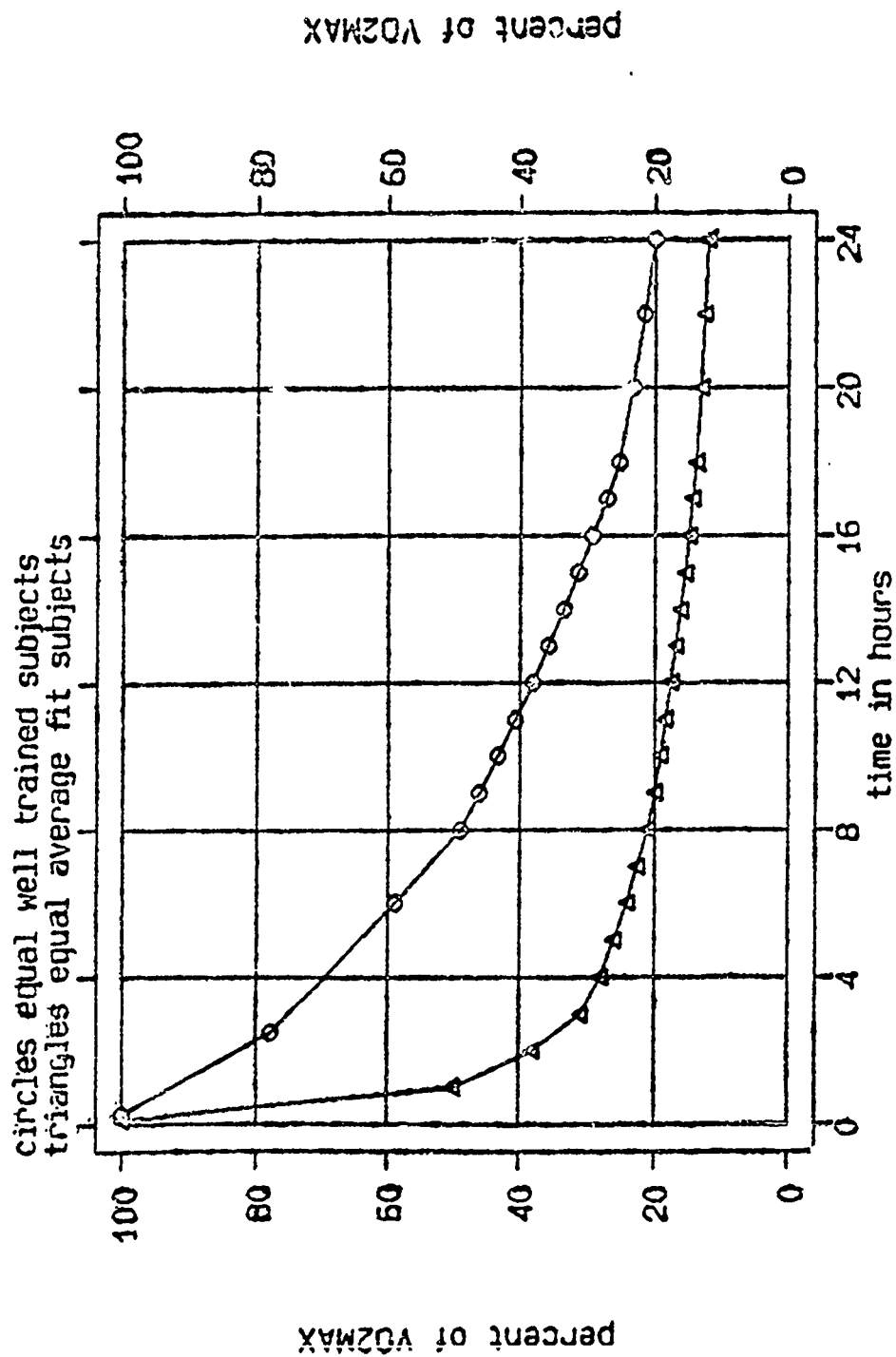
When measured by the amount of metabolic loading (as % of  $\text{VO}_2$  max), the relationship between performance and workload is curvilinear and can be represented by a second-order polynomial equation. Such equations representing cognitive functioning may be possible some day.

Figure 2 indicates the length of time one can work when working at different rates of one's maximum capacity. The curve on top represents those who are trained as opposed to untrained. As you can see, the harder you work the shorter time you can continue to perform.

Of the 100 Naval ratings reviewed by another lab, approximately 20% were estimated to required higher levels of muscular strength fitness than the low or moderate degrees of strength and stamina required of the typical navy job. This survey did not consider Marine Corps or special forces missions, or performing jobs under the conditions of sustained operations and combat. We know that those jobs typically require moderate to high levels of training and fitness. Although much of the job of the infantryman demands moderate levels of physical work (30-40% max) for long periods of time, various levels of aerobic work (50-70% depending upon training level) are typically needed only for short period of time.

The first eight hours of this data shown in figure 2 was developed by Astrand and colleagues. From the literature we were able to extend the Astrand predictions: In a typical unforced march, troops when left alone, marched at approximately 31.4% of  $\text{VO}_2$  max. In previous studies by Englund, et al., and Naitoh, et al., Marine fitness levels averaged about 50 or less  $\text{ml/kg/min}$ . At work loads carrying 25-75% of body weight Marines would be working at 22-39% of their  $\text{VO}_2$  max. For our very fit Marine subjects (average 55%  $\text{ml/kg/min}$ ) their work rate would be 20-35% max. For our highly fit subjects (above 60  $\text{ml/kg/min}$ ) the work rate would be 18-32% of maximum capacity.

If we take this information and project it into a scenario of sustained operations, a major set of additional problems emerge. Our wars of the future look something like this. First, we expect very rapid deployment of requirements for a highly intense war lasting from 10-30 days. We expect to apply maximum force around the clock with large costs in lives and equipment. Such conditions produce a great deal of emotional stress on personnel who are experiencing and witnessing the effect of combat. Sophistications and limitations in weaponry leave little if any margin for error. There





is considerable imbalance between utilizing our weaponry and human abilities and maintaining a trained force.

Now, what is the impact of all of this on military personnel. First of all, we expect the human burden is going to increase to performance limits. There is usually no time for recovery, no relief, rotation, rest and recreation, or reinforcements. It is necessary to understand and cope with disrupted organization support, such as uncertain communications and unreliable logistics, and lost leadership. We expect an extreme intensification of multiple mental and physical stress, and, predictably, there will be inefficiencies in combat performance due to sleep loss, fatigue and threats of life and limb.

What are the typical kinds of problems that are expected in sustained or continuous operations that are crucial to the performance required in this type of combat scenario? We have found vigilance and memory decrements, difficulties in concentration and encoding/decoding tasks, confusion in logical reasoning, and a general slowing down in response and reading written instructions. There is a tendency to shift strategies and also skip routine but critical steps or tasks. There are communication failures and mood changes.

What causes these problems? Typically they are the result of continuous work which produces mental and physical fatigue and sleepiness amplified by circadian processes and other stressors exceeding human tolerance limits.

When do these problems typically occur? From laboratory research we see that the problems in performance occur most dramatically when operations last for more than 24 hours without adequate rest or sleep. However, for some sedentary jobs with high mental components, such as vigilance task, there are decrement marker points after four, eight, twelve hours and eighteen hours where significant changes in performance occur. We also see decrements when rest and sleep segments are fragmented, too short, or given at the wrong time of day. And lastly, we see decrements due to sleep loss and mental workload increases, and when heavy physical workloads are combined with critical mental task requirements.

What have we learned from past combat experiences? These unfortunate "field exercises" like natural disasters, can be rich sources of knowledge if we choose to learn from them. First of all, combat exhaustion is a reality due to stressors such as extreme

and prolonged fatigue, hunger, threat to life and exposure to the elements. Breaking points are reached when physical and mental coping mechanisms reach limits. Secondly, we also see that the casualty numbers and ratios for killed, wounded and psychiatric cases, change with the latter increasing due to the stress of modern warfare. More of the wounded survive due to medical technology and available resources. We have also discovered that even though our R&D facilities are doing an exemplary job at producing advanced weaponry, the "smart technology" is often too sophisticated for most of us to operate under normal let alone stressful conditions. The demands for greater cognitive performance and skill levels have increased. We also see, as has been noted already, man as an individual or a team member, is the limiting factor in the sustained application of force in war.

From this introductory prospective, I would like to discuss what I have learned from the literature and my own work regarding physical work effects and cognitive performance. We can discuss the known literature in terms of cognitive performance while physically working, after working, and performance with physical work and sleep loss. I have previously indicated the division of information into lab and field generated data. The circadian and shift work literature will be left for another speaker or another time. An earlier speaker had emphasized the importance of field work over lab studies. In response, I would like to say that we shouldn't throw the baby out with the bath water in our haste to serve the fleet. We have learned a considerable amount from our lab studies, and as you will see in a few minutes, these data have been very effective in predicting performance in the field.

Figure 3 lists the findings of three studies that measured performance while physically working. Naitoh, Englund and Ryman (1987) found no difference between sedentary and exercise subjects performing an Alpha-numeric visual vigilance task while physically working at rates less than 30% of maximum capacity. However, Reilly and Smith (1986) found that irrespective of whether the task was cognitive or psychomotor, performance tended to fall off when exercise intensity exceeds 40% VO2 max. Also, Sucec, et al. (1988) found a 35% reduction in treadmill Total Run Time for subjects wearing chemical defense gear, which may have been due to ability to move air in and out of the gas mask.

## **LAB STUDIES 1**

### **PERFORMANCE WHILE PHYSICALLY WORKING**



- NO DIFFERENCE IN VISUAL VIGILANCE WITH 1:1 WORK/REST RATIO AT 30% MAX VO<sub>2</sub> BETWEEN SEDENTARY AND EXERCISING MARINES
- COGNITIVE AND PSYCHOMOTOR PERFORMANCE FALL OFF WHEN EXERCISE INTENSITY EXCEEDS 40% MAX VO<sub>2</sub>
- TOTAL RUN TIME REDUCES BY 1/3 IN FULL MOPP4 PROTECTIVE CLOTHING

If you expect people to physically work and then perform cognitive tasks afterward, the literature is divided into whether the physical work period consisted of short-term burst of exertion at high energy loads, or whether the physical work was long-term. Cognitive performance under these circumstances appears to be dependent upon the degree of fatigue and recovery speed. Referring to figure 4, Fleury and Bard (1987) found that treadmill running long enough to reach maximum capacity level tended to improve sensory and adaptive behaviors, but cognitive performance was significantly disturbed. Under continuous work regimens with periodic physical work periods, cognitive performance shows both workload and clothing effect. This research by Englund, et al. (1988) indicated that moderate physical work caused decrements up to 15% whereas high workloads increased the decrement up to 25% or more. Protective clothing reduced cognitive performance by 16% when compared to those subjects working without it. This study resulted in additions to the Astrand work tolerance curves as shown in figure 5. The additional data indicates the work time data for high levels of physical work and work while wearing protective clothing.

Laboratory studies where the measure of cognitive and mood variables was accomplished as part of studies focusing on physical work and sleep deprivation have shown some interesting results as listed in figure 6. These studies also measured cognitive performance after exercise. Svetens, Deboeck and Hueting (1984) tried different types of short term fatiguing techniques which had no effect when subjects performed a visual and auditory dual task following exercise. If, however, the work periods are extended with periodic exercise up to 40% of maximum capacity, the major contributing factors to decreased performance appears to be the amount of sleep deprivation and work shift. Angus, et al. (1985) studying exercise at 25-30%  $VO_2$  max for 20 of 60 hours with 60 hours of sleep deprivation found that the loss of sleep caused decrements in mood and performance. Exercise had no effect except to increase reaction time slightly. In comparisons across SUSOPS studies with a large number of subjects, Ryman, Naitoh and Englund (1985) showed that periodic physical work had no after effect on comprehension of sentence type in a logical reasoning task when the physical work ranged from 0 to 40% of maximum capacity. In other NHRC studies, Hodgdon, Englund, Naitoh (1983) found working at 30% of max in back to back continuous work sessions divided by a three hour nap, that physical work was associated with more rapid degradation in attention. Englund, et al. (1985) showed that 30%  $VO_2$  max periodic workloads did not attenuate subsequent cognitive performance, but sleep deprivation did. The work on the treadmill may have helped slightly. And lastly, Naitoh, Englund,

## LAB STUDIES 2

### PERFORMANCE AFTER PHYSICAL WORK



#### EXTENDED DAY

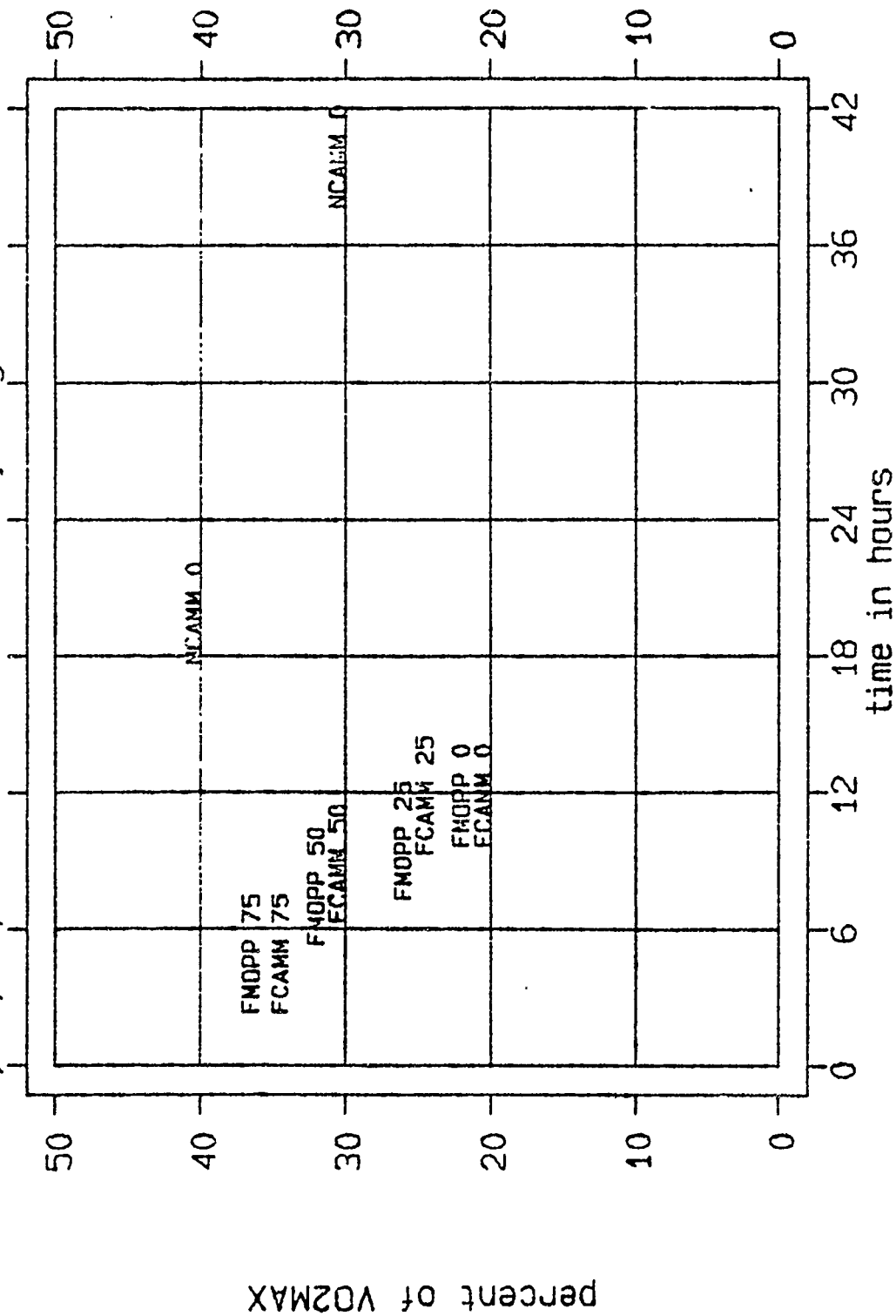
- COGNITIVE PERFORMANCE SHOWS EFFECT OF WORKLOAD
- MOPP4 GEAR CAUSED 16% WORSE PERFORMANCE THAN CAMMIES
- MODERATE WORKLOADS CAUSED UP TO 15% CHANGE
- HIGH WORKLOADS CAUSED UP TO 25% CHANGE

#### MAX TREADMILL TESTS

- SENSORY AND ADAPTIVE BEHAVIORS IMPROVE
- COGNITIVE PERFORMANCE DISTURBED SIGNIFICANTLY

# MOPP MODIFIED ÅSTRAND

F=fit N=normal MOPP=MOPP4 CAMM=CAMMIES  
0, 25, 50, 75 = load as % of body weight



ABILITY TO SUSTAIN EXERCISE WITH VARIED LOAD

# **LAB STUDIES 3**

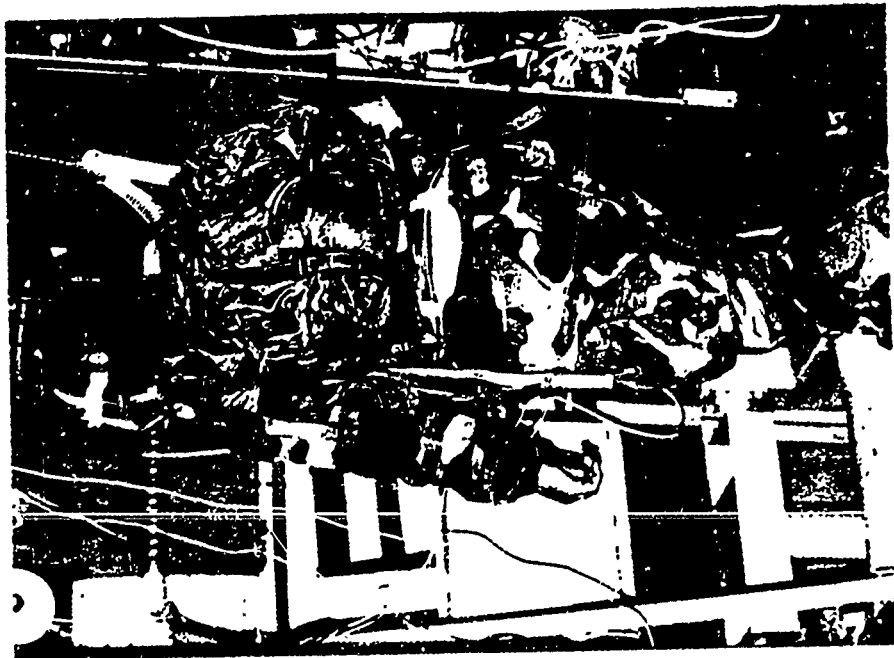
## **EXERCISE AND SLEEP DEPRIVATION**

### **SHORT TERM**

- **LEVEL OF FATIGUE DID NOT EFFECT DUAL-TASK PERFORMANCE**

### **LONG TERM (0-40% MAX. VO2)**

- **REACTION TIME INCREASES BY AT LEAST 10% AND MOOD DECREASES**
- **WORKLOAD LEVEL NOT RELATED TO COMPREHENSION OF SENTENCE TYPES**
- **ATTENTION TO TASK AND CORRECT DECISIONS AFFECTED ON SECOND SUSOPS DAY DUE TO "LAPSES"**
- **NOON IS THE WORST OPERATIONAL START TIME FOR SUSOPS**



Ryman (1987) found that 30% VO2 max workload showed that exercising subjects were slower by 10% reaction time and were less correct in a decision task. There were no differences in logical reasoning, word memory, mood and subjective measure of fatigue. The exercise effect was attributed to "lapses" of attention for subjects falling asleep on the job and producing errors of omission. In those studies the worst performance overall was found by the group starting at noon.

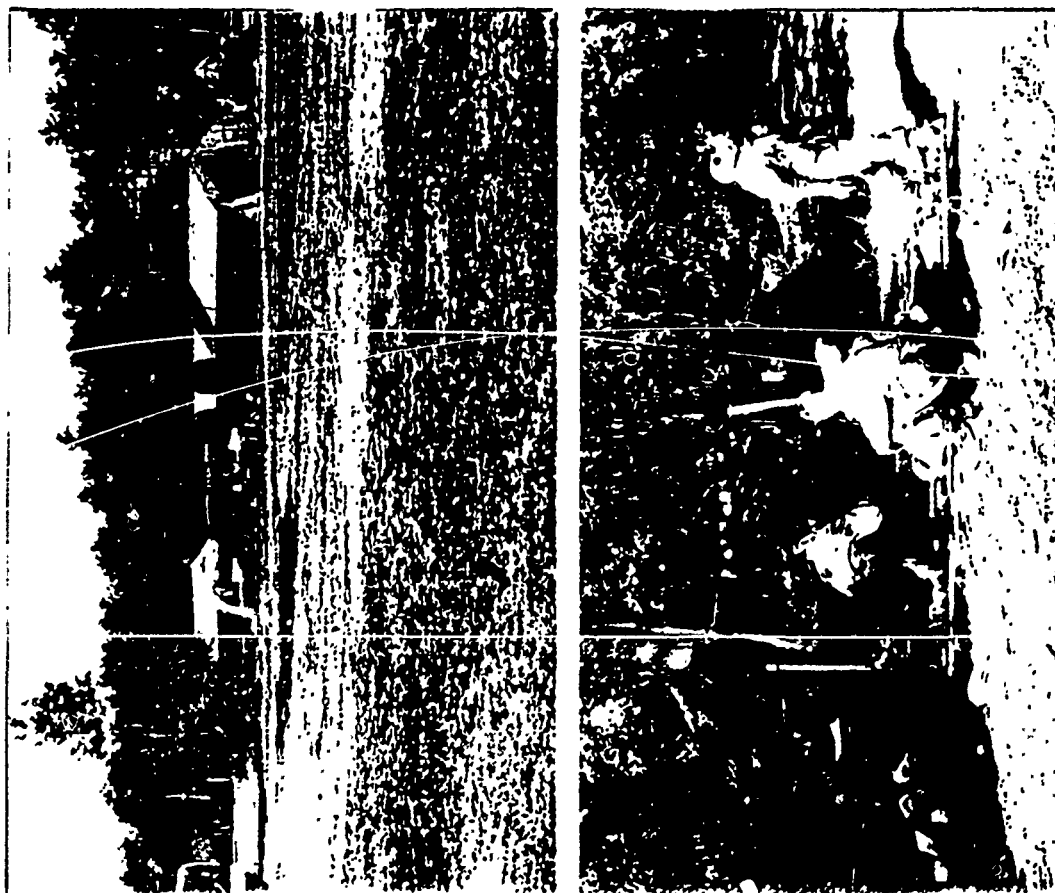
We now turn our attention to studies conducted outside of a laboratory or in a field environment. All of us who have done this work over the years know that there can be problems with data obtained in field studies. Some of the typical problems effecting the validity of field data are: (a) no control over microsleep or rest; (b) most often there is no measure of physical work; (c) very often the scenario is a typical operation, and researchers have no control over start and stop times, or other conditions; (d) it is difficult to compare results across piggy-backed training scenarios; (e) there is usually no control over prior rest or sleep; (f) the conditions are not usually standardized across participants, e.g., test/task administration, task/test hardware and software not standardized; (g) typically there is insufficient training on task/test (baselines meaningless); and (h) under field conditions it is difficult to control motivational influences.

Figure 7 shows the results of two field studies without sleep loss. Unfortunately, they both exemplify the problems associated with some field studies. In the first study in Canada by Angus, Pearce and Olsen (1981) called Fastball, moderately fit (5-58 ml/kg/min) ski patrol subjects walked during the day at 3.7 miles/hour for 21.7 miles each of six days. There were two 15-minute breaks plus one 30-minute lunch. Estimated work rate was 35-40% max. A multiple-choice reaction time task showed a learning curve throughout both baseline and recovery and stable performance during the experimental phase. The second study was conducted by Patton, et al. (1989) of Natick. This was an eight-day artillery exercise in which the soldiers had an average of 5.3 hours sleep and rest of 5.5 hours/day. The soldiers worked only about 22 minutes at 50% and 2.9 minutes at 75% of max work rate per day. There was no body weight loss observed, and muscular strength increased 12-18%.

Figure 8 lists findings of field studies with sleep loss. Add some sleep deprivation to the field environment and increase the amount of physical work and we find changes in performance. These studies, however, still showed the methodological problems typical



## FIELD STUDIES 1



### WITHOUT SLEEP LOSS

EXTENDED DAILY MARCHING ATTENUATED  
LEARNING ON INTERPOLATED CHOICE  
REACTION TIME TASK

NO BODY WEIGHT LOSS BUT MUSCULAR  
STRENGTH INCREASED WITH TYPICAL  
ARTILLERY SUSOPS

of field studies. Murphy, et al. (1984), and Legg and Patton (1987) during an artillery exercise that was more active physically than the Natick study, although the physical component was not measured, and three hours of sleep were given, soldiers lost weight, muscular strength and anaerobic capacity. However, in a 44-hour generic field exercise by Banks (1970), soldiers performed gross tasks like target acquisition, rifle firing and grenade throwing satisfactorily. And, Haggard (1970) showed that simple, well learned tasks like tank driving, gunnery and maintenance showed no measurable decrements in a study by HumRRO. With moderate physical work, but extreme sleep loss studies like that of Haslam (1981-1989) in England, we begin to observe the effects predicted by laboratory work. The Early Call Studies contained moderate physical work made up of typical infantry base/perimeter setups and fire fights with varied amount of sleep. Physical work was not measured. The conclusions were that small amounts of sleep help, physical tasks suffered least and cognitive tasks deteriorated more rapidly and to a greater extent. Performance was down to 50% of base line within 24 hours, e.g., decoding. Small amounts of sleep appear more beneficial after sleep loss. With just four hours of sleep, performance was back to 75% of baseline. All subjects reported visual hallucinations by 2-3 days.

Figure 9 summaries field studies with extreme physical work and sleep loss. Opstad and colleagues have been collecting data on the Norwegian Ranger training course for years. In one study Opstad, et al. (1978a) studied 18 cadets for four days with no sleep (no control for microsleep) and severe caloric deficit. Cognitive performance decrements, which are task dependent, after 24 hours had dropped from 25-45% baseline. and after 96 hours, the drop in cognitive efficiency ranged from 46-60%. Again field studies, and lab studies, have shown that some sleep helps. Opstad, et al. (1978b) studied participants during another Ranger Training course for four days with n=44, same conditions, but four sleep groups: tests of visual vigilance, reaction time, code test, sorting test, command memory, and shooting were measured. The results were similar to the previous study, except that deficits with groups who had three and six hours of sleep over the four days, were less affected by the course conditions.

One of the most important facts emerging from the Norwegian studies is the role of ego defense mechanisms in performance. Miyhrer (1987), during the Ranger Training course in Norway, gave cadets the Defense Mechanism Test which can predict inadequate performance during stressful events. The conclusions were that severe physical exercise plus sleep deprivation, break down typical defensive structure and a

## FIELD STUDIES 2

### WITH SLEEP LOSS

- SOLDIERS LOST WEIGHT, STRENGTH, AND ANEROBIC CAPACITY WHEN PHYSICAL WORK INCREASED
- WELL-LEARNED AND/OR SIMPLE MILITARY TASKS MAY NOT BE AFFECTED VERY MUCH
- WITH EXTREMES OF SLEEP LOSS, PHYSICAL TASKS SUFFER LEAST, COGNITIVE TASKS SUFFER THE MOST
- SMALL AMOUNTS OF SLEEP HELP ALOT
- COGNITIVE PERFORMANCE DOWN BY 50% IN 24 HOURS
- HALLUCINATIONS COMMON WITHIN 2-3 DAYS



Bill Mauldin in Stars and Stripes

*"Maybe Joe needs a rest. He's talkin' in his sleep."*

# **FIELD STUDIES 3**

## **EXTREME PHYSICAL WORK AND SLEEP LOSS**



- **MILITARY STYLE COGNITIVE TASK  
PERFORMANCE DECREASED 20-50%  
WITHIN 24 HOURS, DOWN BY 60% BY 96  
HOURS**
- **3-6 HOURS OF SLEEP IN 96 HELPED**
- **DEFENSE MECHANISM STRATEGIES  
CHANGE, WITH SIGNIFICANT NEGATIVE  
IMPACT**
- **FITNESS MAY ATTENUATE DECREMENTS IN  
COGNITIVE WORK AND FATIGUE RATE,  
BUT COULD INHIBIT RECOVERY PROCESS**
- **MOPP CLOTHING WITH THERMAL LOADING  
HAS DRASTIC IMPACT**

new set is temporarily established. This implies a reduced ability to recognize the threat in dangerous situations. It appears that inadequate defensive strategies are chosen during stressful events and may imply that under extreme fatigue people have decreased ability to execute important commanding functions. Recently Opstad (personal conversation, August 1988) indicated that those rangers who had asserted leadership one day during the course were unable to lead the next day.

There are three subjects that require special mention since they have interactive effects upon physical and cognitive work. The role of measurement of fitness is one of the least understood factors in field performance and in particular, how this factor interacts with the other factors I have discussed thus far. Pleban, Thomas and Thompson (1985) studied a pre-ranger evaluation exercise with military tasks, such as, logical reasoning, map-plotting and encoding/decoding. The course was described as physically demanding with sleep loss for 2.5 days, although physical work load was not measured. The results indicated that fitness may attenuate decrements in cognitive work and moderate fatigue rate; however, fitness may have negatively correlated with cognitive and fatigue recovery processes.

Another problem area is the factor of protective clothing. I have mentioned the clothing and thermal effects previously with regard to my own studies which were conducted in thermal neutral environments. Headley, Brecht-Clark and Whittenberg (1989) investigated MOPP versus no-MOPP in artillery operations lasting up to 24 hours with very hot and humid weather. The MOPP subjects only lasted two hours, whereas the no-MOPPers made it all the way through the increasing performance times as the ops progressed. There was no measure or comparison of physical work except the number of missions completed.

The third factor deals with the phenomena of fatigue. This factor is very difficult to define let alone measure. Fatigue can be thought of as the inability or willingness to continue performance of a mental or physical task effectively and is caused by work overload. Holding (1983) has shown that subjects who are extremely fatigued physically will continue to perform given sufficient incentives. A psychological component appears to play an important role in the continuance of skilled physical and mental performance with increasing fatigue. Few fatigue studies have been conducted in operational settings. Those that have typically involve sleep loss and raised more questions than they answered primarily due to poor methodologies or methodologies more applicable to

laboratory settings. Fatigue and sleep loss are often covariants in studies of continuous, long work schedules, and in turn, both are modulated by circadian processes. Since the effects of these variables interact it is difficult to separate what is attributable to one or the other factor. Figure 10 summarizes the general findings about the effects of fatigue.

This conference ultimately is intended to deal with the problem of modeling human performance. I have taken this opportunity to share my thoughts on the matter by discussing factors which I consider important. Figure 11 represents my contribution to the modeling effort. It is intended to be a generic model describing the interactive effects of multiple factors influencing human performance. From this model, and the work of assembling this paper, I have identified several important issues requiring further attention. Here are some examples of what we need to find out:

1. Mental fatigue needs to be as well known as physical fatigue; in particular, understanding what are the underlying mechanism producing it.
2. Which type of fatigue producing factors primarily apply to shipboard work? To the Marines? (Knowing this will allow up to formulate remedies).
3. For tasks at sea which are primarily sedentary and rely on cognitive performance, what causes the cognitive fatigue? Stress reactions? And what types of fixes are appropriate, e.g., machine changes, training, organization, and contextual. Ships should be designed to enhance performance.
4. Research investigating physical work about 40% of max is lacking in the military setting.
5. Physical work at different work-rest ratios is lacking as is the role of fitness.
6. Interactions of physical work, sleep loss, circadian or other factors are not well understood because most studies do not measure these factors simultaneously.

# FATIGUE

- EFFECTS OF FATIGUE OFTEN NOT RECOGNIZED BY FATIGUED PERSON
- FATIGUED INDIVIDUALS SHOW:
  - DEGRADED PERFORMANCE
  - IMPAIRED LEARNING
  - DIFFICULTY IN THINKING
  - MEMORY DEFICITS
  - INCREASED REACTION TIME
  - LESS CONTROL
  - IRRITABILITY
  - MARITAL PROBLEMS
  - SEXUAL DYSFUNCTION
  - PAY LESS ATTENTION
  - MAKE MORE MISTAKES
  - SELECT RISKIER ALTERNATIVES
- FOR SHORT PERIODS, FATIGUED INDIVIDUALS CAN OVERCOME FATIGUE AND CIRCADIAN EFFECTS
- SHIFTWORK INCREASES PROBLEMS
- COMPLEX TASKS MORE AFFECTED THAN SIMPLE TASKS



Bill Mauldin in Stars and Stripes  
*"Wish I could stand up an' get some sleep."*

7. A concerted review of the literature base is necessary.
8. We need as researchers to identify what we require from the modeling community and what they require from us.
9. Where is the work needed? (a) Lab studies—to elucidate current issues and generate solid data for modeling activities. (b) Field studies—to validate model. (c) Arenas—both Marines and sailors. (d) Locations—shipboard, altitude, cold, heat, and damage control. (e) Areas—field workload measurements and technology, shift work, task loading, load bearing, team effects.

In summary:

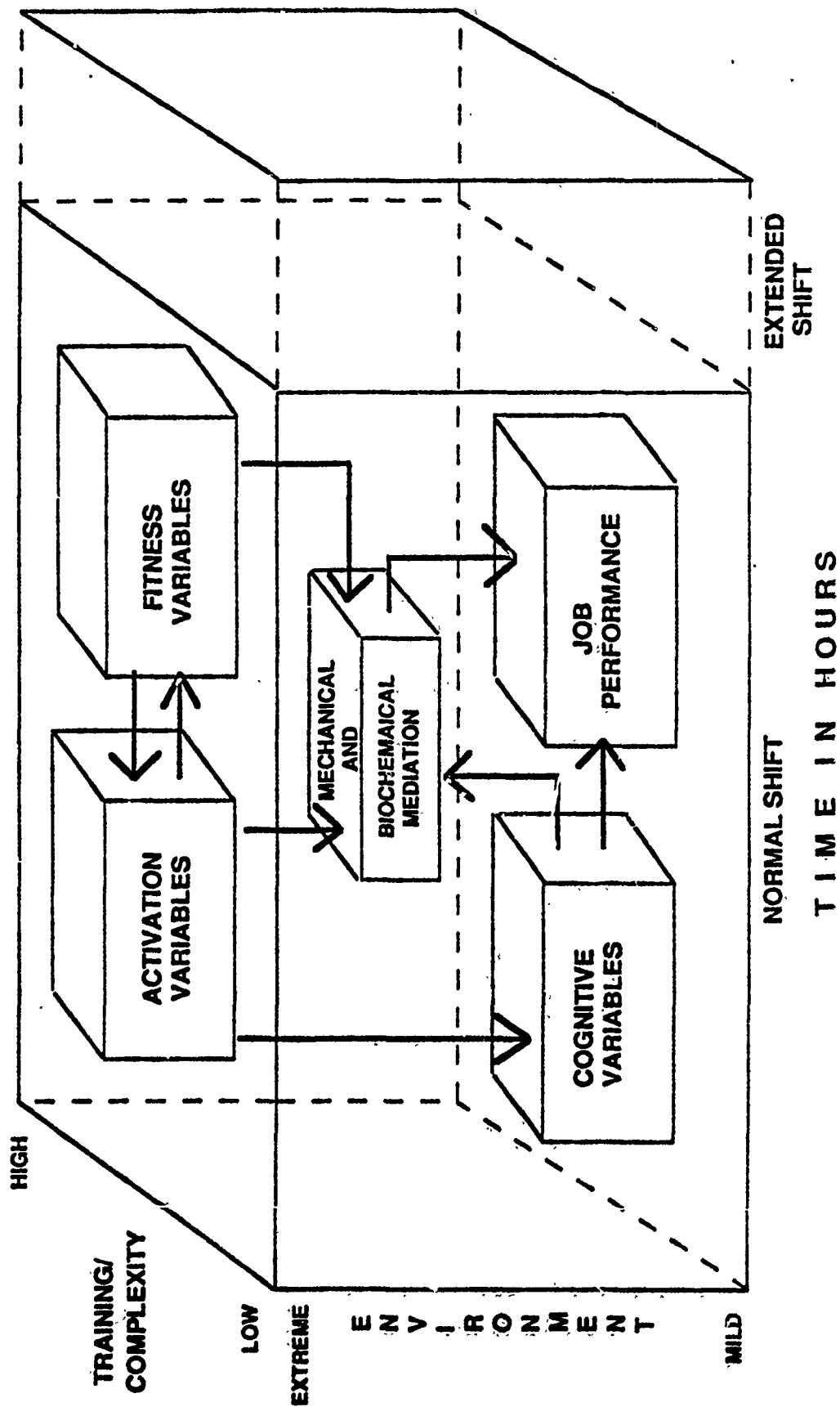
1. Military operations studies in the field thus far show rapid cognitive and vigilance task deterioration but little aerobic or submaximal endurance effects.
2. RSG-4 Report (1986) recommends high levels of fitness are required to undertake prolonged physical activity in SUSOPS.
3. Astrand and Rodahl (1970) reports 50% of max for a whole working day is too high; much worse for the individual not trained for it. (By the end of an 8-hour day the untrained are unable to work more than 22-23% with dramatic drop to 50% of baseline after first hour and 30% after four hours).
4. Optimal loading (less than 38% VO<sub>2</sub> max, 120 beats/min) is near that recommended by Astrand (1967) for heavy industrial work for a complete shift.
5. If hydration and blood sugar are maintained, performance capacity is better maintained during prolonged exercise.
6. Work/rest ratios are extremely important to long-term performance.
7. Field studies are best as validation vehicles, in particular, when measures are appropriate applied and researchers have some input into the conduct of the exercise.



Figure 11 is my attempt to put order into the thinking about sustained performance research. It is a model that I sketched out several years ago and affords the opportunity to visualize the major issues for research in the area. Now it's up to all of us to determine what research is still required to finish the job.

Thank you very much.

# A GENERIC MODEL FOR SUSTAINED PERFORMANCE



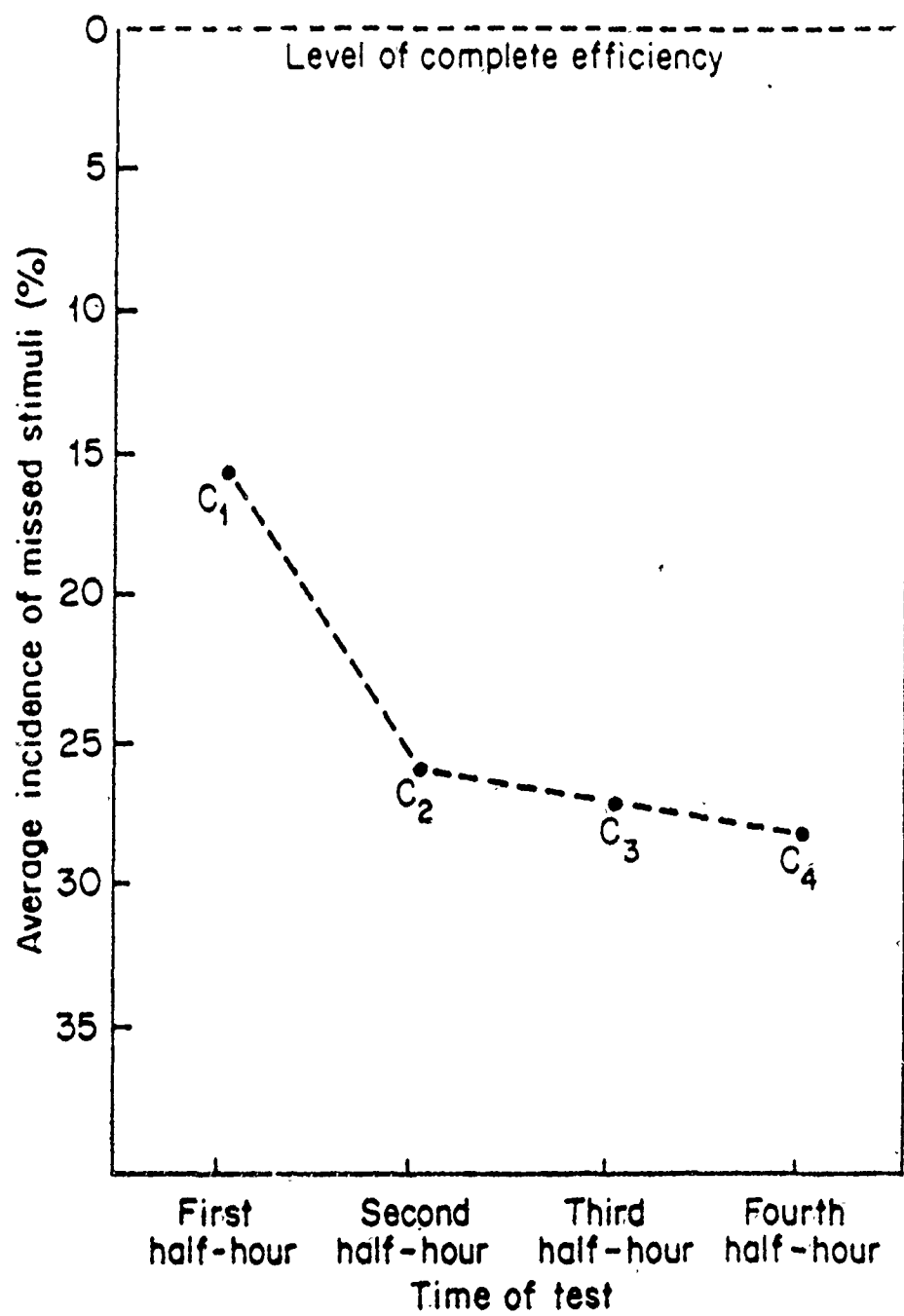
CAPT CHANEY: The next speaker, LT Dave Kobus, will review work on sustained vigilance.

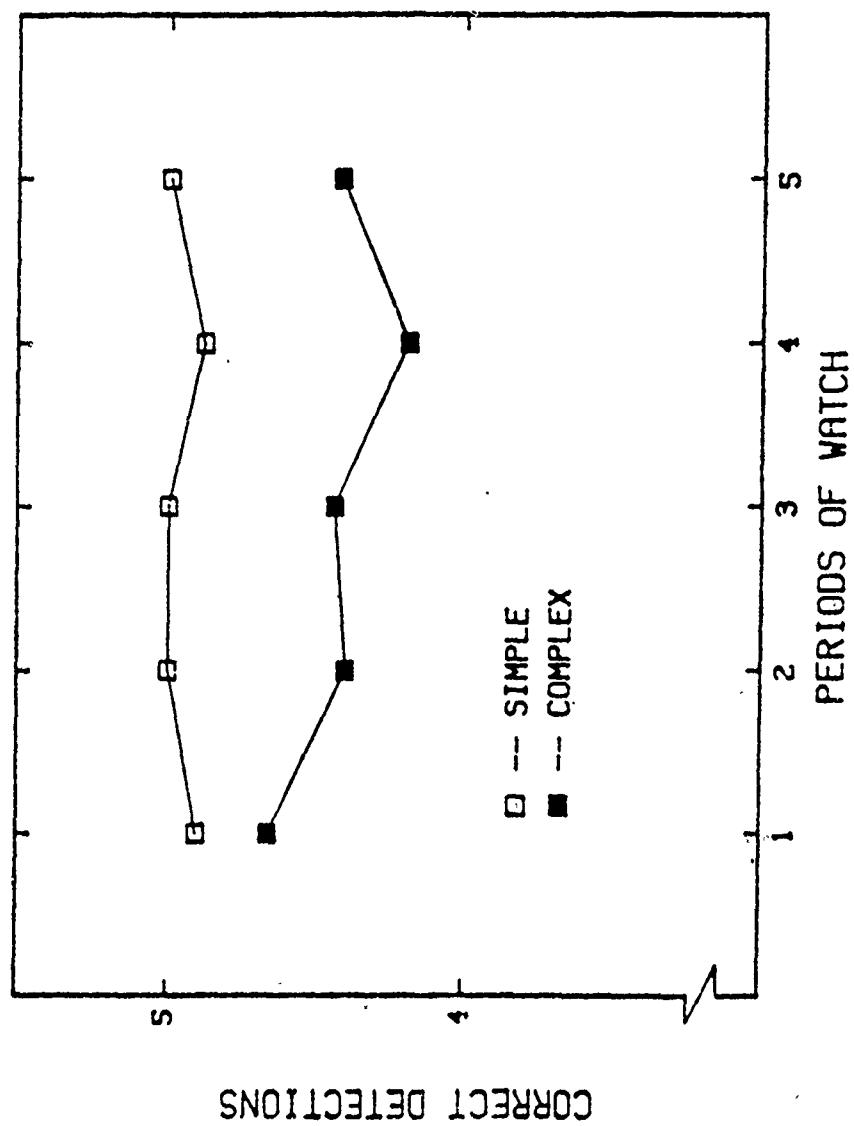
Lieutenant David A. Kobus, MSC, USN  
Sustained Operations Department, NHRC

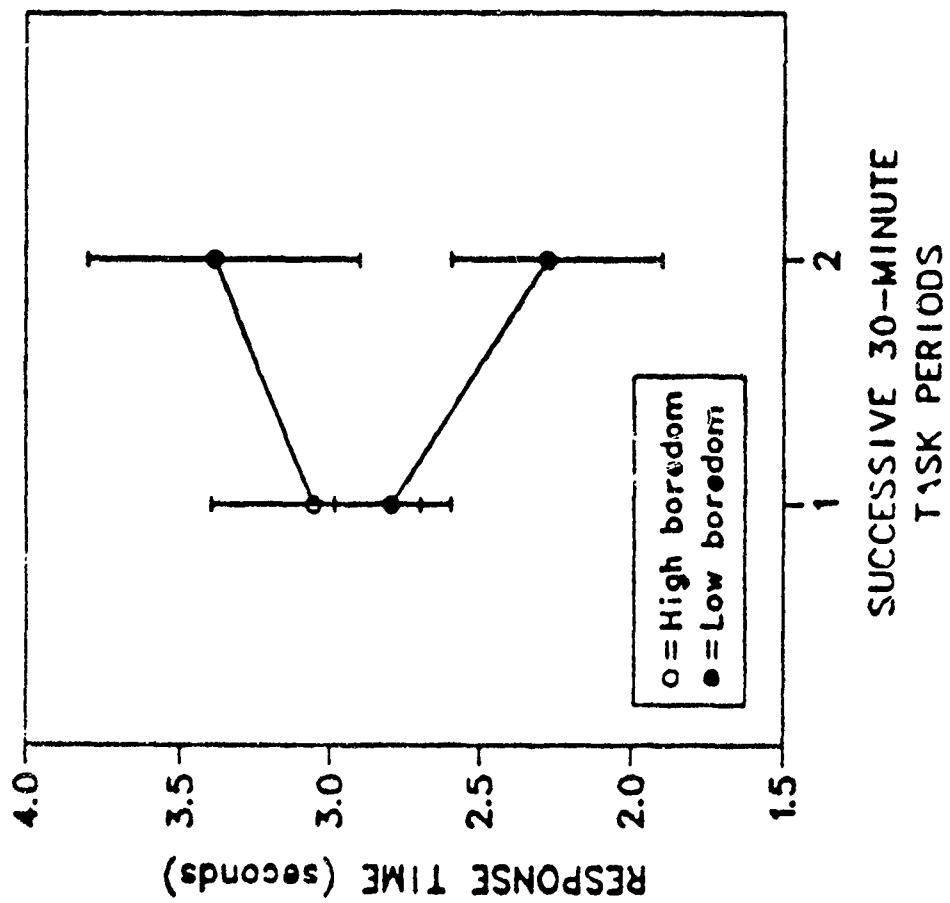
LT KOBUS: Thank you Captain. I feel like a little kid who just had a sugar overdose. While listening to all of you talk, I'm becoming as hyperactive as Dr. Helmreich was this morning. There seems to be so many things to say, and I'm afraid that I'm going to forget to say them all, so I've jotted little notes over my notes, and I hope I don't forget anything. I have been given 20 minutes to review what has taken 40 years to do and that's to cover the issue of sustained vigilance. I'd like to make a comment regarding Dr. Cherry's talk this morning. He said he's interested in what goes on after information is received by the operator. I think that's very critical and something we really need to be concerned with--after they detect the information. The individual first has to detect that information before he can do anything with it. I don't care if you're talking about the tank operator, the sonar operator, the radar operator, or the pilot; regardless of the task, detection always needs to take place. So I'm going to be talking primarily this afternoon about what I call the first three stages of cognition and that's going to deal with what the individual attends to detects, re-attends and then recognizes.

I'd like to give an example of sustained vigilance testing adapted from Joel Warm. I was going to be a little melodramatic and say the time could be today, tomorrow, or yesterday, but hopefully you will understand it.

"A U.S. P3 flies over the North Sea. Inside an observer peers at a speckled, flickering radar screen, looking at a telltale spot of light or blip which would signal the presence of a hostile submarine. The observer has been on watch a little over 30 minutes, nothing much has happened. Perhaps this mission, like so many others, will be fruitless. Suddenly, the blip appears but the observer makes no response. The blip appears a few more times, still, the observer fails to respond. The signal was undetected and, as a result, so was the submarine."







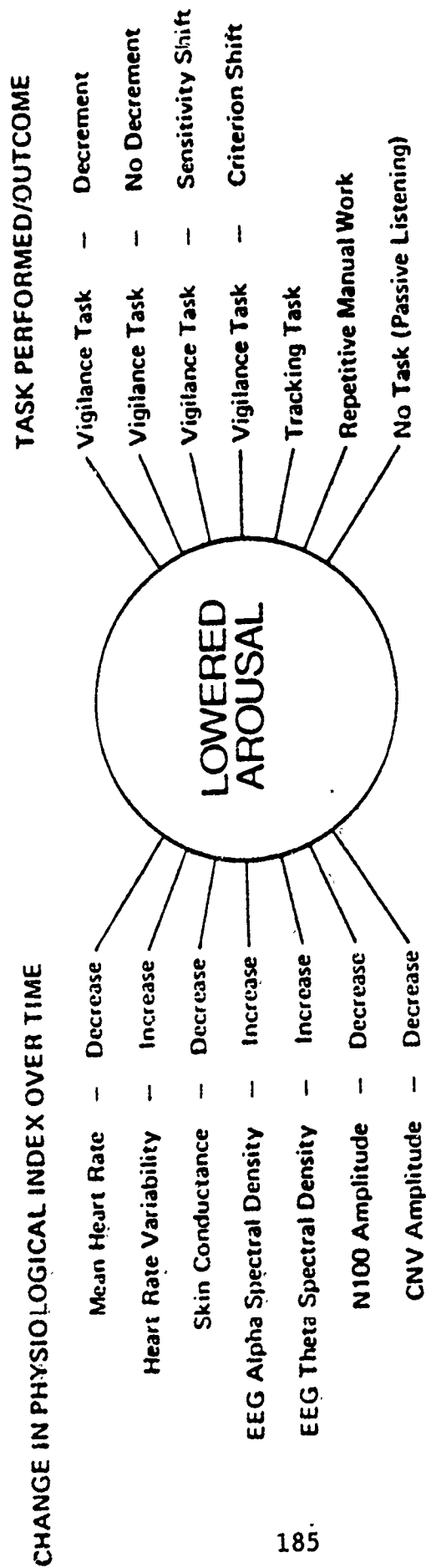
This is a classic vigilance decrement that has been presented by Joel Warm, and it was performance similar to this that led to the work of Macworth right after World War II (WW II).

In Macworth's study he was tasked by the Royal Air Force to look at radar operators who were missing U-boat targets, and the Royal Air Force was wondering what was happening to their performance. Macworth came up with a simulated radar task and found there was a tremendous degradation in performance and in detection performance after just 30 minutes. Additionally, if the task lasted two hours, he found the decrement in performance continued over the two-hour period. This progressive decline of performance has been termed the decrement function or vigilance decrement. Well, I'm not going to worry you with a lot of history. Over the years, a thousand different studies have been performed and published in this area.

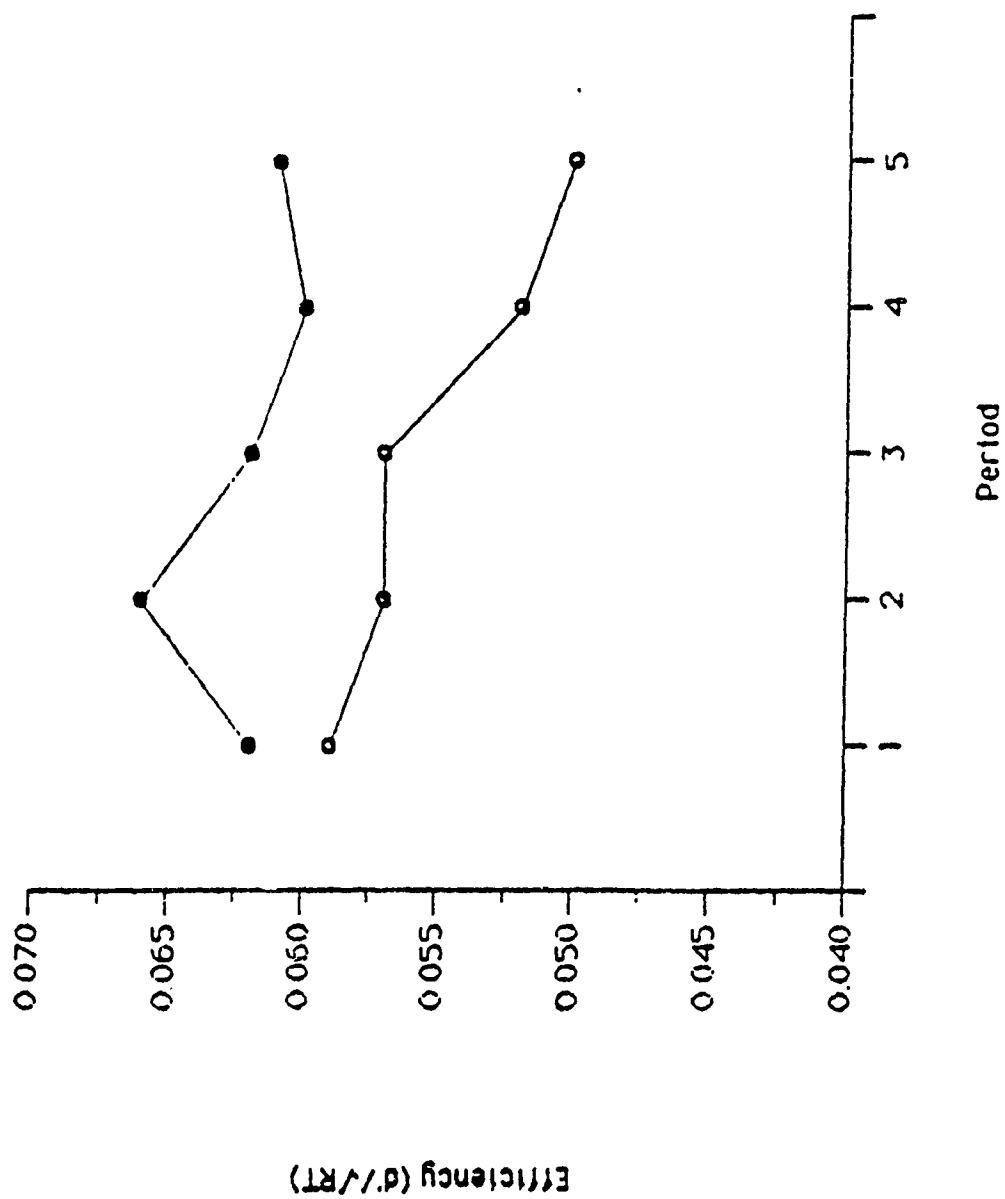
Countless variables have been identified that influence the level of performance. These are the variables you will have to include if you are making a model of human performance. These include variables that are related to stimulus characteristics, signal complexity, and signal rate, but also independent measures that need to be considered like motivation and individual differences. Today, I don't have enough time to cover every variable, so I will just talk about a few of these.

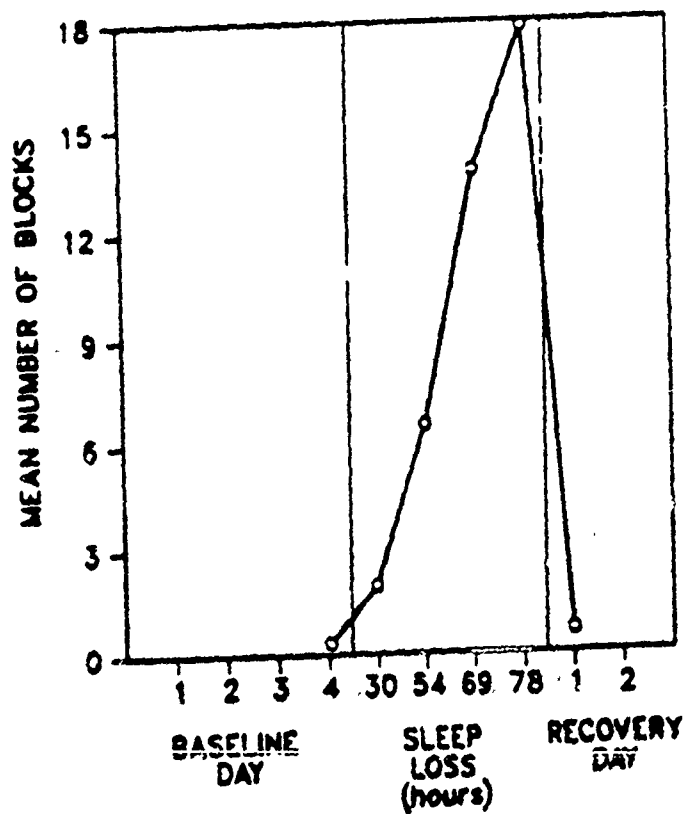
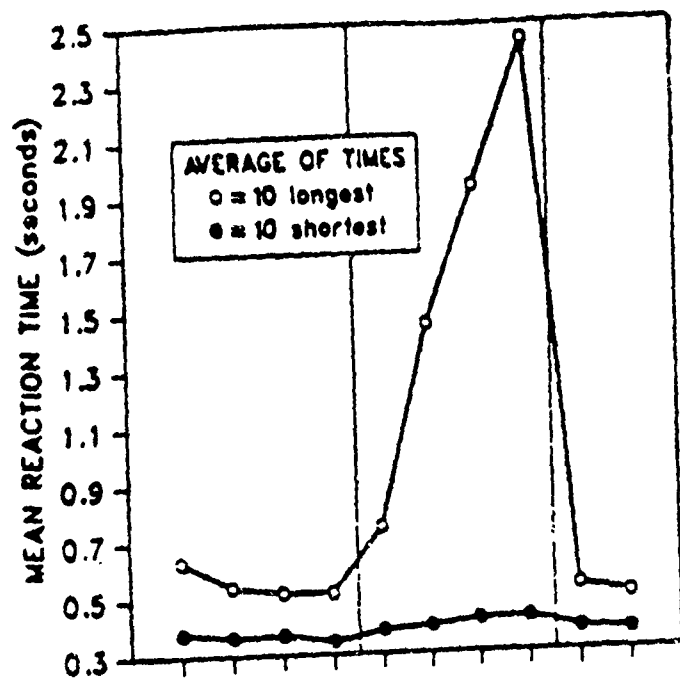
The first one is signal complexity. Keep in mind people that we're concerned with are visual display operators—sonar operators, radar operators, and traffic controllers. These are simple detection tasks. One of the variables is signal complexity. With very simple tasks we see very little or no degradation in performance; however, if the task is somewhat complex, we see a degradation of performance with increasing task complexity.

Boredom also affects the speed of response. If we have a highly bored group, we see a slight decrease in performance or actually an increase in reaction time and as time goes on, these differences are exacerbated between our highly bored group and low bored group. Now, associated with boredom is arousal of motivation. There are a whole host of physiological measures affected due to low arousal as well as various changes in task performance. Here I have vigilance tasks down twice, once indicating decrement and once without the decrement; that really is related to task complexity. We may have the decrement or we may not. If we do have a decrement in performance, it could be related to either a sensitivity shift in the individual or a criterion shift. We also have a









LABORATORY VS. REAL-WORLD MONITORING SITUATIONS

TASK DURATION

WORK-REST SCHEDULE

FREQUENCY OF TARGET OCCURENCE

TARGET DISCRIMINABILITY

NUMBER OF TARGET ATTRIBUTES TO BE MONITORED

COMPLEXITY OF RESPONSE

problem with tracking, competitive manual work, and no task (passive listening). It's the sonar operator I'm concerned with. I am concerned with one other variable and that's the N-100 which we monitor at Naval Health Research Center. It is associated with sonar performance. The N-100 is highly correlated with detection performance, and we find a decrease in the amplitude of N-100 with low arousal.

Circadian rhythm as you know also affects performance. In the morning we all perform pretty well; our performance degrades in the afternoon. Also, with sleep loss we have a significant increase in aberrant reaction times as you would expect. The table for this is right down here. Actually I've shown you the slide for another reason. We know that sleep loss and these variables affect performance, but I think what is important is how they affect performance. I think many times we overlook that. We say sleep affects performance. What I wanted to show you was that with sleep loss these are our 10 fastest response times and these are our slowest response times. What happens is reaction time does increase with sleep loss, but what really increases is the variability in responses. I think that's important to know.

Well unfortunately, most of the investigations that have been performed in all of these tests that I've shown you so far were simulated laboratory studies. Rather few studies have been performed in an operational setting.

Several difference appear to exist between the laboratory and the real world situation. For instance, task duration. Task duration is an important variable, and I'll tell you why. When you run a laboratory experiment, one of the things you have to let the subject know is how long he is going to be there. So expectation is developed and that expectation actually affects performance. If you want to get a performance decrement in a vigilance task, tell your subject he's going to be there 30 minutes but keep him there for about an hour. That's what happens in a real world operation. They guy goes out and sits on the sonar stack or sits at the radar panel for his 30 minutes, only to find out he's going to be there 1 to 1-1/2 hours.

Work-rest schedules. This was brought up this morning, I believe, by Dr. Cherry. Something we don't incorporate in our laboratory studies.

Frequency of occurrence: Many times when they are trying to detect targets, they occur very infrequently. One of the biggest factors in vigilance performance is actually boredom but in the laboratory you can't use one trial. That would be a waste of time so

you end up giving them 10 to 20 trials within the hour and really what you've done is enhance performance.

What do we know about operational tasks? As Dr. Cherry mentioned this morning if you really want to know about the stressors, go right to the source. Ask the individuals what's the number one stressor for them. Mackie did just that. He asked submarine operators, surface ship operators, helicopter operators to rate the stressors that affect their vigilance performance. What I'd really like to point out here is a couple of things. The first five stressors are almost identical among all of these operators, and they are from different communities. We've taken into account in this chart two things: one, the aspect of time and the other, the aspect of fear. Over time we have boredom. Boredom and monotony affect performance if the operators have too much time on their hands. Another aspect of time is operator overload. It can affect performance when we don't have enough time on our hands. But look what happens with fear. Fear is way down here, rated as #19, and I don't think that's primarily due to the fact that most of the people in these studies have never had the opportunity to be in a real life threatening situation.

Boredom, as I said, is number one. These are predictions from the laboratory studies. We expect increased lapses of attention, increased variability in detection time. What do we know from the real world. Well, we know motivation is affected and overall effectiveness is down.

Fatigue. We know fatigue affects performance. Again, from our laboratory studies we see increased lapses of attention, increased operational errors, and overall effectiveness is affected. It has a strong impact on all phases of operations. It also affects physical performance as Dr Englund pointed out. Does fatigue have a significant impact on operational performance?

I'll let you make that decision for yourself. Dr. Helmreich says planes just don't fall out of the sky if there's teamwork. Well, this is right out of the newspaper as of last Wednesday, and it seems that planes are falling out of the sky even with teamwork, if the crew all fall asleep at the same time.

Another important stressor, and I really want you to think about this, as I thought about it when I was in the CO's office this morning, is command pressure. That affects our performance with increased selectivity of attention (or tunnel vision), increased

Average Rankings of the Adverse Impact of 19 Stressors on Overall Sonar Operator Effectiveness (Worst Listed First)

Submarine Operators	Surface Ship Operators	Helicopter Operators
1. Boredom, monotony	1. Boredom, monotony	1. Fatigue, tiredness
2. Fatigue, tiredness	2. Fatigue, tiredness	2. Boredom, monotony
3. Command pressure	3. Displays/controls	3. Displays/controls
4. Displays/controls	4. Night watch-standing	4. Operator overload
5. Operator overload	5. Command pressure	5. Command pressure
6. Workstation design	6. Operator overload	6. Workstation design
7. Heat	7. Workstation design	7. Vibration
8. Illness	8. Noise	8. Noise
9. Noise	9. Illness	9. Cold
10. Air contamination	10. Motion sickness	10. Lighting
11. Lighting	11. Lighting	11. Heat
12. Night watch-standing	12. Heat	12. Platform motion
13. Cold	13. Platform motion	13. Illness
14. Air pressure	14. Cold	14. Motion sickness
15. Platform motion	15. Air pressure	15. Night watch-standing
16. Motion sickness	16. Vibration	16. Risky peacetime ops
17. Vibration	17. Risky peacetime ops	17. Air contamination
18. Risky peacetime ops	18. Air contamination	18. Threat of enemy action
19. Threat of enemy action	19. Threat of enemy action	19. Air pressure

Source: From Wylie, Mackie, and Smith (1985).

Table 2. BOREDOM

Aspects of Performance Reportedly Most Affected	Predictions from Behavioral Research
● Vigilance (search)	● Increased lapses of attention
● Motivation	● Increased variability in detection time
● Overall Effectiveness	● Suboptimal arousal

Table 3. FATIGUE

Aspects of Performance Reportedly Most Affected	Predictions from Behavioral Research
• Vigilance	• Increased lapses of attention
• Overall effectiveness	• Increased operational error
• Strong impact, all phases of operation	• Reduced rate of information processing
	• More variable performance
	• Reduced reserve capacity



## **Pilots falling asleep on job as wearing schedules take toll, experts warn**

### **Airline crews fall asleep at controls, researchers report**

**LONDON (AP)** — British airline pilots on long-haul flights say their entire crews have fallen asleep at the controls because of strenuous work schedules, researchers report.

### **Pilots' fatigue linked to loss of Stealth jets**

But they mention a problem of pilot fatigue that a commander in the Stealth program, Lt. Col. John F. Miller Jr., described as "a time bomb waiting to go off," KIRO said.

response time, reduced quality of performance, and increased frustration and anxiety. We do a lot of complaining when our command puts pressure on us to come up with the right performance. Again, this is from the laboratory. What do we see in the real world—decision making is screwed up, motivation is low, and overall effectiveness is down.

Operator overload. This is a big one. I'd like to point out two things in particular. Decisions and actions are taken with reduced consideration of all available information. It sort of smacks of the VINCENNES operation: not enough time, uncertainty, increased risk of catastrophic breakdown, too much information and too little time to assess it, and need to make a response. What happens? Overall effectiveness goes down.

The question then is how much do we really know. These are all of the stressors we had rated. This is our current state of knowledge linked to performance. I'd like to point out right here that for four out of the top five that have high impact on performance, we have insufficient knowledge at the present time. For only one in the top five, displays and controls, do we have adequate knowledge. As mentioned this morning, there is some effort by the Navy now to go into human factors engineering.

So, what are we doing about it and I mean specifically here at NHRC. Well, one of the things we are doing is to go directly out to the fleet to collect vigilance data. We are presently conducting a study, actually just beginning a study, where we are doing a detection experiment with sonar operators on submarines; it takes 2-1/2 months to collect data. That's only 50 trials per subject. What does it give us? One thing is high task relevance because we're doing actual operational tasks in the natural setting. The thing I'd like to point out, and it's been reiterated many times today, is that as we get greater operational relevance, our degree of experimental control goes down. Although right now it's set up to look at the individual performance, we're going to be able to extend this to teamwork performance of overall sonar operations as well as full ship performance.

So what else can be done? You will note there are several things that have been suggested as ways of enhancing performance in vigilance tasks. I'd like to point out two. You've heard some things about heat and although we haven't said too much about noise, our gentleman from NBDL was talking about ship motion or vibration and ways of enhancing performance. In addition, I want to point out the use of biofeedback as an

Table 4. COMMAND PRESSURE

Aspects of Performance Reportedly Most Affected	Predictions from Behavioral Research
● Reasoning, decision making	● Increased selectivity of attention
● Motivation	● Increased response rate
● Overall effectiveness (particularly submariners)	● Reduced quality of performance
	● Increased frustration, anxiety
	● Increased arousal
	● Increased distractability
	● Reduced parallel information processing

Table 5. OPERATOR OVERLOAD

Aspects of Performance Reportedly Most Affected	Predictions from Behavioral Research
<ul style="list-style-type: none"> <li>Reasoning, decision making</li> </ul>	<ul style="list-style-type: none"> <li>Increased psycho-physiological "cost" in maintaining performance</li> </ul>
<ul style="list-style-type: none"> <li>Overall effectiveness (especially submariners)</li> </ul>	<ul style="list-style-type: none"> <li>Decisions, actions taken with reduced consideration of all available information</li> <li>Increased risk of catastrophic breakdown in performance</li> </ul>

Table 1. RELATIONSHIP BETWEEN JUDGED IMPACT AND STATE OF KNOWLEDGE FOR 19 STRESSORS

CURRENT STATE OF KNOWLEDGE (Linkage to performance)	JUDGED IMPACT ▽		HIGH	MEDIUM	LOW
	INSUFFICIENT				
			1.* Boredom 2. Fatigue 4. Command pressure 5. Operator overload 19. Danger from enemy action	11. Minor illness 13. Motion  14. Vibration 15. Motion sickness 16. Air contamination 17. Risky peacetime operations 18. Uncomfortable air pressure	
	ADEQUATE		3. Display/Control design 6. Work station/ personal equip- ment design	7. Midwatch (circadian effects) 8. Heat 9. Noise 10. Illumination 12. Cold	

alertness indicator. NHRC is presently funded by ONT to look into electrophysiological performance of individuals and relate this to on-line performance. What we're doing is using components such as the N-100 to monitor detection performance, provide feedback back to the operator and supervisor, to indicate the level of performance of that operator.

At the present what can be contributed to modeling efforts? This is a model of vigilance performance that accounts for 97% of the variability for detection performance and for response time performance it accounts for about 77% of the variability. Unfortunately, the model I just showed you is for a single task and we know there is a whole host of elements that affect human performance. Those are the things that need to be taken into account simultaneously, and I think we need to look at them all. Thank you.

**MALE VOICE:** Is there any communication here with the systems commands and do these kinds of data translate into engineering changes?

**LT KOBUS:** We interact now only with NOSC and NSMRL on things that might address hardware changes.

**MALE VOICE:** Are you working with the combat systems groups at NOSC? In two weeks we are going to have a draft set of specs for general purpose display for review and comment, and we'll send one. I wonder if these kinds of findings we're talking about here are being translated for engineers and systems commands to incorporate design changes that would affect vigilance defects in new equipment.

**LT KOBUS:** Let me just address that very quickly. Most people here are either physiologists or psychologists. Any engineers in the group? Oh gosh, sorry. A couple of engineers. Engineers usually don't like us around because we slow down the work. Let me say that again a different way. What I mean by slow down the work is that we have to come in there and clean up after them. Many times what happens is that the design system will overload the man. He can't handle all the capability. I was a sonar operator for nine years. We had great new equipment. What did we do with it? We shut it off. We couldn't handle all the input that we had. Automatic detection, poof!—we didn't need that. We wouldn't believe it. What happens is the engineer's goal is to get a system out there, on the line, as quickly as possible. The more bells and whistles the better.

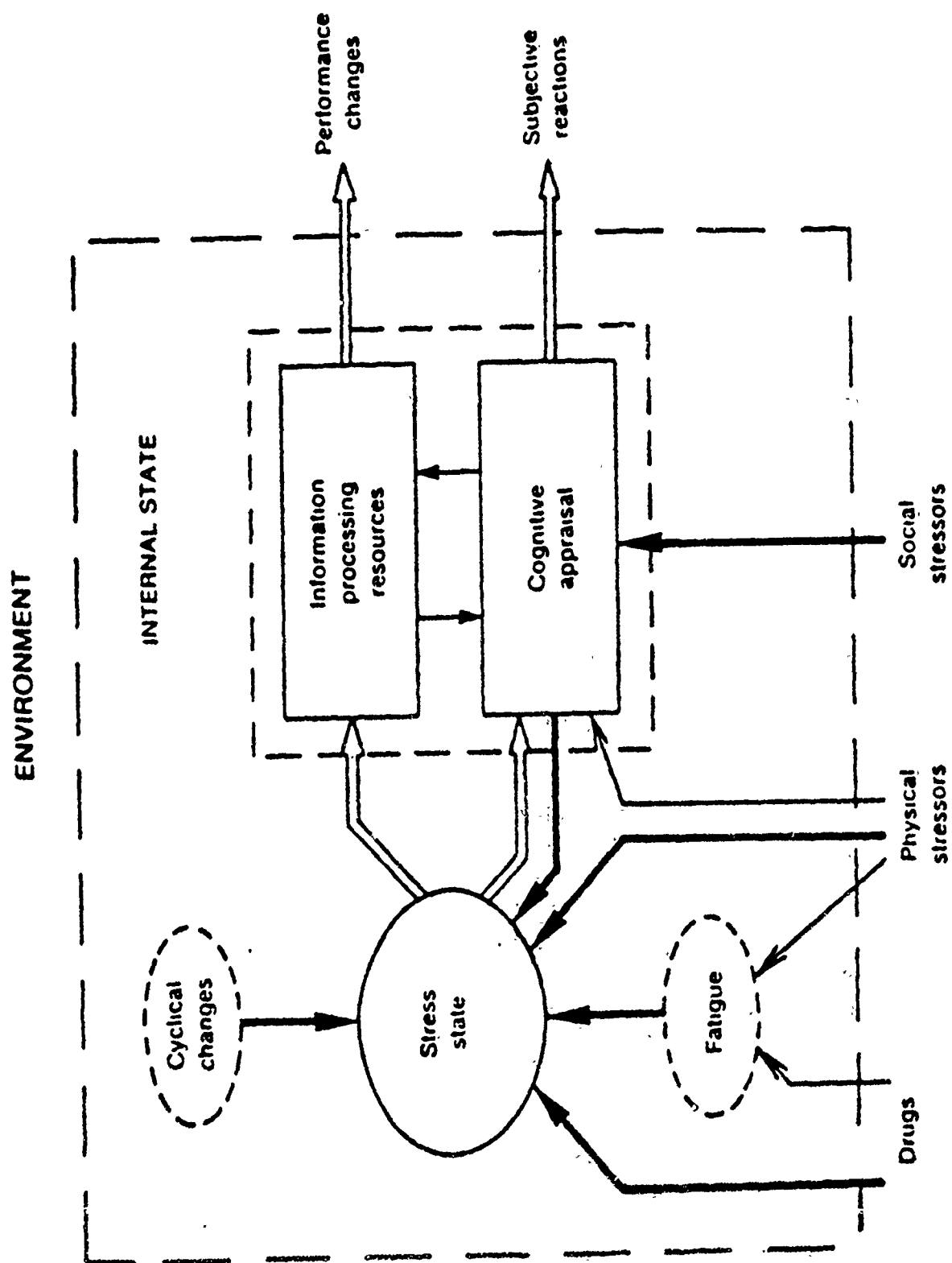
## **Suggested Methods for Ameliorating the Effects of Low Vigilance or Reducing the Vigilance Decrements**

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Reduce temporal/spatial uncertainty of signal appearance  
Reduce uncertainty about what constitutes a signal (through training)  
Increase signal conspicuity  
Increase signal frequency or regularity (i.e., through signal injection)  
Reduce stimulus event rate (where rates are very high)  
Permit operators to work at own pace (if possible)  
Provide appropriate work/rest schedules  
Provide task variation (rotation: interpolation of different activities)  
Institute confidence reporting (multiple levels)  
Provide Performance Feedback  
Instill motivation by emphasizing task importance (especially when the costs of a missed detection are great)  
Provide varied auditory stimulation  
Introduce mild environmental stress (heat, noise, vibration)  
Provide observation by supervisors  
Use biofeedback-associated "alertness indicators"  
Employ alerting secondary tasks  
Train operators to use optimal standards for reporting (i.e., appropriately balance omission/commission errors)  
Use personnel selection techniques to identify individuals with a propensity for maintaining vigilance

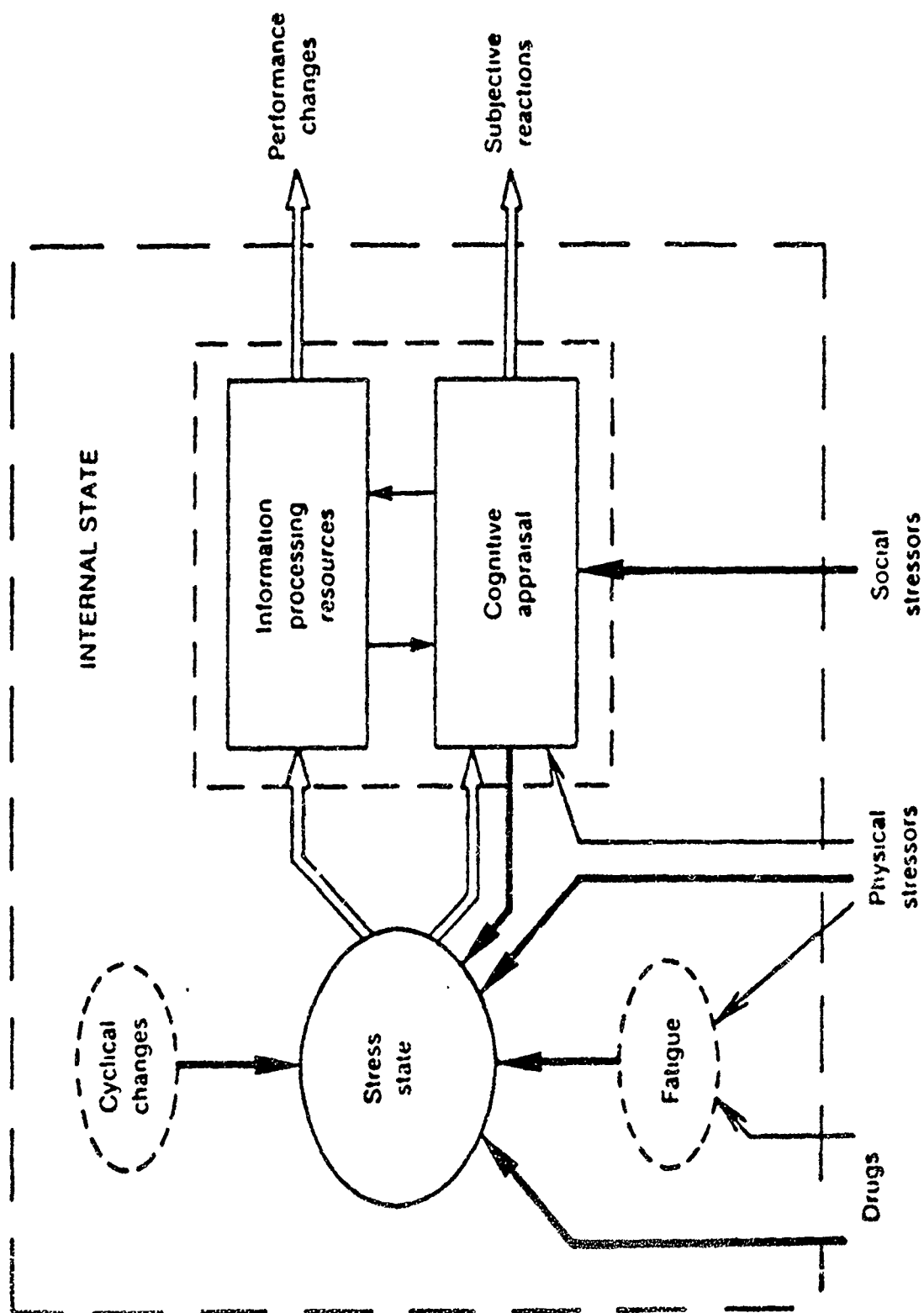
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Based on suggestions of Davies and Parasuraman (1982) and Craig (1984)





ENVIRONMENT



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CAPT CHANEY: Our next speaker is Dr. Paul Naitoh who will discuss the effects of sleep deprivation on performance.

Paul Naitoh, Ph.D.  
Sleep Research Department, NHRC

DR. NAITOH: Thank you very much. This year I'm selling an idea of "napping on the work site" in order to recuperate from fatigue of sleep deprivation. I'd like to distinguish it from "napping on the job" which should be avoided at all cost.

If you sleep in your chair, facing away from the office door and your colleagues, you are "napping on the job," because no one knows that you are asleep. We assume that you are awake and working, a dangerous assumption in some work environments. If you turn around in your chair to face the office door or your work team members and take a nap, this is "napping on the work site." Everyone knows that you're sleeping--hopefully with full approval of your supervisor and the members of your work team.

This afternoon, I'd like to discuss sleep deprivation effects (SDEs) on performance (Table 1). First, I'd like to state that sleep loss does, in fact, affect performance. Secondly, I'd like to touch briefly on the complexity of defining stressors. We tend to carelessly say that sleep produces the stressor effect. I would like to give you a little more information about what we mean by stressors and sleep loss. Then, I'd like to give you a brief overview of what we know about sleep deprivation effects and what kind of sleep deprivation we are studying now. Lastly, but most importantly, I'd like to discuss with you the kind of research we should be doing in the future. I list three things I consider to have priority, one of which is concerned with human performance prediction models.

(1) Sleep loss affects performance. To illustrate that sleep loss does affect performance, I picked two examples (Table 2). The first example is the NHRC Plus-7 task, and the second one is the Multiple Talk Performance Battery (MTPB) designed by Dr. Earl Alluisi and his colleagues. The MTPB is also known as a "Synthetic Task."

The NHRC Plus-7 task is a simple mental addition task. For example, a subject is asked to add 7 to 403 mentally and then to enter 410, the answer, into a keyboard. The subject is to add another 7 to the previously obtained sum, 410, and enter the new sum

### Sleep Deprivation Effects (SDEs) On Performance

1. Sleep Loss Affects Performance.
2. Sleep Loss Is A Stressor
3. What Do We Know About SDEs On Performance?
4. What SDEs Are We Currently Studying?
5. Targeting For Behavioral Prediction Model.

Table 1

1. Sleep Loss Affects Performance.

- o Example 1 NHRC Plus-7 Task
- o Example 2 MTPB (Synthetic Task; Alluisi, et al.)

Table 2

417 to the keyboard, and so on. Figure 1 is a polygraphic snapshot of Plus-7 task. You see on the top two electroencephalograms. On the third channel, SP stands for Skin Potential; HR, heart rate; FP, finger pulse; Resp, respiration. This subject, Jim Y., is very steady in adding, completing six additions in 30 seconds. Figure 1 shows that the task session started five minutes ago during the fourth baseline day. Figure 2 shows the same subject after five minutes into the task following two nights of sleep deprivation. During sleep deprivation, you see that the number of additions was reduced by one-half to three additions. The polygraphic snapshot tells you what happened. Obviously his ability to add correctly and to memorize the answer is intact after sleep deprivation because he pressed the answer 424 after correctly adding 7 to 417 (Task channel of figure 2). What happened to him was that somehow he could not respond in a steady fashion. He experienced two 10-second long lapses where there were no responses made. This is a kind of study where we examined what is happening to human beings during sleep deprivation.

The Plus-7 is a much simpler task compared with the MTPB or Synthetic Task by Alluisi, Coates, Morgan and others. Dr. Alluisi's MTPB is shown in figure 3. The subject can be asked to do all or some of the six tasks (e.g., probability monitoring, target identification, code-lock solving, etc.) simultaneously. Under these complex laboratory conditions, a performance decrement is very clearly seen during sleep deprivation.

In figure 4, you see that Alluisi and his colleagues evaluated MTPB performances of three groups of subjects under three different sleep deprivation durations, each lasting from 36 to 48 hours. The baseline performance on DAY 7 and DAY 8 (left two panels), then, the performance during two nights' sleep deprivation (DAY 9 and DAY 10), and performance after recovery sleep (DAY 11 and DAY 12). I would like to emphasize that performance decrement due to less than two days' sleep deprivation can be as great as 30% of the baseline. These examples will convince you that there are, in fact, sleep loss effects on performance of laboratory tasks.

(2) Sleep loss is a stressor. Before I give you an overview of what we know about sleep deprivation, I'd like to touch briefly on whether or not sleep loss is a stressor. Rechtschaffen and his colleagues<sup>1</sup> suggested that sleep loss does not show classical indications of stress (see Table 3). That is, the sleep deprived subjects do not develop adrenal hypertrophy, increased corticosteroid secretion, and other stress symptoms.

Naval Health Research Center Plus-7 Task (Baseline)

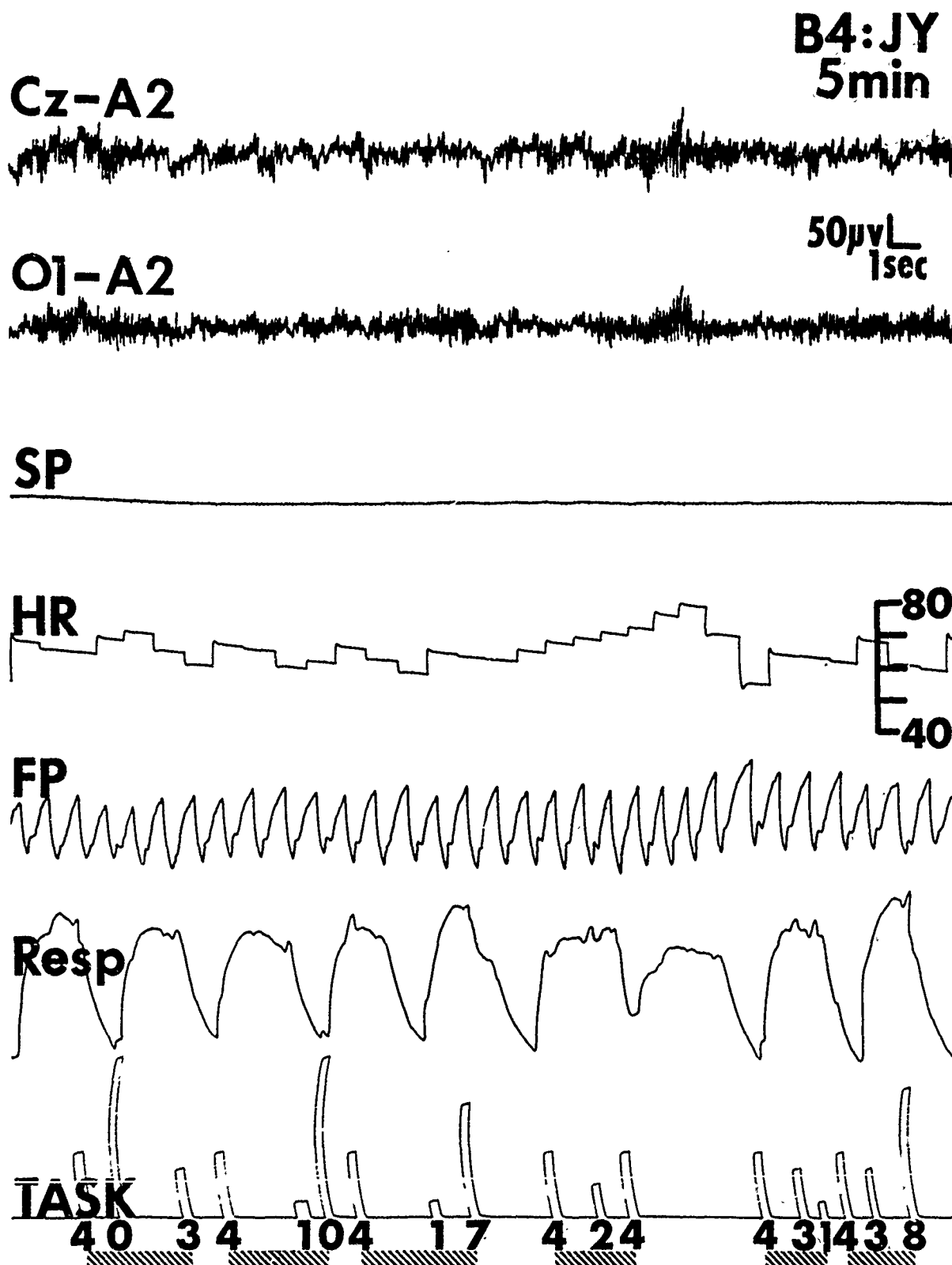


Figure 1

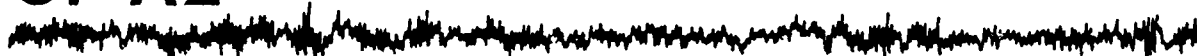
Naval Health Research Center Plus-7 Task  
2 Nights of Sleep Deprivation

D2:JY  
5min

Cz-A2



O1-A2



50 $\mu$ V  
1sec

SP



HR



FP



Resp

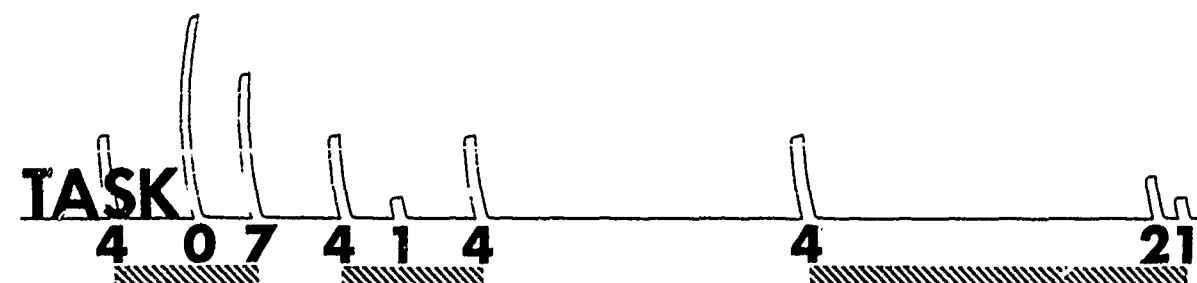
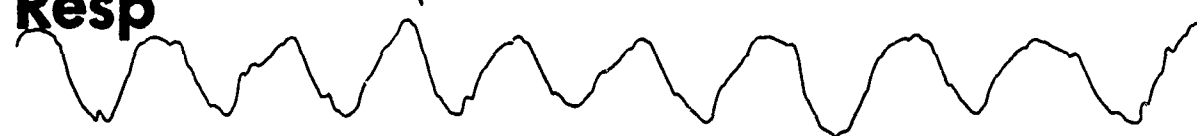


Figure 2



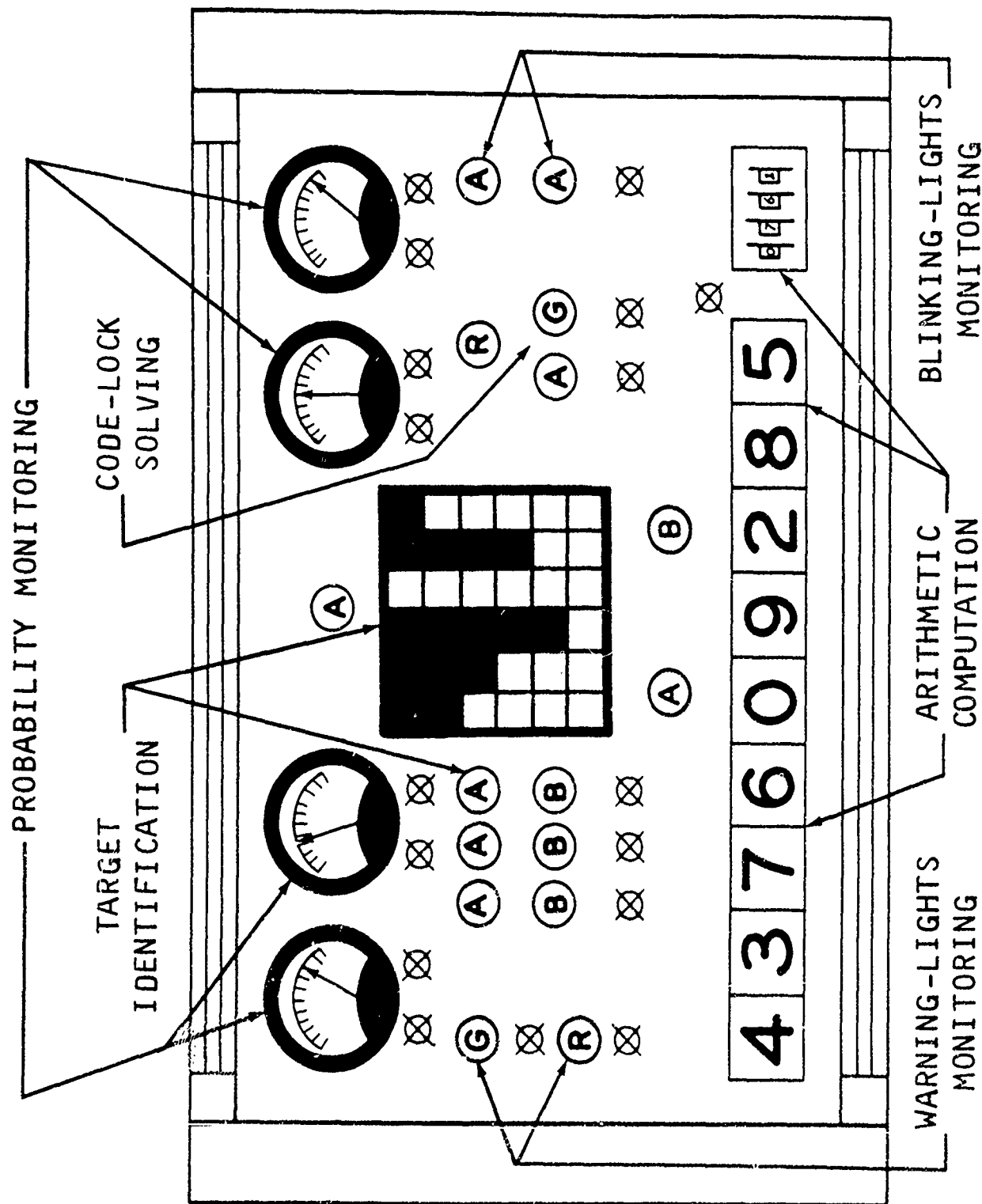


Figure 3

## 2. Sleep Loss Is A Stressor.

- o Rechtschaffen et al. (1989) suggested that sleep loss does not show Selye's classical indicators of stress.
- o Sleep loss synergistically increases performance degrading effects of other stressors.

Table 3

# Sleep Loss and Synthetic Task (Alluisi, Coates, Morgan, et al.)

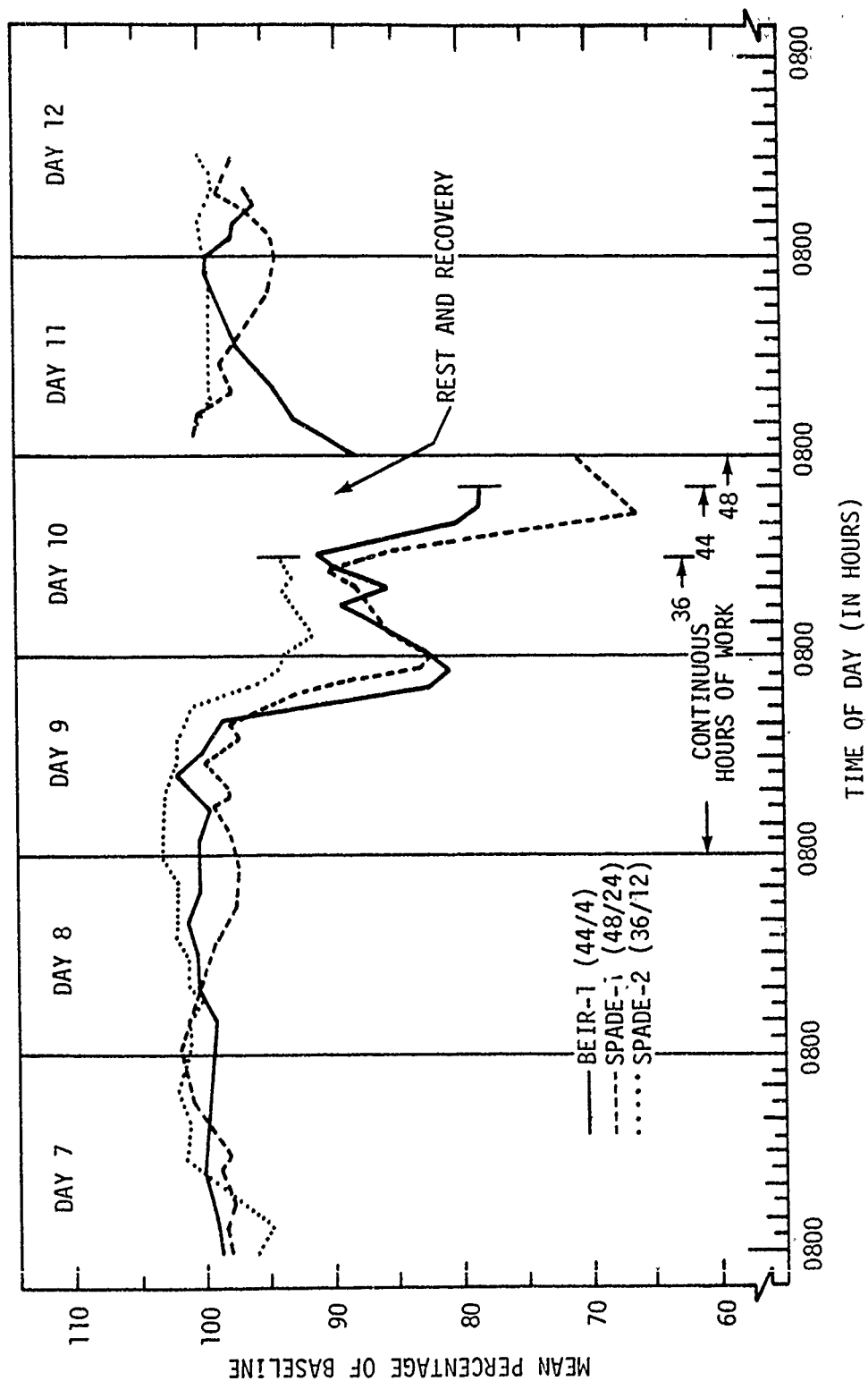


Figure 4

Instead of being a classical stressor, we believe that sleep loss is a stressor in the sense that it synergistically increases degrading effects of other stressors. Sleep loss interacts with other stressors and tends to amplify the ill effects of other stressors.

(3) What Do We Know About SDEs On Performance? We know that sleep loss interacts with cold, heat, noise, alcohol and heavy physical workload in degrading our performance. Research on SDEs in the 1980s, and hopefully in the next decade, are marked by a tremendous upsurge of military interest in sustained operations (Table 4). A series of studies of SDEs on military performance have been conducted at the Army Personnel Research Establishment (UK) by Diana Haslam and her colleagues.<sup>2</sup> At the Defense and Civil Institute of Environmental Medicine (DCIEM) in Canada, Robert Angus and his associates have contributed to understanding of SDEs on behavior, physiology, and biochemistry.<sup>3</sup> Walter Reed Army Institute of Research (Washington, D.C.) has kept its leadership role in SDE research.<sup>4,5</sup> At the Naval Aerospace Medical Research Laboratory (Pensacola, FL), a research team, of Charles DeJohn, Dennis Reeves, O. G. Blackwell, and others, are studying Navy air sustained operations using a stimulant to assist in maintaining flying performance. At the U. S. Army Aeromedical Research Laboratory (Fort Rucker, AL), Gerald Krueger<sup>6</sup> has been involved in sustained operations research.

(4) What SDEs are we currently studying at NHRC? What kind of sleep deprivation effects are we currently studying at NHRC (Table 5)? We have decided to thrust ourselves into the arena of finding the measures to cut down the degrading effects of sleep deprivation on performance. We believe that we know enough about SDEs and that now is the time when we ought to find some means to minimize SDEs. Currently we are looking for stimulants to maintain performance during prolonged work period. We are also thinking about using short naps to counteract SDEs.

(5) What needs to be done? An important question we should be asking will be about a future research direction. What kinds of SDEs we should be studying for the next year or for the next couple of years? I have listed three areas which need research (Table 6).

First of all, we need research on the effects of sleep loss in frustrating and hostile work environments. In the 1940's, Tyler and others<sup>7</sup> at the California Institute of Technology, conducted sleep deprivation research involving several hundred volunteers. This study was conducted in a work environment where volunteer subjects were harassed

3. What Do We Know About SDEs On Performance?

- o Synergistic interactions of sleep loss with cold, heat, noise, alcohol and heavy physical workload.
- o Series of studies at APRE, UK (Diana Haslam), DCIEM, Canada (Robert Angus), Walter Reed (Gregory Belenky), NAMRL (Charles DeJohn). USAARL (Gerald Krueger), and NHRC.

Table 4

4. What SDEs Are We Currently Studying At NHRC?

- o Search for counter-measures to reduce performance degradation
- o Navy Air SUSOP: NHRC Navy SUSOP  
Stimulants  
Ultra-Short Naps

Table 5

5. What Needs To Be Done.

- o Example 1 Research on sleep loss and frustration in work environments.
- o Example 2 Research on sleep loss and war-gaming involving "Decision Making" under Compressed Time Stress.  
DCIEM/NHRC/Walter Reed plans for sustaining war-gaming.  
Examinations of TWSEAS-IMC data and of AURA.
- o Example 3 Research on behavioral prediction models.

Table 6

psychologically and subjected to a long night march under paratrooper-like hard disciplines. Under these working conditions, some of the volunteers developed frank paranoid mentation, expressed overt aggression, and experienced 22% dropout. In contrast, the volunteer subjects in the Walter Reed study showed none of the above reactions, although they were deprived of sleep for a similar duration of time.<sup>8,9</sup> The major difference of the Walter Reed study from a 1947 Cal Tech study is the warm and supporting work environment extended toward the subjects in the Walter Reed studies. We cannot do the Cal Tech sort of research today in laboratories, because we cannot harass our subjects to the extent of simulating hard, real-life, frustrating combat environments. I believe, however, that we can do research on synergistic interactions between work environments and sleep loss by expert field observations.

The second research we should conduct is the effects of sleep loss on war-gaming which involves decision-making under compressed time stress. Currently, DCIEM and Walter Reed are active in sustained war-gaming research. We at NHRC will be examining the data set from the Tactical Warfare Simulation Evaluation and Analysis System (TWSEAS) at Camp Pendleton.

Lastly, the most interesting research in the future is to look at the possibility of writing a behavioral prediction model. The very first question we should ask is whether we can really write behavioral prediction models. On the strength of Walter Reed data bases, I can tell you unequivocally that we can write such a model predicting performance in sustained operations.

(6) Targeting for Behavioral Prediction Model. In the remainder of my presentation, let me give you more details about what kind of evidence makes me assert that a behavioral prediction model can be written. Once having established that a behavioral prediction model can be written, I will give you more details about NHRC Nap-mediated Performance Restoration Model (Table 7).

Figure 5 is taken from a Walter Reed study, showing performance scores of eight separate tasks taken by many subjects.<sup>5</sup> This study involved 72 hours of sleep deprivation. The Y-Axis shows percent change from baseline performance. The X-axis shows hours of sleep deprivation (hours awake). These eight tasks are different from each other, but their performance scores show a family resemblance: a declining trend in performance for all eight tasks. To emphasize a trend common to all eight tasks,



6. Targeting For Behavioral Prediction Model.

Behavior Model can be written (e.g., Walter Reed database)

NRHC Nap-mediated Performance Restorative Model

Table 7

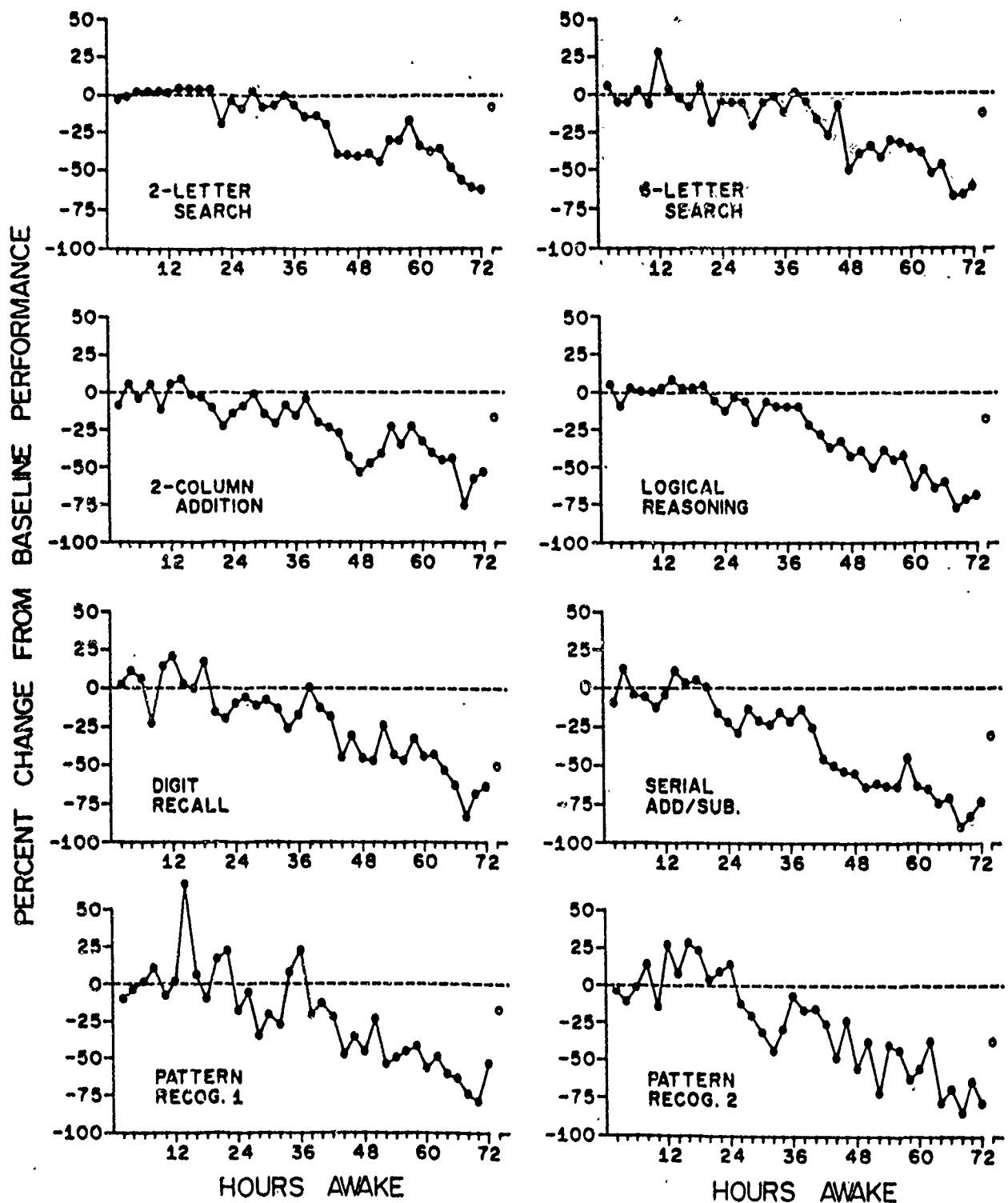


Figure 5: Mean change in performance vs time awake for eight tasks averaged across seven subjects. Open circles show recovery after a four hour nap (Walter Reed).

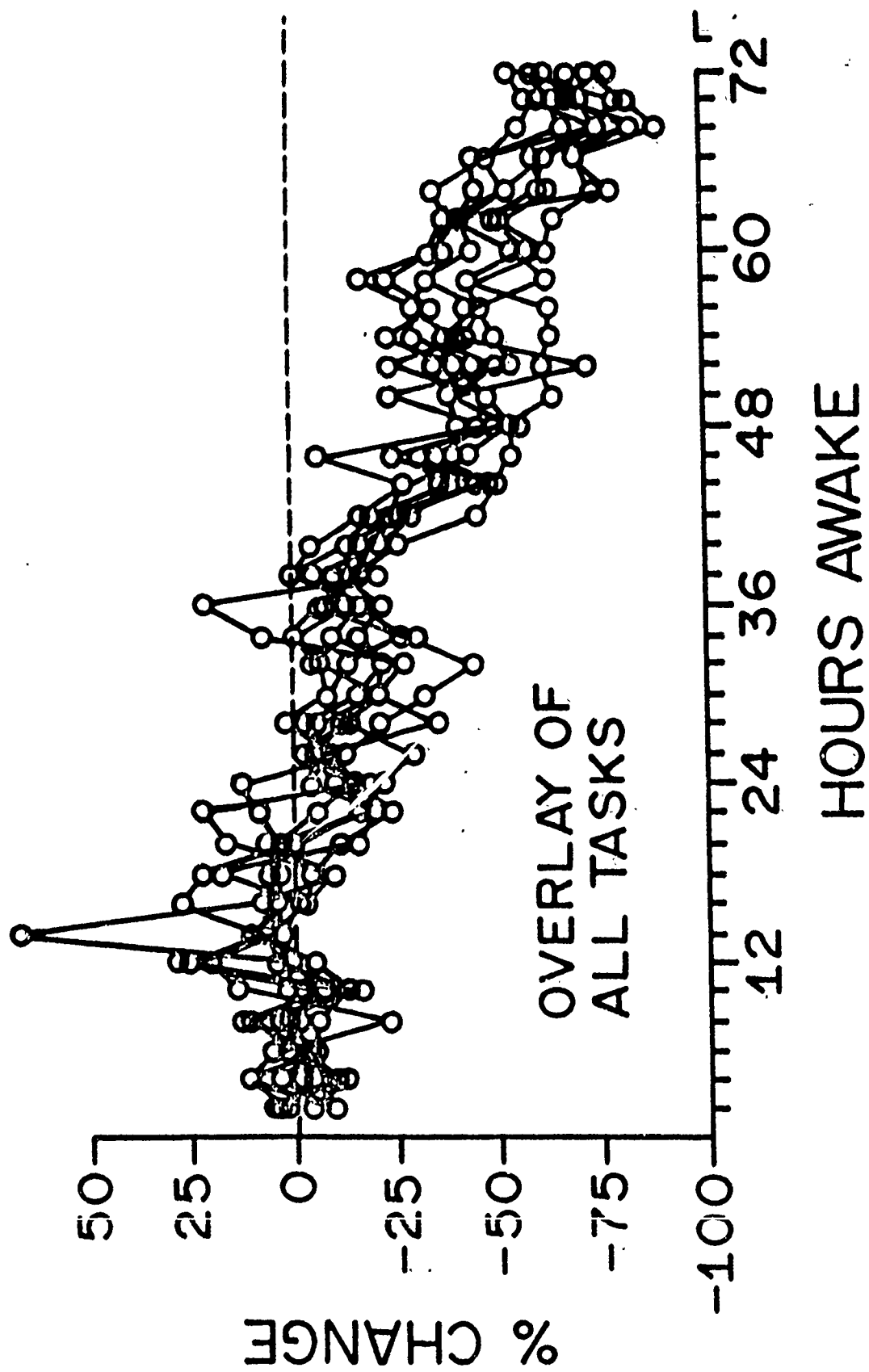


Figure 6: Superimposition of the eight tasks (Walter Reed).

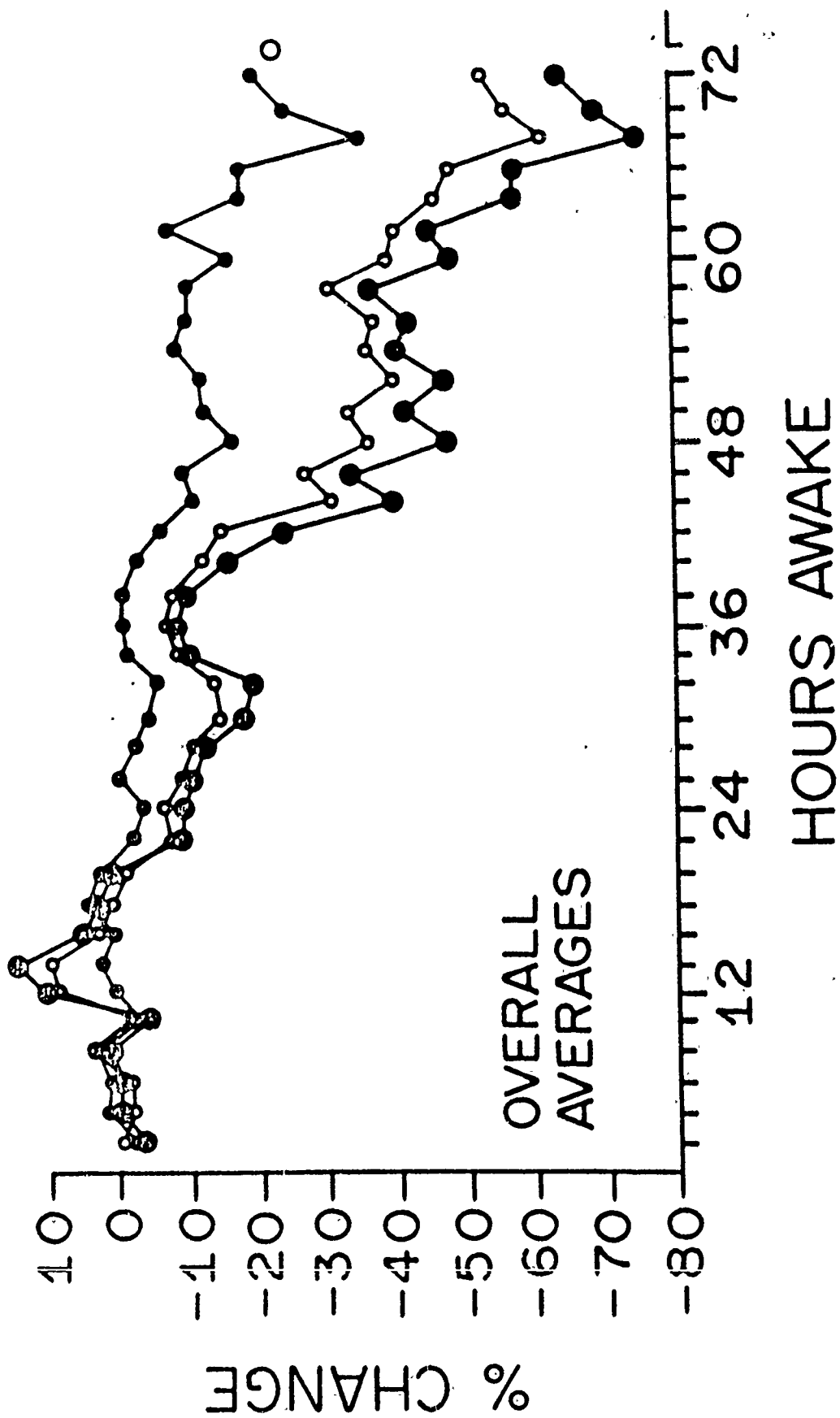


Figure 7: Grand Averages across all subjects and all tasks. Small closed circles show the change in accuracy, small open circles show speed and large closed circles show throughput (Walter Reed).

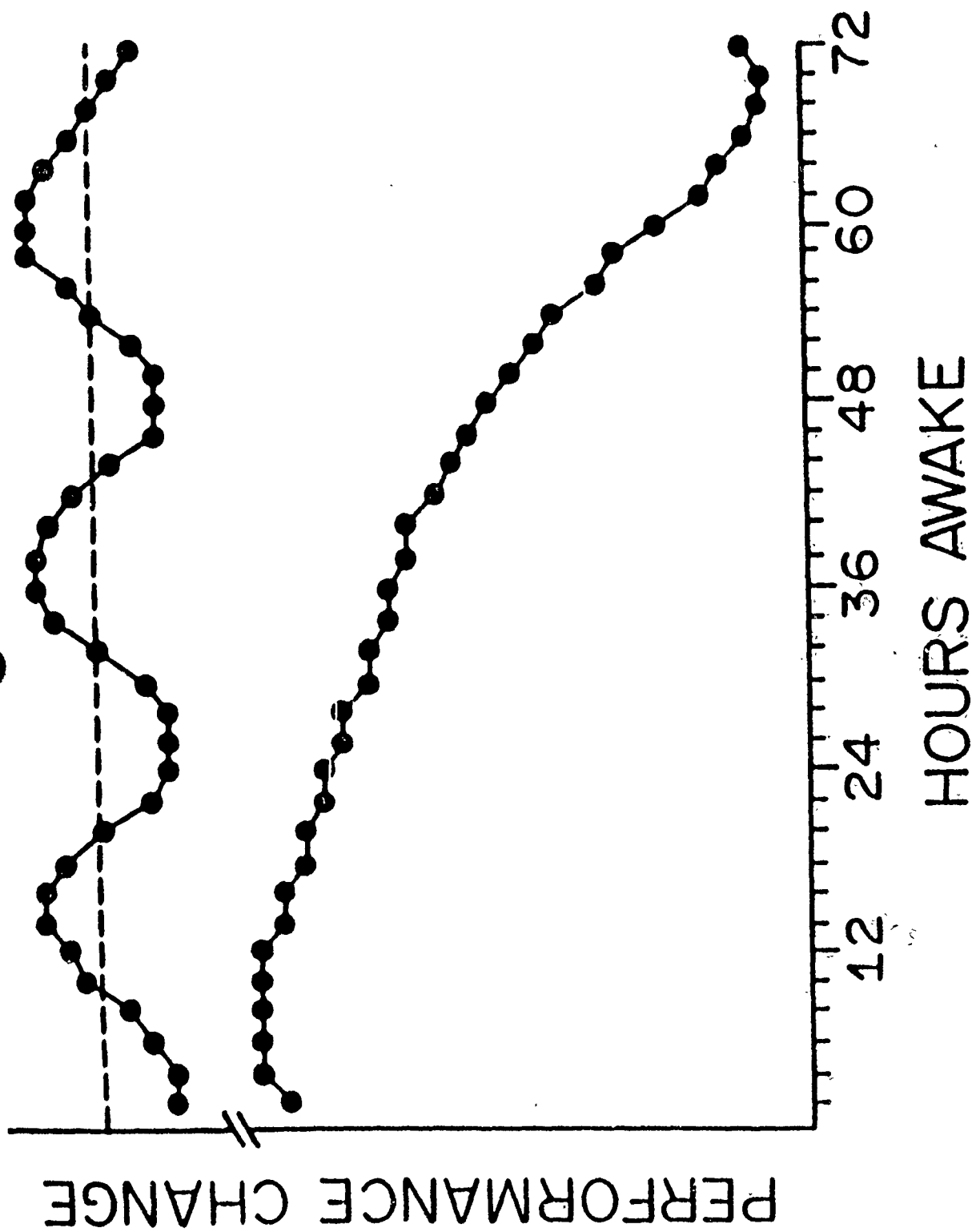


Figure 8: TOP: The 24-hour circadian rhythm extracted from the throughput values.  
BOTTOM: A modeled approximation of the sleep deprivation effect upon performance after the circadian and random variations are removed (Walter Reed).

Naval Health Research Center  
 Nap-Mediated Performance Restorative Model

SLEEP MANAGEMENT\*

$$\begin{aligned} \text{Recuperative} &= \left\{ \begin{array}{l} \text{Duration} \\ \text{of Nap} \end{array} \right\} + \left\{ \begin{array}{l} \text{Time} \\ \text{of Nap} \end{array} \right\} + \left\{ \begin{array}{l} \text{Duration of} \\ \text{Prior CW} \end{array} \right\} + \left\{ \begin{array}{l} \text{Startup Time} \\ \text{of Prior CW} \end{array} \right\} \\ \text{Power of Nap} & \end{aligned}$$

$$\begin{aligned} & W_1 \qquad W_2 \qquad W_3 \\ \text{RP} &= X_B(t) + W_2(W_1K) + W_3(W_1K) \end{aligned}$$

\*Sleep Discipline/Sleep Logistics

Table 8

Naval Health Research Center  
Nap-Mediated Performance Restorative Model

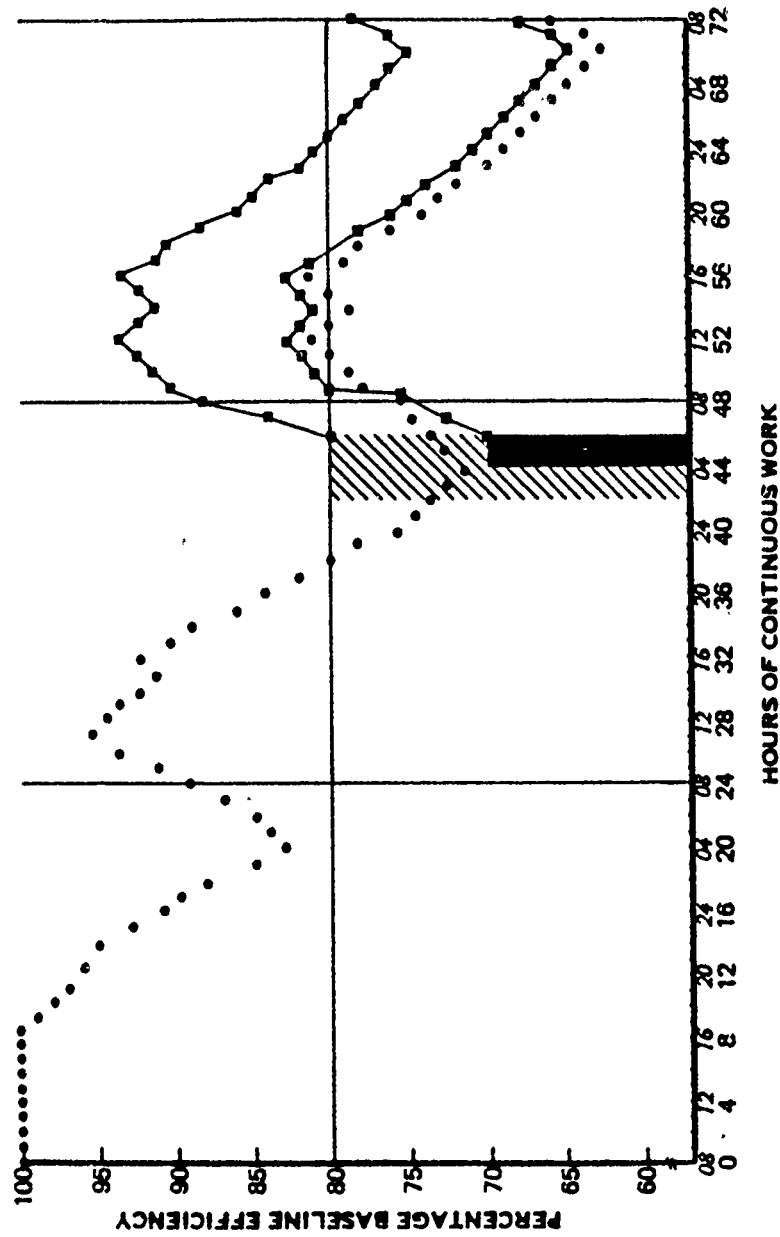


Figure 9

these eight curves were superimposed to produce figure 6. You can see an overall trend of declining performance scores and an additional rhythmic component.

Averaging of these performance curves reveals common features in these tasks more clearly than a simple superimposition technique could (figure 7). Walter Reed has, however, a sophisticated method of Complex Demodulation which breaks down a complex curve<sup>10</sup> (such as you see here in Figure 7), giving us a better idea of what kinds of common trends it contains.

The results of Complex Demodulation is shown in figure 8. This figure is presented to convince you that sleep loss produces predictable performance decrements. The first predictable performance trend, across many subjects and across eight tasks, is a gradual and almost linear decrement in performance. The second one is a circadian rhythm.

Given that performance decline is predictable during a period of sleep deprivation, we can create a behavioral model. NHRC's "Nap-Mediated Performance Restorative Model" (figure 9) used this high reliability in performance scores to come up with an equation to predict nap's restorative power (RP). The NHRC data suggested that a nap's restorative power depends on four major factors: (1) duration of nap, (2) time [local] of nap, (3) duration of prior continuous work [without sleep], and (4) start-up time of prior continuous work. A recuperative power equation was then developed (Table 8). The output of this equation was applied to produce the basic performance decrement model in produce figure 9.

Figure 9 was published as an illustration for our paper in the Journal of Human Ergology in 1982.<sup>11</sup> What you see here is a generic performance curve derived from a behavioral prediction model showing a three day long sleep deprivation or military continuous operations without sleep. The X-axis shows the time of day, from 0800 of the first day to 0800 of the third day. If we have no nap-intervention, we expect performance decline as shown with unconnected small closed circles (see figure 9). Suppose, however, that you let experimental subjects sleep two hours between 0400 and 0600 near the end of the second day of this continuous sleepless work period (see the solid bar in figure 9). Our Recuperative Power Model predicts performance improvement shown by connected small open squares. Improvement in performance is minor due to the fact that the nap was too short. If we let the subjects sleep four hours between 0200 to 0600, we expect that performance improvement is substantial as indicated by connected filled squares.



Obviously, the naps can be taken at any time of day to improve performance in a post-nap period. We have discussed napping at work site as a counter-degradation measure, but other counter measures, such as stimulants, can be applied to the basic performance model to evaluate effectiveness of such counter-measures. What we need is a mathematical equation for stimulants and other drugs, that is, Recuperative Power of drugs. Currently, we are targeting our efforts to define more precisely what kinds of performance recovery we would gain by sleeping a very short time, from 5-20 minutes.

QUESTION: About sleep deprivation being a kind of stressor that does not fit to Hans Selye's concept of stress, do you know any mechanism which regulates other stressors in a synergistic fashion (as you have mentioned)? Do you have some feeling or some idea or some suggestion how this might be happening?

DR. NAITOH: I can comment on that, but I am not quite sure if I am right.

QUESTION: Maybe there are some physiological changes occurring in that period and this can be the basis of synergistic interaction.

DR. NAITOH: All I can say for sure is that sleep loss per se is not a classical stressor. Sleep loss may cause immunological changes or changes in the blood picture. For example, researchers observed anemia caused by sleep loss, but they do not know how humans are losing blood iron during a period of sleep loss. There are many small physiological changes during sleep loss, but we cannot tell you mechanisms of how sleep loss interacts with other stressors synergistically.

QUESTION: What are the stressors in figures 5, 6, 7 and 8 other than sleep loss?

DR. NAITOH: Stress response occurs when a subject tries to stay awake, not directly from sleepiness per se. When you are asked to stay awake and do a job, only then do you get a stress response.

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Note: Permission to use figures 5, 6, 7 and 8 was granted by Dr. David Thorne of Walter Reed Army Institute of Research.

CAPT CHANEY: Our next speaker is Dr. Ross Vickers, who will discuss individual differences.

Ross R. Vickers, Jr., Ph.D.  
Operational Performance Department, NHRC

DR. VICKERS: What I've been asked to do for the purposes of this conference is to review what evidence we have regarding the potential for incorporating individual differences, such as measured ability, personality and similar kinds of characteristics into our performance models. At the virtually certain risk of demonstrating my naivete when faced with this particular problem, I tried to conceptualize what one might expect to be incorporated into a model in terms of individual differences. It seemed to me at the outset, on a purely analytic basis, what we would be looking for would be quantitative functional relationships between individual differences and performance. The quantitative functional differences would be expected in the long run to incorporate appropriate parameters, whether those be intercepts or linear slopes or something raised to the X power or something of that nature, that would change under conditions of operational stress. In particular I was concerned that we would probably be dealing with something like a mathematical function that could be put into a computer subroutine where one would call in appropriate values for the individual difference variables and other qualifying environmental circumstances to produce a prediction of performance outcomes.

Now, with that in mind, I asked myself what would be some appropriate individual difference measures to consider for inclusion in such these particular models.

The desirable attributes of such measures seemed relatively straightforward (figure 1). A basic requirement would be that the measures selected should demonstrate relationships to performance. The best candidate measure would have established evidence of generalized ability across a number of different situations so that the subroutine, if you incorporated it into your model, could be expected to apply ideally in the heat, cold, wet or in a number of different places even though some of the parameter values might change with time. You'd like to know that the underlying constructs could be conceptualized and measured in with sufficient precision to give you a reasonably well focused set of input measures to generate the output from your subroutine.

Now, with those characteristics in mind, I looked through the literature on individual differences as they relate to performance. I also drew some past experiences from when I was working on cold weather research to help direct attention to what we know of individual differences as they relate to operational performance, defined as to what a military person might actually be doing in the field. Based on that previous experience, I came to the conclusion that at least with respect to the cold there isn't a great deal of information on the relationships between individual differences and military performance. The consensus from what I heard earlier today is that this circumstance is true for some other extreme environments, such as heat, cold and so on, as well. This being the case, my conclusion was that the best starting place that we have for identifying important individual difference predictors of performance at this time is the body of evidence concerning what happens when people are performing their jobs under conditions that are relatively normal. We can hope that we have substantial generalized ability for these prior findings to provide the beginnings for the functional subroutine I was talking about.

Now, if we consider regular jobs, there is another choice to be made. Do we consider only military literature pertaining to individual differences in performance or do we consider both civilian and military literature? A number of review articles have made some comparisons pertaining to this decision. The comparisons between the relationships obtained in military and civilian populations considered a number of different kinds of individual difference variables and their relationships to performance. There wasn't a great deal of difference in the results across the different population. This is a reasonable finding given that the kinds of jobs one does in the Navy, Army or Marine Corps are comparable to at least certain types of civilian jobs, as indicated by matches between dictionary of occupational title classifications and NECs, for example. These matches are not ideal one to one matches, but close enough to provide evidence that combining military and civilian studies, is justifiable. This point is important, because a good evaluation of what's going on requires a relatively broad data base. One reason for this is that reviews of the validity of individual differences as predictors of performance have shown consistently that drawing on a small data base or a small number of studies, each typically with a small sample size leads to the inevitable conclusion that any associations identified a great deal of variability across studies. Combining prior civilian and military studies helps avoid statistical artifacts that lead to this conclusion and provides a basis for some initial estimates of the relative utility of different kinds of individual difference predictors.

## DESIRABLE ATTRIBUTES OF PREDICTOR MEASURES

1. Strong relationship to performance
2. Established generalizability of validity
3. Established identification and measurement of major components

## VALIDITY COEFFICIENTS FOR DIFFERENT TYPES OF PREDICTOR

	Average r
Supervisor/Peer Evaluations	.427
Physical Ability	.315
Special Aptitude	.268
General Mental Ability	.248
Biodata	.243
Personality	.149

NOTE: Adapted from Schmitt, N., Gooding, R.Z., Noe, R.A. & Kirsch, M. (1984). Metaanalyses of validity studies published between 1964 and 1982 and the investigation of study characteristics. Personnel Psychology, 37, 407-422.

Now, what I have done in figure 2 is to adapt some information from an article published by Schmidt, et al. in 1984, reviewing validity studies and other work studies that attempted to predict job performance from individual differences and characteristics over about a 19 year period. What is presented here is the average bivariate validity coefficient, expressed as a Pearson product-moment correlation or its equivalent. I have rank ordered the different types of predictors by the strength of the average correlation coefficient, and you can see that supervisor and peer evaluations did somewhat better than ability measures which did somewhat better than biodata, although maybe not very much better. Personality measures did rather poorly.

The most important point to be made from the findings in figure 2 is that a number of these individual difference predictors have reasonably reliable relationships to performance. These relationships typically fall in the small to moderately strong association range. It should be noted, however, that the rank ordering strictly off effect size in figure 2 should not be taken too seriously. The reason for this qualification is that the size of these coefficients depends on the criterion as well as the predictors and the criterion that has been predicted by supervisor and peer evaluations, for example, is not always that which has been predicted by physical ability measures. Now, if we consider the criterion measures, individually, as here in figure 3, the basis for this qualification is evident.

**MALE VOICE:** Is that the present supervisor and present performance or is that predicted in the sense of a previous supervisor?

**DR. VICKERS:** Those would be concurrent in all likelihood. When we consider the particular type of criterion, I listed several here that were shown in the article and are of pertinence to most any type of an organization, certainly the Navy. The most important thing about this figure, it seems to me, is that the work sample is actually observing the person doing what he is supposed to do on the job. This is the kind of functional operational criterion that Dennis Kelleher talked about this morning. This functional criterion is the one that can be predicted with the highest precision, albeit not a great deal more so than wages, promotions, achievement in school, performance ratings, and possibly turnover. In principle, then, we can expect that individual difference measures can be used to predict the type of work criterion of most interest for this conference.

## VALIDITY COEFFICIENTS AS A FUNCTION OF TYPE OF CRITERION

	Average r
Work Sample	.401
Wages	.378
Status Change	.359
Achievement/Grades	.270
Performance Ratings	.260
Turnover	.246

NOTE: Adapted from Schmitt, N., Gooding, R.Z., Noe, R.A. & Kirsch, M. (1984).



## AVERAGE VALIDITY COEFFICIENTS FOR WORK SAMPLE CRITERION

	Average r
General Mental Ability	.426
Physical Ability	.419
Special Aptitude	.280

NOTE: Adapted from Schmitt, N., Gooding, R.Z., Noe, R.A. & Kirsch, M.  
(1984).

Given that individual differences can predict performance, the logical question is which predictors do we use? The ones shown in figure 4 are the ones that have been used in prior studies. In the prior figures, values reported were based on the results of 99 different studies with varying numbers of studies going into each of the average correlations. These estimates in figure 4, as I recall, are based on a relatively small number of studies, only 4 or 5; maybe 11 for general mental ability. From the values given in figure 4, we can expect that about 16% of the variance in work sample performance can be predicted by individual difference measures. I should note as well, something I forgot to mention previously. These correlations reported have not been corrected for restriction of range or the reliability of the predictor and the criterion variables. If anything, therefore, these values tend to underestimate the strength of the associations. Note also that many individual difference predictors that show some promise with regard to other types of performance criteria apparently haven't even been considered in relation to work samples. Their omissions include, importantly perhaps, personality variables, which I think are starting to get a little bit more attention now. How well they will fare in this particular revival, I don't know. I was interested and excited about the types of comments Dr. Helmreich made earlier this morning.

So, where does all of this leave us? What should be considered for the future? Well, I've listed some things in figure 5 that I thought might be important. They really boil down to a couple of different issues. First, this review is necessarily a review and not a preview. It's what has been done and not necessarily what should be done to produce optimum performance prediction models. For this reason, these data probably are best viewed as a promising point of departure for future work.

One point that merits consideration goes back to the idea that we are concerned with functional relationships between individual difference variables and performance. We need to know how those functional relationships are modified by exposure to extreme environments. For example, if you have a linear relationship, such as that in a standard regression model, does exposure change the slope of the regression, is it the slope that changes, the intercept, or both? Or does exposure change the basic functional relationship itself in some fashion to make it curvilinear or nonlinear? Second, we haven't considered additive models for the bivariate associations discussed above. Third, we haven't considered the possibility of joint or interactive effects of different kinds of individual differences. I was up at Pickel Meadows at a time when a simulated task performance battery was being run to evaluate physical fitness predictors of physical

## ISSUES FOR CONSIDERATION IN MODEL DEVELOPMENT

1. How do situational factors affect generalizability?
2. How can key predictors be most efficiently identified?
3. Does linearity approximate true functional relationships well?
4. Are individual differences effects additive?
5. How can ongoing developments in theory be efficiently integrated?

performance tasks of Marines in cold weather. I talked to a captain who had gone through the particular course who said he had done quite well, much better than some of the other young men who were going through the course. The reason he gave was that he had sense enough to use his head as well as his legs and back. He recognized at the outset it was going to be a tough overall haul of 5-6 hours of hard work, and he paced himself. That's a simple example of how mental ability and physical ability may interact and maintain performance effectiveness, but we really don't know very much about it at this point, I'd say.

The next issue we have to deal with is how we can efficiently extend the data base we already have. One possibility that has been suggested by recent developments is that we can increase the generalize ability of our findings by classifying jobs into job families that require similar types of work. It then is possible to use experts, people who have been out there and observed the performance of those particular jobs, to preselect the most promising individual difference variables to put into our models. Both of these approaches seem to work, at least at first blush.

A final issue, obviously is that there is a need for additional study of some individual difference-performance combinations that have been omitted from prior work. This might include studies of personality predictors of actual job performance, a possibility which could get rather interesting.

Conclusion. We have "something" to put into the individual difference sections of performance models. As was noted earlier in the day, this state of affairs is better than having nothing to put into these models. However, we don't have a whole heck of a lot at this point, certainly not enough to precisely define those functional relationships I was talking about at the outset. For this reason I think there is also a very high probability we can improve on the state of affairs rapidly if we just concentrate on specific issues.

CAPT CHANEY: Dr. Larry Palinkas has had a chance to work on group interactions both in Antarctic and in space travel. I think he is very well prepared to discuss this topic.

Lawrence A. Palinkas, Ph.D.  
Medical Decisions Support Department, NHRC

DR. PALINKAS: Ross has just told you about individual differences, and I'm here to follow up by telling you about the group aspects of performance. He told you how little we know about the individual differences and their relationship to performance. Perhaps we know even less about the organizational aspects. Whether in military conflict or during peacetime, it is fairly obvious that military personnel rarely act in a vacuum or as isolated individuals but rather as members of a group, whether that group is a squad, a company, a ship, a command, or a battalion. Hence, the examination of individual differences must be understood in the context of the organization. As Hackman and Morris (1975) have observed, most studies observe only part of a complex phenomena, such as the contribution of input factors like the personality variables, the member skills and attitudes that Ross referred to, as to the outcome factor which is group performance, ignoring that it may be the process of group interaction that holds the key to understanding group performance.

Military organizations affect this relationship between stress and performance in two fundamental ways, as a source of stress and as a moderator of the effects of other forms of stress such as combat. Throughout the morning you have heard about one on one relationships between stress and performance, yet that relationship is a lot more complex, particularly when you begin to look at the organizational context. Today, I want to examine the role of organizational factors in the stress-performance relationship from both of these perspectives.

Insight into small group and organizational influences on stress and performance may be derived from three major categories of research on the subject: studies of military groups during war and in peacetime; studies of small groups and settings such as air crews or isolated duty stations which have some applicability to military settings; and studies of organizational stress and performance in the civilian sector.

A number of organizational characteristics which have influenced the relationship between combat stress and military performance have been examined in studies in military personnel. During World War II, for instance, a number of classic studies like The American Soldier by Stouffer and his colleagues (1949), attempted to relate military performance under combat to group solidarity and training in a more systematic and rigorous way than had been done previously. Marshall's classic study, Men Under Fire (1966), related the combat performance of infantry units to training practices, leadership selection and training, and unit morale. Elite combat units during WW II had consistently low ratios of psychiatric and indirect-to direct casualties—less than 6% in elite units, contrasted with anywhere from 10-54% in other types of military units (Mullins & Glass, 1973). These differences were attributed chiefly to differences in unit morale and cohesion (Noy, 1987).

During the Viet Nam conflict, the rotation policy of a one year tour of duty contributed to low unit morale and high numbers of psychiatric casualties among American military personnel (Bourne, 1970; Palinkas & Coben, 1988). The policy weakened unit cohesion and effectiveness since each soldier was concerned more with his own survivability than with that of his group. Officers, NCOs and enlisted men were rarely together for long enough periods of time to form the feeling of belonging and pride so necessary to form high levels of morale and cohesion. Lewy (1980) also pointed to a decline in leadership quality in the armed services during the Viet Nam Era—of course, he wasn't referring to the Navy at that time—as contributing to reduced combat effectiveness.

A number of studies of battle stress among Israeli defense forces personnel found that unit morale correlated highly with increased combat effectiveness and decreased psychiatric casualties. In general, units with high morale were more combat effective and less likely to be suppressed by enemy fire (Belenky, Noy, & Solomo, 1987). Military performance during combat was also related to the nature of the combat assignment. Levar and his associates (1979), for instance, found that soldiers who were in support units had much higher rates of psychiatric casualties and battle stress during the Yom Kippur War than frontline personnel. In the 1962 war in Lebanon, commander competence was a major component of trust in the commander correlated most highly with combat effectiveness. Finally, highly cohesive units with strong horizontal and vertical bonding and strong unit self-confidence, experienced minimum numbers of

# MILITARY ORGANIZATION INFLUENCES STRESS-PERFORMANCE RELATIONSHIP IN TWO WAYS

- as a source of stress
- as a moderator of effects of other forms of stress

combat stress casualties as well as maximum possibilities of reconstitution of units after battle.

Research on unit cohesion and its association with military performance during peacetime has been examined in a number of studies of U.S. Army personnel. The creation of military units possessing the kind of unit cohesion that could ensure enhanced levels of bonding, confidence and mutual trust, prior to commitment to battle and, therefore, low levels of psychiatric breakdown due to battle stress was the motive for the development of the Unit Manning System in 1981. A study of military units formed under the COHORT (Cohesion, Operational Readiness and Training Unit) system found the following. These units scored consistently higher than other units on most dimensions of psychological readiness for combat. They were able to resist potentially corrosive effects on rotation, turbulence, changes in leadership and equipment, changes in fighting doctrine and organizational reconfiguration. They enhanced the potential for bonding among individual members, their leaders consistently performed collective tasks and sustained themselves under stress better than in conventional units, and they were viewed as consistently better at movement, maneuver, occupation and communication at the small unit levels than their conventional counterparts.

On the basis of these findings, it was concluded that psychological readiness for combat was comprised of five dimensions: (1) horizontal cohesion among peers, (2) vertical cohesion between officers and enlisted, (3) individual morale, (4) confidence in group combat capability, and (5) confidence in leaders.

Another study of unit cohesion in peacetime by Manning and Engerham (1987), found strong correlations between unit cohesion scores and the results of annual general inspections, general PT test scores, operational readiness testing scores, and the number of battalion members arrested in the previous 12 months.

Associated with cohesion in military test units is the concept of group cooperation. A study by Gunderson in 1976, found that self-reported measures of work group cooperation correlated significantly with shipboard division leaders' assessments of group performance. However, this and other studies in military groups during peacetime have not explicitly addressed the role of cohesion or cooperation as either a source of stress or as a moderator of the stress-illness relationship.



# AREAS OF RESEARCH ON SMALL GROUP AND ORGANIZATIONAL INFLUENCES ON STRESS AND PERFORMANCE

- Military Groups
  - wartime
  - peacetime
- Small Group Studies
  - aircrews
  - isolated duty stations
- Organizational Behavior Studies
  - tasks
  - roles

# COMBAT STRESS AND PERFORMANCE STUDIES

- World War II
- Vietnam
- Israeli Conflicts

## ORGANIZATIONAL INFLUENCES ON COMBAT EFFECTIVENESS

- Group Cohesion
- Leadership
- Morale
- Rotation/Tour of Duty
- Unit Assignment (combat/support)

## MILITARY UNIT COHESION AND PERFORMANCE

1. COHORT units score consistently higher than nonCOHORT units on most dimensions of psychological readiness for combat.
2. COHORT units are able to resist the potentially corrosive effects of rotation, leader turbulence, changes in equipment, changes in fighting doctrine, and organizational reconfiguration.
3. COHORT units enhance the potential for family-unit bonding.
4. COHORT unit leaders consistently perform collective tasks and sustain themselves under stress better than conventional units.
5. Leaders view COHORT units as consistently better at movement, maneuver, occupation, and communication at small unit levels (platoon, company) than conventional counterparts.

A second area of study is the influence of group processes and organizational factors in small group settings such as air crews and personnel assigned to remote duty stations. Bob Helmreich already surveyed what we know about group performance among air crews, so I won't go into that now. With respect to something I do know a little bit about, which is Antarctica, the research that is available found four factors, which you also find in the literature on air crew factors, as being significant in affecting group performance: leadership, interpersonal style, group relations, and communication patterns. A study by Biersner and Hogan (1984), for instance, of two isolated Antarctic research stations found that in one of which the leader received high ratings from other station members and had an overall successful winter over, maintenance and technical tasks were performed at consistently high levels and social compatibility remained high during the nine months of isolation. At the second station, however, the leader received poor marks from fellow winter-over personnel. Station equipment was in poor repair, technical competence met only minimum standards, and conflicts among members of the group were frequent and severe.

In an ongoing study of Antarctic stations by members of the Naval Health Research Center, we are also finding the same pattern of differences in leadership style having an effect on overall performance among isolated Antarctic research station winter-over crews.

Studies of organizational behavior in the civilian sector have identified a number of factors contributing to stress and its effect on performance. McGrath (1971) identified six classes of stress or sources of stressful situations in organizations: task based stress; role based stress which relate to difficulty, ambiguity and load; stress intrinsic to behavior settings, such as the effects of crowding or undermanning; stress arising from the physical environment which we have heard a lot about this morning and this afternoon; stress arising from the social environment in the sense of interpersonal relations, and stress within the person's system, that being the individual.

In this model, stress may originate from three different arenas, the physical and technological environment of the organization, the social interpersonal environment, and the person-system of the organizational member. Now, most of the research in the civilian sector is focused upon the organizational tasks and organizational roles. In the area of organizational tasks, studies have found that performance is related to tasks which are monotonous and unchallenging, jobs with substantial overload, forced

## DIMENSIONS OF PSYCHOLOGICAL READINESS FOR COMBAT

- Horizontal Cohesion
- Vertical Cohesion
- Individual Morale
- Confidence in Group Combat Capability
- Confidence in Leaders

## SMALL GROUP INFLUENCES ON STRESS-PERFORMANCE RELATIONSHIP

- Leadership
- Interpersonal Styles
- Group Relations
- Communication Patterns

overtime, and jobs paced by technological considerations. In the area of organizational roles, research has pointed to a significant stress-performance association in jobs with high degrees of role conflict and ambiguity, jobs with little influence or participation, and jobs with a high degree of responsibility.

Research on organizational behaviors also focused on characteristics of the organization which can moderate the effects of stressful tasks and roles. One of the primary moderators is the level of motivation of the individual organizational member and of the group itself. Three major theoretical approaches to work motivation have been examined in the research on organizational behavior and performance. Reinforcement, need, and expectancy theory have each generated a variety of models and numerous studies with various and conflicting results.

However, the nature of the relationship between job stress and job performance has not been consistent. An examination of this research reveals four distinct models arising from the stress-performance relationship in an organizational setting: the traditional curvilinear U-shaped relationship that someone referred to this morning; a positive linear relation, i.e., the more the stress the greater the performance; a negative relationship; i.e., the more the stress the worse the performance; and no relationship whatsoever. Although a number of studies have pointed to the existence of a curvilinear relationship, there also have been several studies which have found the possibility of the other three models, particularly the third model, a negative linear relationship, as well. Differences in findings may be attributed to differences in measures of stress and performance, operationalization of terms and control of confounding relationships.

On the basis of this review, a number of small group and organizational influences on the relationship between stress and military performance have been identified. These include: morale and motivation, cohesion and compatibility, leadership, organizational tasks and roles, and communications. Having selected these characteristics, however, a number of issues need to be addressed. Chief among them is the task of measuring the characteristics. There are a number of ways they can be assessed in a quantitative fashion. For instance, scales measuring role conflict and ambiguity such as the ones developed by Kahn and his associates (1964) or House and Rizzo (1972) have reliability coefficients which range between .72 and .85. In the Israeli studies, morale was assessed by means of survey responses to the following items: trust in company commander; confidence in one's skills as a soldier; feelings about the legitimacy of war; trust in one's

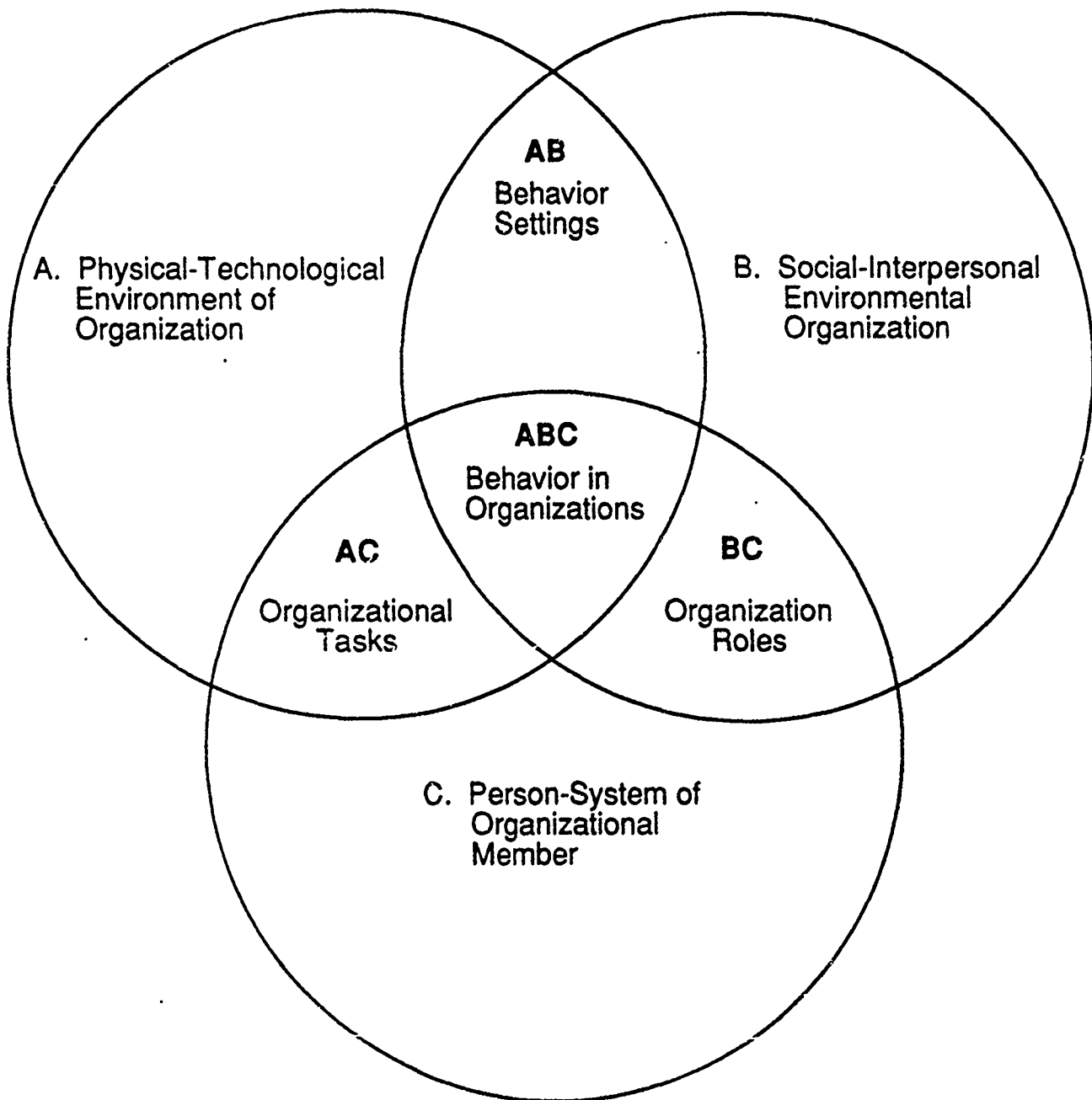


## SOURCES OF STRESSFUL SITUATIONS IN ORGANIZATIONS

1. Task-based stress (difficulty, ambiguity, load).
2. Role-based stress (conflict, ambiguity, load).
3. Stress intrinsic to the behavior setting (e.g., effects of crowding, of undermanning, etc.).
4. Stress arising from the physical environment itself (e.g., extreme cold, hostile forces, etc.).
5. Stress arising from the social environment, in the sense of interpersonal relations (e.g., interpersonal disagreement, communication, etc.).
6. Stress within the person system, which the focal person "brings with him" to the organization (e.g., anxiety, perceptual styles, defense mechanisms, etc.)

(Source: McGrath, 1976)

# THREE EMBEDDING SYSTEMS FOR BEHAVIOR IN ORGANIZATIONS



(Source: McGrath, 1976)

# THEORETICAL APPROACHES TO WORK MOTIVATION

- Reinforcement Theory
- Need Theory
- Expectancy Theory

## MODELS OF STRESS-PERFORMANCE RELATIONSHIP IN ORGANIZATIONS

- Curvilinear/U-shaped relationship
- Positive linear relationship
- Negative linear relationship
- No relationship

## VARIABLES WHICH INFLUENCE MILITARY PERFORMANCE

- Morale and Motivation
- Cohesion and Compatability
- Leadership
- Organizational Tasks
- Organizational Roles
- Communications

weapons, one's self and one's comrades; the unit's cohesiveness and the quality of relationship with commanders.

In other studies, the distinction between military units which are cohesive and units which are not are based on questions such as the following. These questions are derived from a scale developed by Manning and Engerham (1987) with a reported reliability of .98 and validity between .65 and .82. For the most part, however, these characteristics have been assessed in an impressionistic or qualitative manner. Assessments of cohesion, morale and motivation in civilian organizations have been on self-reported data, others on assessment of leaders or supervisors and still others on published scales and protocols. The assessment of organizational influences on performance, therefore, has to begin with a uniform set of measures with each of the variables identified above.

Another problem is that of deciding the most appropriate measures of performance in a military setting. Previous studies in military groups in combat, have used fit for duty versus personnel removed from combat for medical or psychiatric reasons, as a measure of performance. Studies in military groups in peacetime have used more sensitive measures such as scores or percentage of missions passed during field exercises, PT scores, or skill qualification test scores. Studies of air crews have focused on speed and accuracy in response to organizational problems as measures of performance. Studies in isolated duty stations have used leader and group assessments of group task accomplishments, social compatibility, and emotional composure as performance criteria. Research is necessary to identify the most relevant measures of performance from these settings to that of combat and noncombat situations in the military.

Finally, we have to exercise caution when we look at this relationship, whether we're looking at the organization as a source of stress or as the moderator in the stress-performance relationship. Many of these characteristics which may seem to moderate the relationship between performance and other forms of stress such as fatigue and vigilance may, in themselves, be source of stress, whether it's low morale, low cohesion, or low motivation to work. So we need to identify when these characteristics act as a source of stress and when they act as a moderator in the relationship of other forms of stress in military performance. Thank you. Any questions?

## MEASUREMENT OF MILITARY UNIT COHESION

1. How often, aside from meetings, does the C.O. talk with you personally?
2. Is your squad (section) leader ever included in after-duty activities?
3. If we went to war tomorrow, would you feel confident going with this unit, or would you rather go with another?
4. How often, aside from meetings, does your platoon leader talk with you personally?
5. Who would you go to first if you had a personal problem, like being in debt?

## CRITERIA FOR UNIT MORALE IN IDF STUDIES

- trust in the company commander
- confidence in skills as a soldier
- feelings about the legitimacy of the war
- trust in weapons
- trust in self
- confidence in one's comrades' readiness to fight
- the unit's cohesiveness
- quality of relationship with commanders



CAPT CHANEY: Earlier you heard Commander Banta talk about certain aspects some of which are derived from our trip to the Gulf. Six uniformed "real" scientists and I, a uniformed non-scientist, went to the Gulf, and we have some things to present to you. We will be using this television monitor to some degree, so if you can't see, please feel free to move around.

LCDR Guy R. Banta, MSC, USN, NHRC

LCDR BANTA: We have introduced discussion today on varied physiological and psychological issues that should be considered when examining avenues of model development. The laboratory affords us an opportunity to segregate each specific performance response in a very controlled setting. Treadmills looking at aerobic/anaerobic capacity, submaximum workload, max workload; looking at strengths, dynamic strengths, isometrics, anthropometry (the interaction of dynamic strength with static strength or actual physical measurements from man-machine improved interface design).

Dr. Kobus talked about the event related potentials looking at the electrophysiological responses during cognitive function so we can quantify such things as attention deviation and other "fine" or further analyses, be they physiological or psychological; time to set up and address the biomechanical and physiological responses with finite measuring tools is needed.

The simulated environments, very life like, hyperpressure chambers, hypopressure chambers, heat and cold chambers, motion devices for aviation, shipboard, space exploration.

Impact-acceleration to assess the effect of acceleration/impact on human performance response and safety.

Ship vibration and vertical impact.

The computer support to allow us to make these fine tuned laboratory assessments are available to us in various forms.

As I mentioned a moment ago, the time to properly attach whatever devices we need to our subject population.

The subject profile. In the real world they are variable—all sizes, shapes, males, females, whatever. In a laboratory setting we can design our protocol around the number and type of individual, the profile whether he is fit, old, young, fat, thin, whatever.

Laboratory support. The many biochemistries we need to be looking at—blood and hormonal response, urine electrolytes, things of this sort—are available to us in a laboratory setting.

We have had a fair number of discussion points about cognitive testing for signal detection, dual and complex task, and psychomotor interaction.

The laboratory is an excellent arena to initiate the means to understand the basic science questions, a means of filtering the compounding variables that define human performance. But, it is in the field environment that we can only truly define those compounding variables and measure the operational relevance and feasibility of the laboratory developed countermeasures we have been talking about. It is the real world where we define the magnitude and complexity of operational synergistic loading, multi-stressors, if you will, on human performance.

We have discussed so far today, first, that in the field we hope to have a better means of identifying the significant variables impacting human performance that should be utilized in the development of our predicted models; second, it is better to address issues of "proper" criterion measures, i.e., the comparability between the simulated laboratory tasks, tests and environments we have established and the real world tasks. Third, develop a better understanding of the complexity and handicaps in properly measuring performance responses and thereby develop improved methodology.

To help you understand and appreciate the multi-stress environment of the real world that we have been talking about this morning, and the issues as a researcher that confront us in trying to quantify performance, we're going to show you a little film, as Captain Chaney just mentioned, that we took when we were in the Persian Gulf this last year. And while you are watching this, think again about all those issues we discussed today—the types of physical workload and cognitive demand, location of the job task, the environment—complexity and difficulty of assessment; and the fear, anxiety state, and mood of the individuals that must have been present during this period.

(The following is a narrative while the film is being run.)

The Persian Gulf is a body of water bordered by Saudi Arabia, Iraq, Iran just off the Gulf of Oman and the Arabian Sea. The environment is somewhat like San Diego (if you believe that I'll tell you another one), about 130° F in the summertime. We were there in the fall and the temperature was still not far from that. Prior to the cease fire, this area was an area of high threat: shore missile attacks, air attacks and still present yet today, even with the cease fire, uncharted mines in the water.

Our presence there has involved various surface ships, mine sweepers, Special Forces, Explosive Ordnance Divers (EODs), and helicopters. When looking at physical workload, I must remind you that during ship operations it's not only individual workload but it can be group effort (team work). There is some time for rest but also a time for boredom, there are varied locations, and job tasks, environments such as varied sized ships and boats and helicopters, all of which can subject an individual to a lot of motion and heat stress, frequent fear and anxiety about possible hostile threat. Some individuals work in areas of less physical demand but have more operator mental vigilant task requirements—sonar, air traffic and radar. There are topside gunners and observers, frequent General Quarter drills, fire fighting preparedness, and sometimes and, unfortunately, the actual event.

Explosive ordinance diving is a busy job in the Persian Gulf due to the constant threat of mines. We talked about cold water diving earlier today. How would you like to dive in 97° F water? Additionally, contend with sea snakes, poor visibility, having to swim to and place markers on items we think are mines which have been identified by the ship's sonar, and formally placing charges on those mines and seeing that they are exploded.

The environmental impact and level of performance is always changing. It depends extensively on the job task and location of that job task aboard a ship:

- (a) The wind effect on job-task topside. If the ship is heading in the right direction (against the wind) then we can benefit from an evaporative cooling aid as far as the solar heat impact is of concern to performance capability.
- (b) Availability of shade. We saw on some ships placement of canvas covers over selected watch standing locations in order for the watch stander to be shielded from the solar heat. Not all ships had that. It just happened to be something

that the commanding officer of that ship allowed to occur.

- (c) The solar heat itself.
- (d) The humidity level with and without different types of clothing, be it your regular dungarees or combat gear.
- (e) Low level white lighting, a cooler environment, an environment or integration, such as in the CIC, complex, cognitive tasking, auditory, visual, a state of group interaction.
- (f) And of course, boredom. We'll talk a little bit more later about boredom and sleep availability during periods of long watches in this type of environment.
- (g) Radiant heat, noise, very high temperature demands as one would find in a typical engine fire room. I mentioned earlier about personally recording a temperature in an engine room area of 160° F in September aboard a steam driven ship. Monitoring of those areas occur frequently in order to dictate or try to dictate when the watch stander should leave the area. As I discussed earlier this afternoon, that's not always operationally feasible.
- (h) Availability of fluid. The sailors that work in our ship's engine/fire rooms are taught quite well on what to drink and how to drink, but if the water system shuts down aboard a ship—or the power goes, so does the water.
- (i) Air venting. Many of the engine room spaces are designed with air vents to force outside air in to help cool the space. However, if the outside air is also extremely hot it doesn't accomplish the job very well. I took a temperature reading of the outside air vent within an engine room and recorded 104° F.
- (j) Motion. We have already talked about motion a little. There are varied sizes and types of ships and many involved with stack gas which adds to the stress. The Naval Biodynamics Laboratory (NBDL) in New Orleans has done quite a bit of work with David Taylor's Ship Research and Development Laboratory in looking at the effects of motion on human performance. They have identified that the location aboard the ship, where the individual might be standing or performing his tasks impacts the effect of motion has on his performance capability. Motion sickness. In this area there is one aspect that I'm quite concerned about, and that is, what is the impact of motion sickness medication on performance—what is the synergistic impact of medication, motion, heat on performance?

Work-rest sleep cycles. Aboard one of the ships on which we were collecting data, we had the opportunity to witness the almost impossible capability of a senior petty officer in an engine room to stay awake while on watch. He was the leader of the group in this area. I discussed earlier today about the necessity in some engine rooms, because of the heat load, to work one half hour on with a few hours off, back on, around the clock, and when the machine breaks down, someone has to go back in and fix it. This senior petty officer that I am discussing did and thereby had to remain up for over 48 hours and still had to stand his watch because it was only a three man watch team. This guy actually fell asleep while we were taking his picture.

Physiological monitoring. We talked about the various techniques and capabilities of monitoring. In the field environment, subject availability and acceptance of your monitoring techniques is always an issue. When you start walking around with a rectal probe aboard ship they begin to look at you a little funny. Finding the time and place aboard ship to put on a monitor system is always difficult. A guy just comes in off watch and you hear, "You have to hurry up doc, I've got to get back on watch." Additionally, you must make your equipment sailor proof, operational exposure, and environment proof. Telemetry systems are not feasible. They are short ranged so generally we have to use solid state recording devices. When using this sort of equipment we have to be careful to time match so that when we return to the lab, we don't have to figure out what happened at one time period as compared to another--just another factor to complicate the monitoring environment further.

Laboratory support aboard ship. Most often we don't have all the fancy blood chemistry systems that are available in a hospital setting. Space alone is very limiting. There are concerns about electrical power--50 hertz system aboard ship. Can we run our centrifuges using this type of system? Freezer for storing blood chemistries and urine samples, need to be below, say 20° F. Most of the ship's galley freezers are above that, and cooks are frequently going in and out all day long. Therefore, quite frequently our laboratory freezer turns out to be an igloo cooler with a land-based runner (CAPT Chaney) bringing us dry ice every time we came back to port. Urine sample collection is another fun issue. If my petty officer was with us this afternoon, he'd tell you a few stories about how he had to collect a timed urine sample when the subject had already gone on watch. We found him literally hanging off the side of the ship with a urine bag, having his subject (a line handler when coming into port) give a sample.

Once again, issues of cognitive performance testing in the field. One, there is a question of meaningful assessment. The question of ability to accurately identify change that is occurring during testing arises. whether or not it is the test or the actual performance change. Dr. Kobus addressed quite well issues about presenting frequent targets during computerized cognitive sonar/radar tests. Such frequency is not realistic to actual job performance.

However, during testing we can't take the same amount of time as for the real world. Another issue is the Hawthorne effect: "We are there taking a test." "My performance is being looked at over my shoulder." "I'd better do well." "This is challenging." "This is fun." The testing environment is a challenge. The noise from every day shipboard makes it at times impossible to do such testing as signal detection. The time of the day we give the cognitive tests--night time--day time. Pre- and post-watch testing of course has to revolve around the watch standing. The time it takes to take the test itself. It's nice to have these sailors report for taking their test batteries right when you expect them and leave right after they complete, but "General Quarters" happens, the subject may have to go down below to relieve the guy who has already been on watch past the PHEL curve limits, or some other "operational" reality.

Learning curves. In the laboratory we all know we usually like to have our subjects come in for a number of days, a number of hours, for frequent testing, so that the learning curve for a particular test battery can reach a plateau. In an operational setting you may not be afforded that opportunity. When you first present the test battery you have begun to collect data. You will not be able to capture your subject's time long enough to acquire "learning." When questioning operational relevance and cognitive performance, we must address group interaction. What are the individual responses within that group interaction? What are the differences in job tasks? Look at the interaction of officers and enlisted, each having a different task within that complex integrated group arena. Proper and quick attention to detailed complex cognitive loading varies by job task. The engine room for example: being able to integrate a variety of different gauge readings and being able to tell whether or not that the ship is performing correctly. Surface air observation with the high demand for vigilance and attention to target tracking.

Flight, the aviator, the air crew. Constant audiovisual input and psychomotor demands. Having to land, take off in bad weather, trying to land on that so-called "postage stamp"—all extremely stressful. In addition to the aircrew, flight deck personnel have an extremely dangerous and stressful environment. Flight deck personnel have to worry about bringing an aircraft on board, letting one go; a lot of personnel have to stand around in this area. In fact, when we were aboard one of the ships, two blades from a helicopter collided during landing and rotor blade pieces went through the ship's bulkhead, fortunately, above everyone's heads.

One shipboard area, recently made more noticeable to the public since the VINCENNES is the Command Intelligence Center (CIC). Complex, dual task interaction go frequently as well as boredom. Each watch stands 12 hours on, and supposedly 12 hours off. Again, when short staffed, time off is minimal. Trying to keep your attention and your vigilance at peak performance for when a not so often target shows up, especially when it's not an ongoing combat situation is extremely tiring. Tiredness is quick to come about and quick to effect one's capability to attend.

Additional stressor concerns. Fear and state of anxiety. Troop maneuvers: ship to ship, ship to land, air to land. The anxiety of preparing for battle. The anxiety of preparing for something, but you do not know what or where. Flight, not just for the air crew but for the passengers riding in these devices that should not be able to fly. Explosive ordinance divers. We discussed earlier the adverse environment in which divers had to work. The anxiety associated with the job-task itself is immense. I recollect a mine that was discovered while we were at sea and one of the EOD guys had to swim out and place an explosive charge on that mine. But it didn't go off. He had to swim back to it, check it out, and redo the charge. The weaponry around you constantly reminds you why you are there and adds to continued stress. Of course, surface battle preparedness, waiting for the unknown. General quarters. You can't see them. You don't know where it's at. Is it going to happen? Is it to going to happen?

A comment about air observation. In the heat of high activities, overhead flights at a moments notice was quite frequent. You can imagine supersonic jets suddenly coming at you—the concept of the Stark is always there. That distant cloud of fear in the back of your mind is a mine exploding. The mines in the Persian Gulf are free floating; it's not well established where they might be. Our mine sweepers are constantly searching for them and maintaining clear shipping lanes.

I hope we demonstrated to you that when it comes to assessing human performance and developing predictive models, we first have to identify the real world multi-stressors, synergistic impact on humans, so in a laboratory setting we can properly develop and address pertinent and relevant hypotheses. Thanks

MALE VOICE: Can you give us some of the results you got from your trip to the Gulf?

LCDR BANTA: Well, as you can appreciate data collection, especially from the field environment, has compounding variables very difficult to segregate out, to analyze. Ongoing analysis is occurring. We've spent quite a bit of time looking at thermal effects, ship to ship interactions. Our preliminary report has been provided to the Surgeon General and thereby to the CNO. I don't actually know where we stand in regards to going any further than that.

CAPT CHANEY: As you can imagine this is a super sensitive issue. We were actually geared up to go the Gulf just about that time, and because of the situation of the VINCENNES, we were put off because it was a sensitive situation. Some of our people were involved with the investigation. As a result, we waited until fall to actually go back. We have accumulated the data on paper; it has been presented to the Surgeon General in part, and some of the study Dr. Kobus is still ironing out will be presented behind closed doors on the request of certain people and that is because of the sensitivity in regard to too much attention being focused on this situation, bringing back things that don't want to be brought back. I think you can understand what this is all about. So, we are geared to present the information and will do it after proper clearance. Again, we start with the Surgeon General, get his permission and until it is cleared through him directly, nothing will be passed. Our line of communication was for me to get on the plane and fly back. Literally, we did not discuss this on the telephone. So, that is a long answer to a short question, but right now we are not in an position to reveal too much of this at this session.



CAPT CHANEY: Our next speaker is Bill Pugh; he's head of the Department of Medical Decision Support Programs.

William Pugh  
Medical Decisions Department, NHRC

MR. PUGH: My objective is to try and get a handle on integrating information within a subject area, and my plan is to attack this from a somewhat abstract or theoretical perspective. I will be followed by Dr. Hodgdon who will give you a more applied concept of what this is about.

Let me start off by saying that integrating information within a subject area is certainly a precursor for developing complex or comprehensive models within a particular subject area. So, I would like to develop or present an approach for integrating data that is designed to facilitate the development of models and particularly mathematical models. I'd like to begin by defining what a model is, or at least what I think of when I'm speaking of models, so I took one of the definitions of a model out of Webster's Dictionary. We can see that a model can be conceived of as a mathematical description of a particular entity or state. I like that particular definition because mathematical models allow us to get these processes into our computers and exercise them with our computer technology.

With respect to mathematical descriptions, I selected a simple linear equation and pointed out that we can break this mathematical description down into variables, operations, and constants. Variables are the phenomena or factors used to predict outcome events. Operations are used to transform those variables. For example, we can do a log transformation or square root transformation. In addition we can use the operator to combine variables together or represent an interaction. Constants are used to weight or combine variables and convert measure to a desired metric.

When we are developing our models, we can use these mathematical descriptions to capture or describe various phenomena which may be of interest. One of the types of phenomena we discussed today is the effect of time. A variable may be linearly dependent upon time, or it may have a curvilinear relationship. The kind of data we have seen today look something like the second or third graph. The record figure would be used to describe an adaptation process, habituation, or learning where we have a process that rises and then tapers off over time. The third graph would be used to

describe a process that had an acceleration effect. For example, earlier today we saw that people under heat stress have a heart rate that accelerates and as heat goes up that increases at an accelerating rate.

So, these are just examples of how we use our mathematical terms to capture physical and behavioral phenomena.

Another type of phenomenon that can be incorporated into mathematical formulae is the interaction between variables. One variable alone may not allow us to predict our outcome variable. We may have to take the junction of two variables together to describe our outcome event and we can do this either with statistical designs or branching designs. Within the framework of statistical designs, there is the analysis of variance model with an interaction term and the regression model where we multiply two variables together. However, I want to point out that we can achieve the same objective with branching designs. I think within our computer models we often really use conditional statements ("if" statements) to account for the joint effects of two or more variables.

Finally, I'd like to point out that interactions are not only limited to the model itself and processes within the model, but the process of the user exchanging information with the computer is a form of interaction. The computer may go through a process where it takes a right or left turn and then gives a presentation to the user, whereupon the user responds by making a choice. The joint outcome of those two variables--what the computer did and what the user did--gives us some outcome events. Therefore, we can use branching designs but such designs may be no different than a linear equation.

Finally, there is the idea of using linkages to put these different phenomena together. Something that may be an outcome variable at one time may very well be a predictor variable the following time, so I have "V" and "X" shown as outcome variables at Time #1 and as predictor variables at Time #2. In an example earlier, LCDR Banta discussed various factors that went into performance. There was the ambient temperature, the metabolic rate and other factors that went into a model and those were linked together in this type of fashion. The second example where you have "X" being a predictor of "X" is an autocorrelation type phenomena. That might be a phenomenon like we saw in the sleep data with the circadian rhythm. So, these are ways and examples of how we capture these processes, describe them with mathematical equations, and get them into the computer.

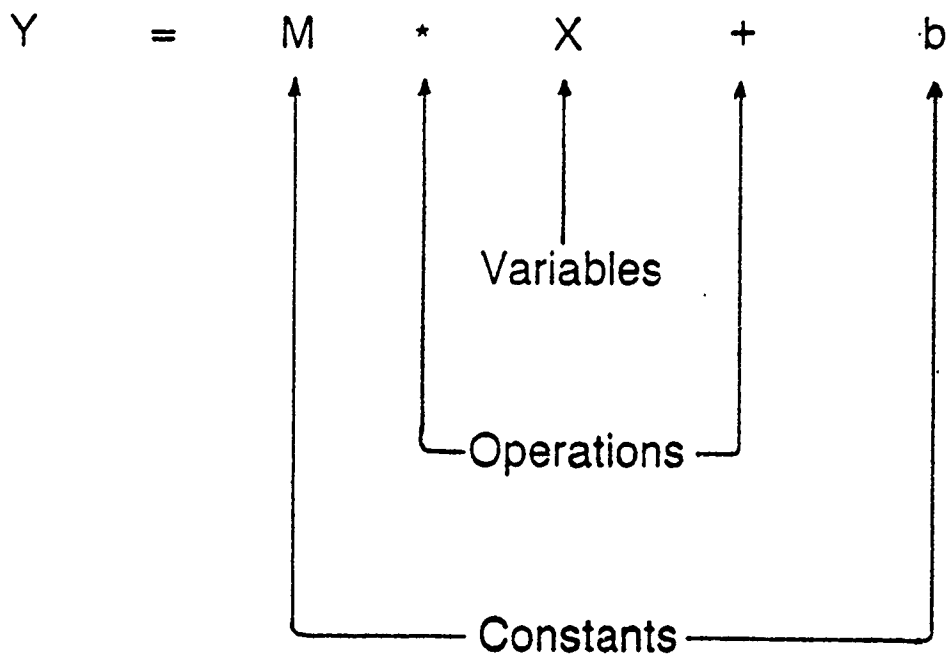
## DATA INTEGRATION FOR MODEL DEVELOPMENT

1. DEFINITION OF MODEL
2. BUILDING MODELS
3. MODEL IMPLEMENTATION
4. SUMMARY AND DISCUSSION

## MODEL

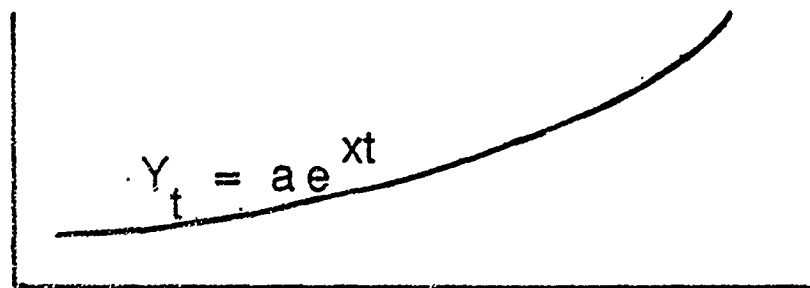
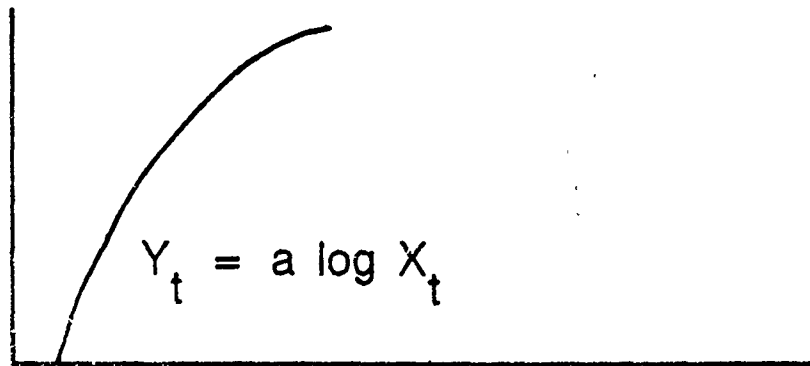
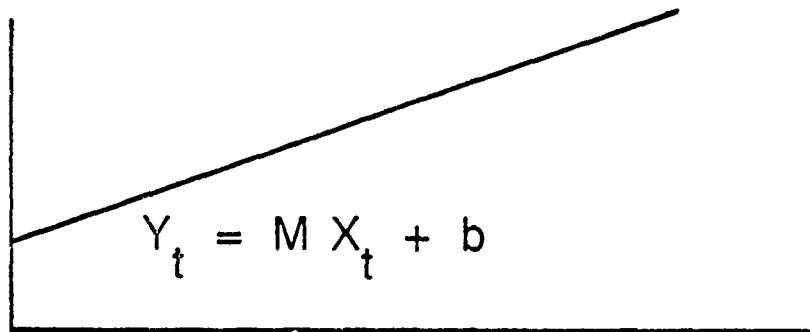
A SYSTEM OF POSTULATES, DATA, AND INFERENCES  
PRESENTED AS A MATHEMATICAL DESCRIPTION OF AN  
ENTITY OR STATE OF AFFAIRS.

## MATHEMATICAL DESCRIPTIONS



## DYNAMIC MODELS

$$Y_t = f(t)$$



## INTERACTIVE MODELS

$$Y = f(X_1, X_2)$$

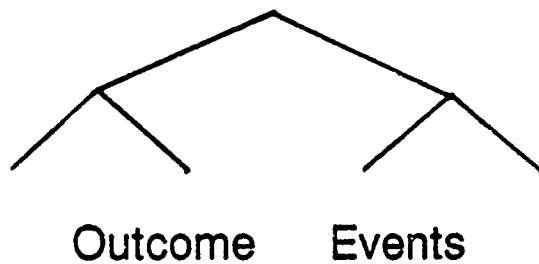
### Statistical Designs

$$Y = A + B + AB + e$$

$$Y = W(X_1 * X_2) + K$$

### Branching Designs

Choice  
Points



With such linkages we can put this all together into one integrated or comprehensive model where we have our initial states, we have the primary or direct effects of certain variables, we can add in indirect effects, the effects of time, learning, adaptation, previous states autocorrelations, the effects of circadian rhythms and variable interactions.

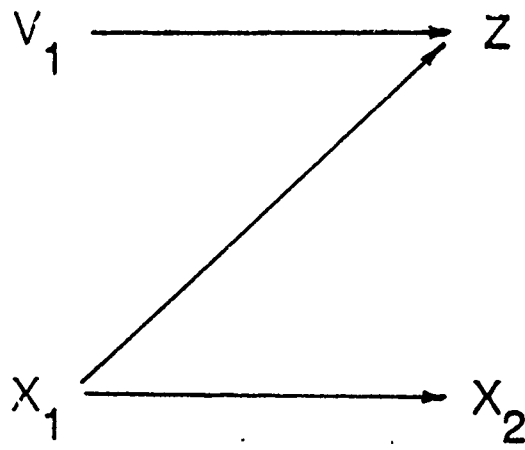
Now that you see what I have in my mind when I'm thinking about a model, we can proceed to consider how one develops a model. We must identify the relevant variables we need in our equations. We need to determine how those variables are combined together. Then we must decide how to weight and scale them. If we break the process down into those three steps it will facilitate our integration of the data base with an eye towards model development and particularly mathematical model development.

Methods we can use to accomplish those tasks are: first, start out with your tried and true literature review for finding what are the important variables. You do what other people have done and find out what people have found out in the past. I still don't know anything that beats that for identifying the important variables. Then, one must determine the form of the relationship among the predictor variables and with some outcome criterion. Historically, we've done that with a literature review. More recently, techniques and methods have been devised which may be thought of as a systematic literature review, and we can call this meta-analysis. This is where we line up all the literature and go through in a methodical fashion, depending upon what form of meta-analysis we are using, and either count up how many studies reported that a particular variable had a significant effect, whether the effect was manifest as a positive relationship in all studies or whether there was a positive effect in some studies and negative effects in other studies. Is there some moderator variable we need to consider? This is the type of process that Dr. Vickers was discussing when he was looking at his average correlations. And, as he noted, we can either compute an average correlation, or we can become more sophisticated and adjust the correlation values to determine whether there is a difference merely because of sample sizes between studies or if there is really an inconsistency among studies.

Such techniques are meta-analysis techniques and that is something I think we need to consider when we are looking at the form of the relationships with the outcome variables. To get the parameter estimates needed to produce predictions of an outcome variable that are in a proper metric, we can use our tried and true regression analysis. I



## LINKAGES



TIME 1

TIME 2

$$Z = AV_1 + BX_1 + D$$

$$X_2 = PX_1 + E$$

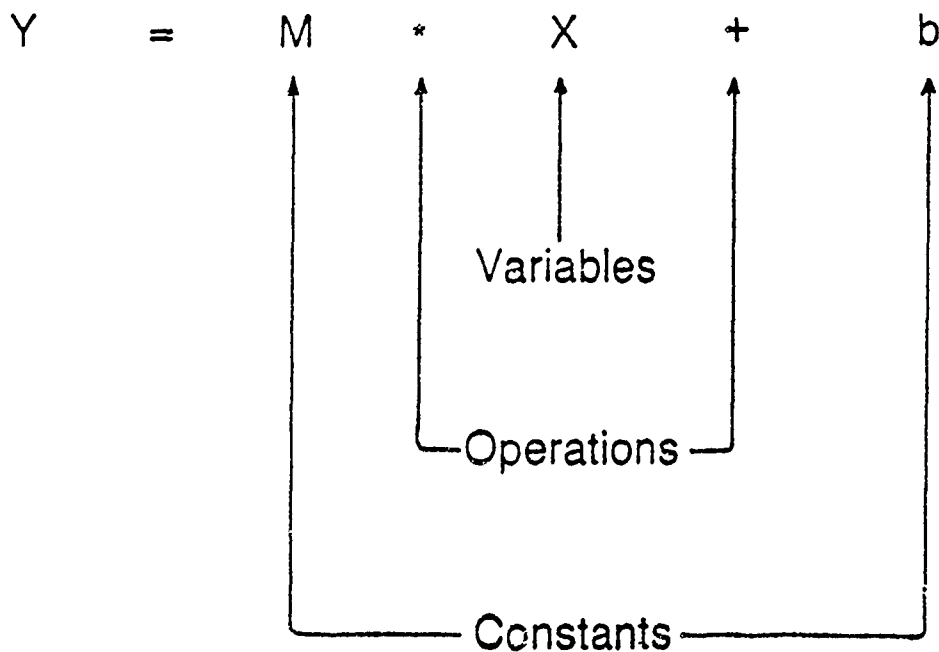
## INTEGRATED MODEL

$$Y = \begin{array}{ccccccc} \text{Initial} & + & \text{Direct} & + & \text{Indirect} & + & \text{Effects} \\ \text{State} & & \text{Effects} & & \text{Effects} & & \text{of Time} \end{array}$$

$$+ \begin{array}{cc} \text{Previous} & + \\ \text{States} & \text{Variable} \\ & \text{Interactions} \end{array}$$

## MODEL BUILDING

- o Identify the relevant variables.
- o Determine the form of the relationship among the variables.
- o Develop estimates of the model parameters.



## METHODS

- Literature Review

Identify relevant  
variables

- Cluster Analysis

- Meta-Analysis

- box score
- study effect
- combined probability
- approximate data pooling

Determine Form of  
relationships

- Regression Analysis

Estimate parameters

think to get a complete picture it is important not only to look at the model development process but how are we going to implement that model. We can implement the model by doing our study and publishing it. That is a way of implementing a model. We can develop an equation, publish it in the scientific literature and, for a long time, that's where things led. Now, we are putting our models into computers and, as we heard earlier, we can program a hand held or lap top computer to accept values for variables and generate an outcome. This makes a model a little more relevant to users out in the field. We can get more sophisticated and start using something like the expert system shells, the network shells that are coming on line. With a shell one can put mathematical descriptions into the computer, and the computer uses that description to generate an outcome variable. The advantage with system shells is there are a number of maintenance functions available where we can change the model more quickly without extensive reprogramming. We can add new variables and look and see how the outcomes change. Finally, I have added something here--what I call an enhanced system shell where, not only are we able to put in our mathematical descriptions into the computer and maintain those and change them when we want, but we include the addition of outside observations which allows the model to go through something which you might "think of as learning." Therefore, the system actually can change the form of the relationships and change the outcomes based on the new data coming in.

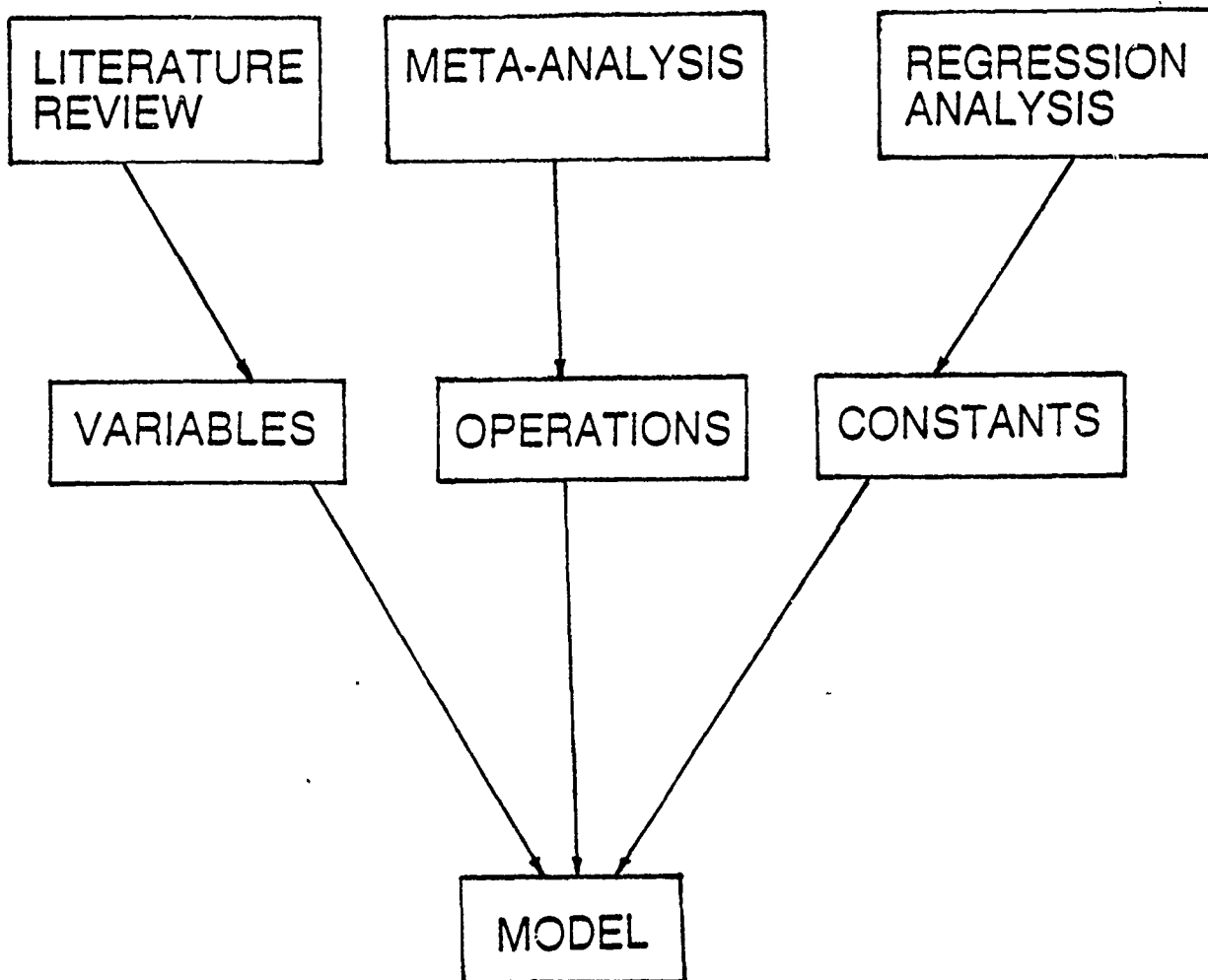
To build a model, we want to start off by integrating the data and the information in the subject area, and we can do that by looking at the literature to identify the variables, doing our meta-analyses to determine the form of the relationship among those variables, and use regression analysis to get the correct scaling on those variables. Then we have our model. At this point we can publish. Or we can take this information, put it into a computer model, exercise that model, and then get a distribution of outcomes.

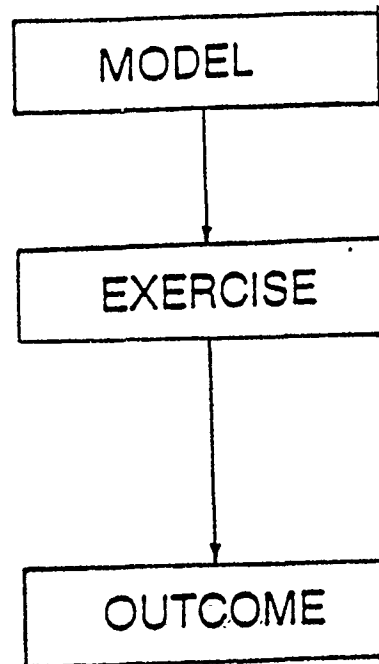
The next step is to go to our system shells. Here we maintain information on variables and operations, and we can readily change those thereby getting more flexibility on the kind of outcome events we can observe.

Finally, I'd like to think of the process as a closed loop (here we have the whole loop) where we not only maintain our information as mathematical descriptions and update our model periodically, but we're feeding in new observations on information

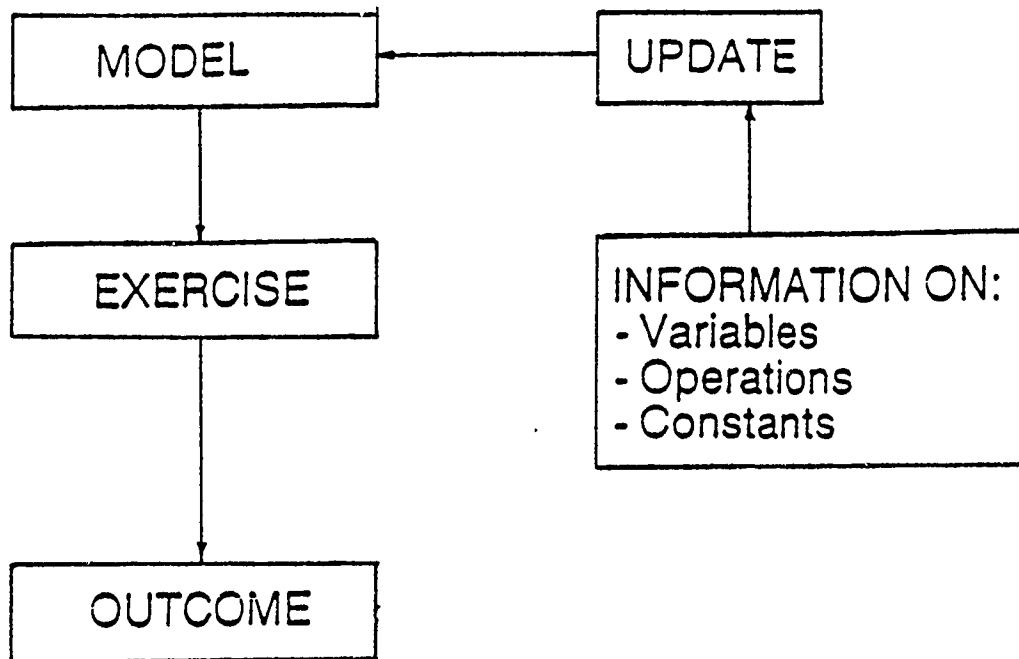
## MODEL IMPLEMENTATION

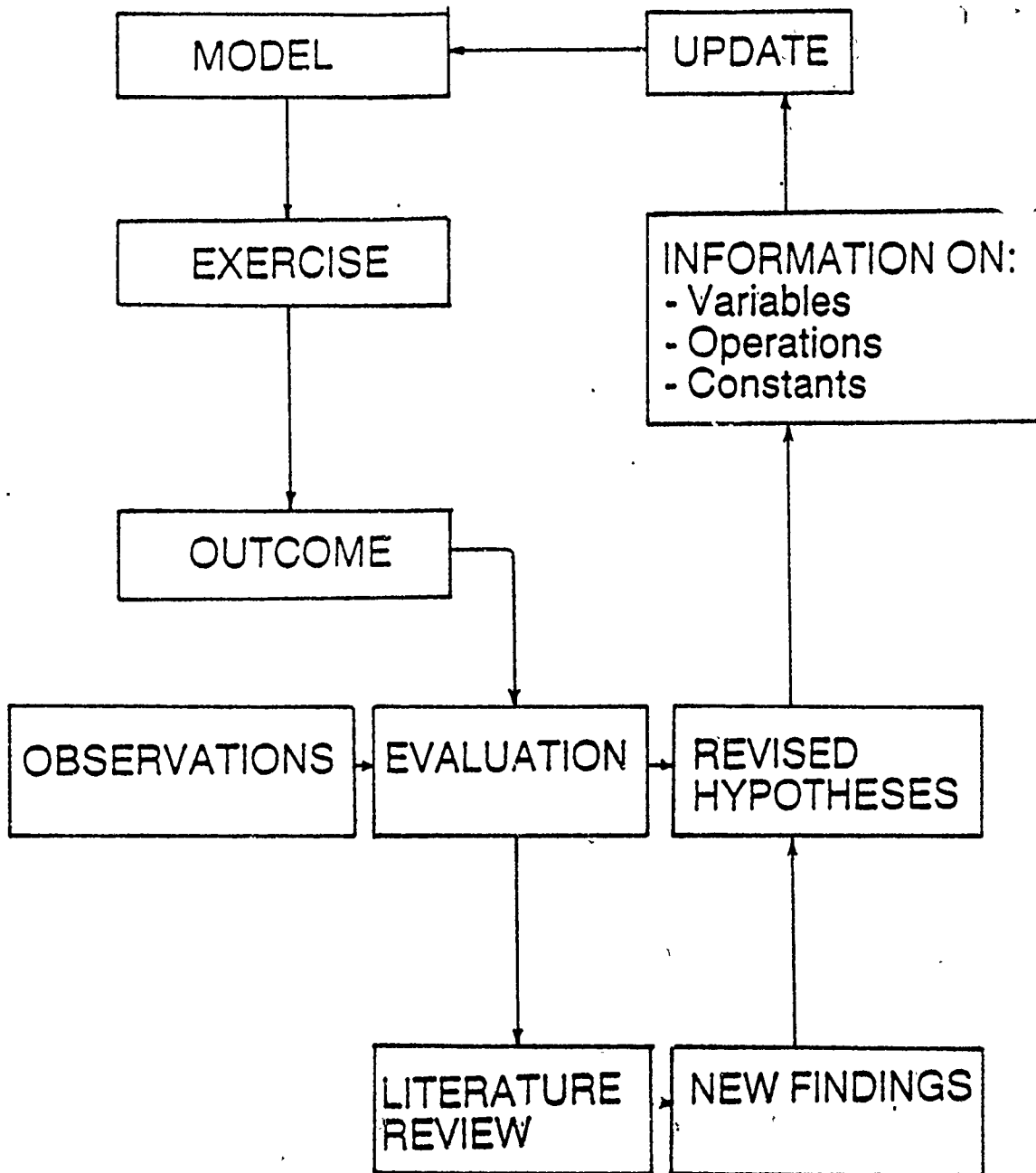
- o PUBLISH MODEL DESCRIPTION IN THE SCIENTIFIC LITERATURE.
- o IMBED THE MODEL DESCRIPTION IN A COMPUTER PROGRAM.
- o USE AN EXPERT SYSTEM SHELL TO MAINTAIN AND EXECUTE THE MODEL DESCRIPTION.
- o USE AN ENHANCE SYSTEM SHELL TO:
  - MAINTAIN THE MODEL
  - EXECUTE THE MODEL
  - GATHER AND ASSIMILATE DATA FOR REVISING THE MODEL
  - DYNAMICALLY ESTIMATE MODEL PARAMETERS











obtained from interactions with the user in order to conduct evaluations with the system itself. This information can be fed back and be used to generate new outcomes. This is not necessarily entirely automated but I believe we should at least think of our models within this context. Now you may realize that my primary concern is not so much with the integration of data so we can build a model. Rather, I am interested in how we can use models to help integrate data. I'm interested in these shells but not from the perspective of building the shell and software itself. I am interested in how the model will help us integrate the data. A model is a way of bringing information together; that's what I'm interested in, and we can start using the models to help us integrate the data.

**MALE VOICE:** I've got no problems with this. To me a model should be a thing you can manipulate in order to understand something you can't manipulate. Let me give some examples of this. The simplest are our animal models. We're usually on safe ground modeling a system that can itself be put into the laboratory. With humans you can't control all the variables you bring into the laboratory. What we usually do in models of systems or situations where we can't control the environment is to decide based on what has happened before and seemed to be successful, what variables probably ought to be relevant and we're interested in; however, many of these are inaccessible, so unfortunately, all too often we end up measuring nothing. We also get caught in a tangle, e.g., we confuse correlates with causes. Being Westerners we all want to identify which variables are independent and which are dependent. Also we're paid to do that. Unfortunately our tools which are sophisticated but descriptive, are of very little use in sorting out the dependent from the independent variables. I would suggest that to a substantial degree using mathematical models which have nice, crisp, comforting forms which are very easy to put into a program and manipulate really means that we can delude ourselves a lot faster than we used to. Models of the kind you were starting to describe; i.e., ones I would call logical models and base models, that you could build in a hurry with expert systems and which may, if you're careful, be more accessible to attempts to apply using the time honored scientific method, e.g., where you hypothesize something and then try to verify the hypothesis. In our pursuit of more and more precision we forget that what we had was probably grossly inaccurate to begin with, but our systems never tell us whether they are inaccurate. I think in particular in the behavioral field, either physiologically or psychologically, we've got to go back to a very basic level and make sure you are on firm ground and do some little experiments to see if you are heading in the right direction. When you are doing physiology, here again

you have physical reality that you are observing which you can't put in the laboratory, but somebody across the country can generate the same make and model or at least use behavioral tests with similar parameters.

MR. PUGH: Okay, I can agree with part and not necessarily disagree with the rest, but maybe I should amplify what I was saying a little better. First of all, I agree that in these models, one of the purposes is to be able to put in moderators, or things that can only be inferred, and that's what this model does for us. And, I agree, especially because my background is psychology, that a lot of things aren't out there; they're in the head somewhere, and we can only know about them from inference. That's one reason I'm very interested in this whole area of model development. My argument is that we can look at the models as a tool for bringing us together. I think it will help to go back to Dr. Banks' presentation at the beginning and remember his suggestion that we focus on a limited set of models. If we can settle on a model or small set of models this process will allow us to get together. Now, we can get the physiologists, psychologists, and engineers together and use the model as a forum for us to start communicating and find out if the learning process moderates the physiological processes, and we can put that in together and build a common edifice. Therefore, building the model is not necessarily done only to end up with a model; during the building process we are communicating and unifying our theoretical positions and that to me is the payoff.

MALE VOICE: The problem is if you exhibit a model as a collection of different equations to an electrical engineer, he'll take that as God's truth. Unfortunately, in his environment it probably is truth. In psychology or physiology it is a wish, hope, an opinion or an argument point but that's about as close as it is likely to get to truth.

# A MODEL OF LOAD CARRIAGE IN THE HEAT

Operational Performance Programs  
Naval Health Research Center

## **Purpose of the model:**

To predict the time required to cover a distance given a set of physical and physiological attributes, speed, grade, terrain and clothing definitions, temperature, humidity and wind conditions, and the magnitude of the load carried.

**Operational Performance Programs  
Naval Health Research Center**

DR. GUNDERSON: Jim Hodgdon is our last speaker and he will be talking about MicroSAINT and ways we might use this to construct models.

James A. Hodgdon, Ph.D.  
Operational Performance Department, NHRC

DR. HODGDON: Since this is a talk concerning stressors as they might apply to modeling, it would not be complete unless we displayed at least one model on the board. I intend to do that. This is billed as a talk on MicroSAINT but it grows out of a different concern. Originally, I was going to speak about some of the physiological and physical effects of carrying loads in the heat. Since there was a wealth of literature on the subject, I decided to build a model to reflect these effects. Well, I created this model, and now it has become a topic in its own right.

I appreciated Commander Hall's comments because I'm going to show you some ways in which they are true. In demonstrating this model, I hope to show you some of the benefits of creating models and some of the errors that can occur when one accepts these models or the equations that generate them at face value.

The particular model I'm presenting here was designed to predict the time required to cover a defined distance, given a set of physical and psychological attributes, speed, grade, terrain, clothing definitions, temperature, humidity and wind conditions, and the magnitude of the load carried. This ought to sound very familiar both to Commander Banta and Dr. England, who have presented some of the formulae from the U.S. Army Research Institute of Environmental Medicine (ARIEM) group that described physiological responses to load carriage. In fact, it is those functions that are incorporated into this model.

In this model I included energy expenditure rates, rectal temperature change, sweating rate, body weight change due to sweating, and glycogen utilization rates. During load carriage the energy expenditure rate formulas are, in fact, those of Givoni and Goldman from U.S. ARIEM, with some additional information on terrains from Soule, Givoni and Goldman. The rectal temperature change equations are from Biovanni and Goldman; the sweat rate equations are from Shapiro, Pandolf and Goldman. For glycogen utilization rates, I fit an equation to some data presented by Saltin and Karison. The best fit equation is an exponential function of percent of the maximal rate of oxygen consumption ( $VO_2$  max).

# SOURCE MATERIAL

1. Energy expenditure rates:  
Givoni, B. & R. Goldman,  
J. Appl. Physiol. 30:429-433, 1972.
2. Rectal temperature change:  
Givoni, B. & R. Goldman,  
J. Appl. Physiol. 30:412-422, 1973.
3. Sweat rates:  
Shapiro, Y., K. Pandolf, & R. Goldman,  
Eur. J. Appl. Physiol. 48:83-96, 1982.
4. Glycogen utilization rates:  
Saltin, B. & J. Karlsson,  
pp 289-305 In: Advances in Experimental Medicine &  
Biology. v2, Plenum Press, NY, 1971.



## Modelling Software:

### **Micro SAINT** (Micro Analysis & Design)

- \* Develop, execute, & analyze network simulation models
  - Develop task networks.
  - Establish alternate paths of execution.
  - Define and manipulate variables controlling the model.
  - Collect simulation data.

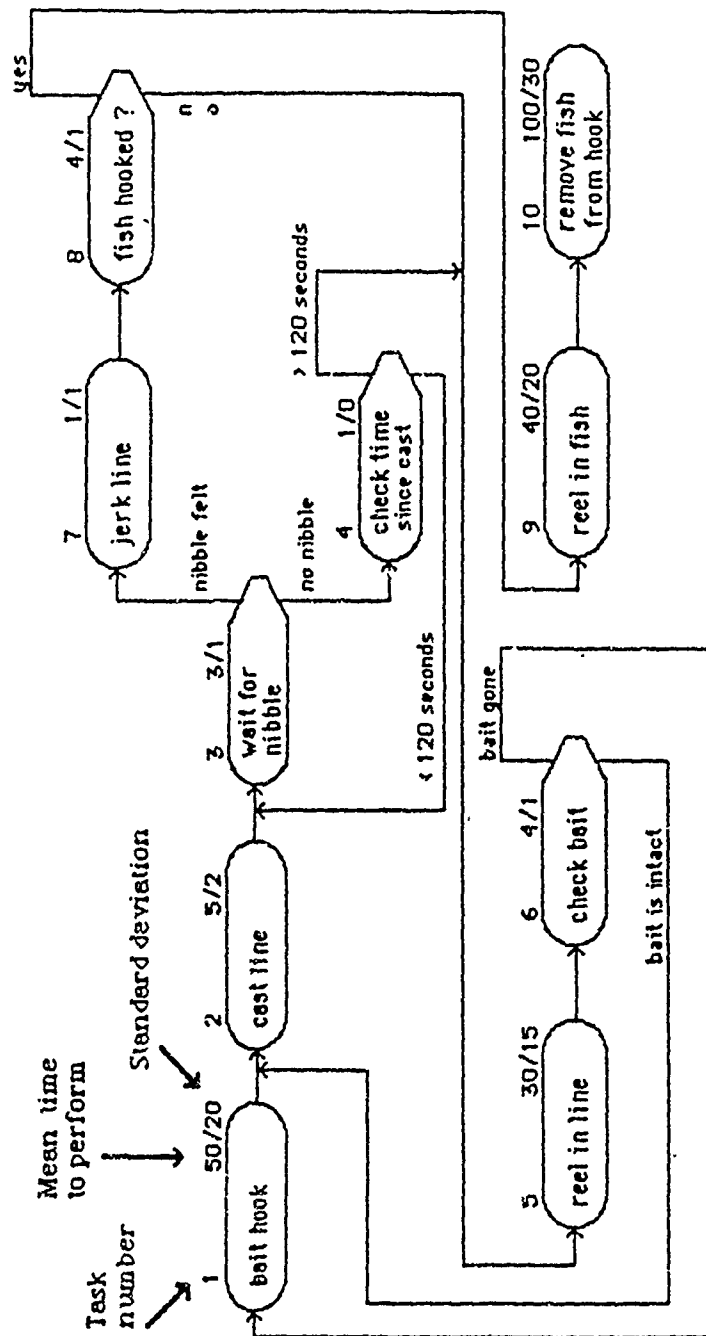
Operational Performance Programs  
Naval Health Research Center

For the modeling software, I chose MicroSAINT. The reasons for that choice are not particularly elegant. I wanted to gain experience using MicroSAINT because it's a network simulation program that is available to DOD investigators at no charge, having been developed under DOD contract. MicroSAINT software is designed to allow development, execution, and analysis of network simulation models. The software provides separate menus to allow development of task networks and establishment of alternate paths of execution for those task networks, allowing comparison of results of several different organizations for the same kinds of tasks. You can define and manipulate variables which control the model and by doing so, you can generate some population statistics for your results. You can also collect simulation data by running the model.

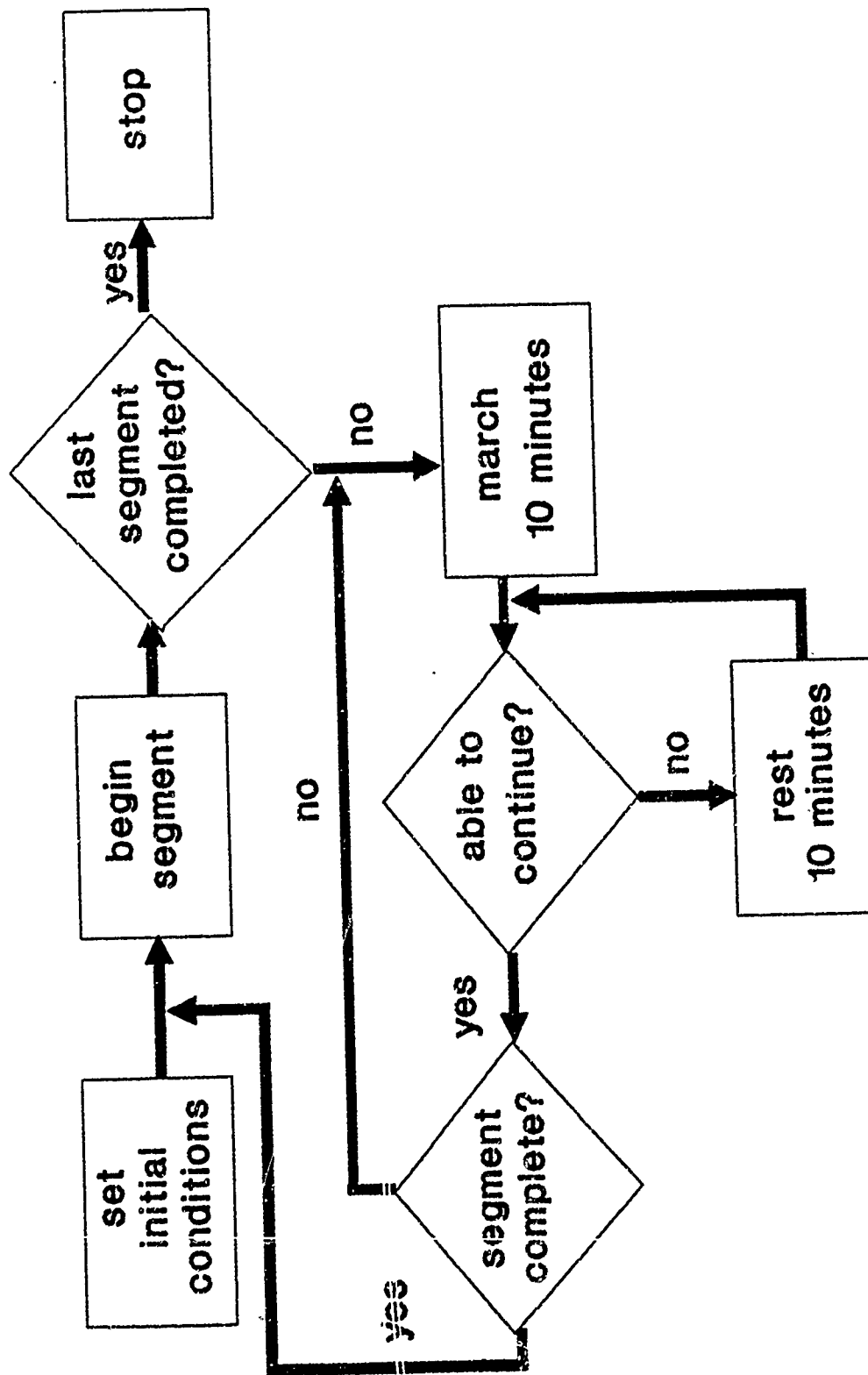
This may be redundant information for some of you, but for those of you who have not seen a task network model, this is an example of one that comes out of the MicroSAINT manual. It's a model of those tasks that take place while one is fishing. If one is trying to catch a fish, one baits the hook, casts the line and waits for the nibble. One either feels a nibble and tries to hook the fish, or one doesn't feel a nibble and goes back to see if something has taken the bait off the line.

The particular model that I have developed looks like this. I establish a set of initial conditions, defining the environment, defining the people, and defining the work rates. Then, work is performed in what I call segments so I can have work performed under one set of conditions for one segment, change to a second set of conditions in a second segment, to a third and so on. As soon as a segment is begun, the model checks whether or not the last segment has been completed. If it has, the model stops. If not, then the model has the individual march for 10 minutes. This is the way the time function is integrated into the model. In this block, the 10-minute march, predictive equations are utilized to change physiological variables. The rectal temperature is adjusted to reflect the effect of the environment over the 10 minutes. Glycogen is utilized, and body weight is lost as sweat due to marching under the defined conditions for 10 minutes. Then, the physiological state of the individual is checked. Based on certain assumptions, a decision is made whether or not the individual is able to continue. If so, the model checks to determine whether or not he's at the end of the work segment. If he is, he starts a new segment; if it's not the end of a segment, he marches for another 10 minutes. If he is not able to continue, then he is forced to rest for 10 minutes, and his physiologic state is again assessed.

This sample model is a simulation of a person trying to catch a fish. The illustration below is a block or flow diagram of the sequence of tasks involved in fishing.



# Load Carriage Model



Right now there is a limited set of checks that actually take place. In accordance with some review work by Pandolf, I have arranged it so that if the rectal temperature exceeds 39.5° C, the man stops marching. There is a fair amount of experimental data to suggest this would be true. I have somewhat more arbitrarily set it so that this man's rectal temperature must drop a full degree, to 38.5° C before he is deemed fit to continue.

It won't be a factor in the results I'll show you, but there is another check such that if glycogen content falls below utilization of 90% of the glycogen, then the individual modeled is limited to 50% of VO2 max as his upper workload and there is a fair amount of literature data to support that kind of contention.

I would like to show you the results of some runs on this model. But first I want to tell you the initial conditions I established. For the personnel, I provided a mean and a standard deviation for height, weight, VO2 max and body fat based on data from Marine Corps personnel embarking on operations at Twenty-nine Palms. One of the nice things about this particular shell is that you can enter distributional statistics, and it will draw values for height, weight, VO2 max and body fat randomly from a distribution having the parameters specified. So, each time you run the model successively through each utilization, the individual that is put into the modeled situation has a different height, weight, VO2 max and body fat. I fixed the initial muscle glycogen weight and rectal temperature because I didn't have distributional statistics for these.

AUDIENCE: Right there you are composing full distribution.

DR. HODGDON: I know. I'm not taking into account relationships between the distributions for one thing.

AUDIENCE: Do you have any idea the runs you are going to have to make before you get. . .

DR. HODGDON: I start it up one week and come back. On the other hand, there are also relationships, for instance, between % fat and VO2 max and between weight and % fat, so they are not independent distributions. I haven't, at this point, worked out ways of dealing with the interrelationships among the variables.

# MODEL CHARACTERISTICS

## Personnel:

Height (cm)	179.0	$\pm 7.0$
Weight (kg)	73.4	$\pm 8.0$
VO <sub>2</sub> max (inl/kg-min)	54.3	$\pm 4.5$
Body fat (% of wt)	15.0	$\pm 2.5$
Muscle glycogen	17.0 (g/kg wet muscle)	
Initial rectal temp	37.0 (deg. C.)	

With the environment, a somewhat unrealistic one, I modeled the temperature as a sine function so the temperature varies over the course of the day. This term, clock minus 20 minutes, sets the starting time for the model at approximately 7:00 a.m. The average temperature across the course of the day is 27° C with a range of 20° C. I fixed the partial pressure of water at 20 torr. So, what we have is a really humid desert and that doesn't occur too often. I have called for two work segments, the first of which is marching across level ground at 4.8 kilometers per hour (3 mph) for five miles on what is given a terrain coefficient of one. This would be similar to walking on asphalt at an easy pace. The wind speed is five meters per second. The insulation and permeability values for the clothing are those for standard fatigues and the individual is carrying a load of 32.7 kg. which is, in fact, the average Marine Corps pack and gear ensemble weight. In the second segment, they slow down to two mph, but they march up a 5% grade, again for five miles, with terrain coefficient of 1.6 which mimics heavy brush. The other things stay the same. The conditions for the segments were set to simulate walking along the road and then climbing some mountain through heavy brush. You can get the screen to display a set of variables for you as the model iterates, keeping track of the event tasks which are taking place, and all of this will just march along in time.

As I said, this particular program can be used to generate distributional statistics. In this case, these are the frequencies of execution times for those two segments. It is very much a bimodal distribution with a much smaller group on one end. I ran the model 100 times, and in 83% of the cases the two legs were finished in 250 minutes. There is, however, a small group of 17 men who took approximately 1,000 minutes to complete. The time is long because these men had to rest.

In a moment, we'll start looking at why this program. I want to point out some of the other features. All of these plots I'm showing you were generated by MicroSAINT. It gives you the capability of displaying on a time axis any of the variables of interest in the model that you choose. I want to call your attention to the ambient temperature. You can see that from about 250 minutes until about 800 the temperature is above 30° C. It's pretty warm. This is the average rectal temperature response for those people who completed the two segments in 250 minutes. You can see that there is a rise which approaches a leveling off at the end of the first segment. Then the workload goes up as you start climbing the hill through the brush. There is another rectal temperature rise, and again it almost levels off.

# MODEL CHARACTERISTICS

## Environment:

Temperature:  $27.0 + 10 \cdot \sin(\text{clock} - 120 \text{ min}) / 1440 \text{ min/day} \cdot 360 \text{ deg/day}$   
(deg. C.)

Partial Pressure of water: 20 torr

## Work:

	Seg #1	Seg #2
Speed (km/hr)	4.8	3.2
Grade (%)	1.0	5.0
Distance (km)	8.0	8.0
Terrain	1.0	1.6
wind speed (m/s)	5.0	5.0
insulation (clo)	0.99	0.99 (fatigues)
permeability (im)	0.74	0.74 (fatigues)
Load carried (kg)	32.7	32.7



System Time: 110.00

RUN 1 OF 100

Completed Task:

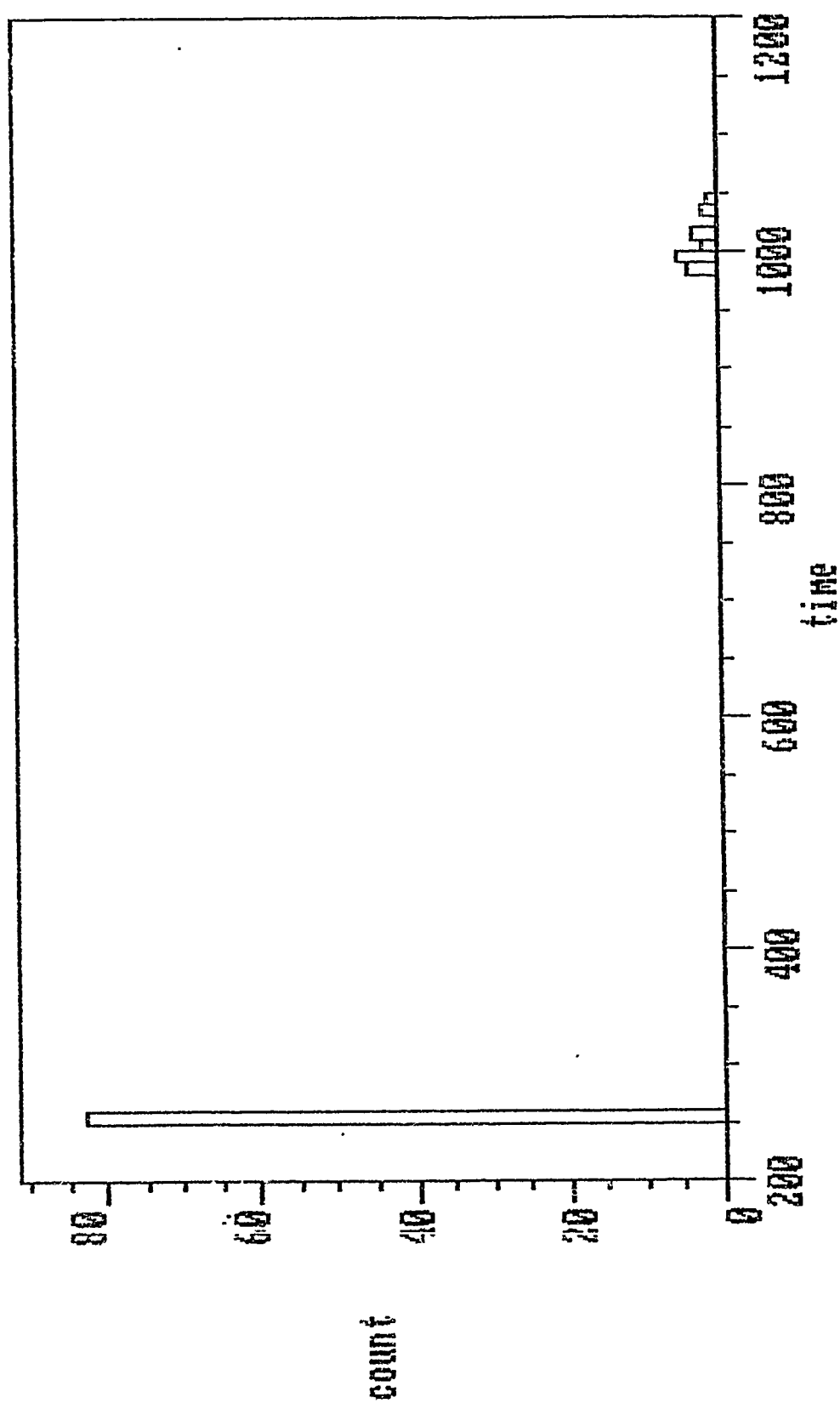
VARIABLES:

	Tag:	EVENT QUEUE:
ttime	1.66666651	0 At 110.00 Task end: 3 march
wt	71.4435806	0 At 120.00 Continuous:
pctwt	0.89292526	
vo2	29.9516754	
pctvo2	54.3454322	
temp	26.4366436	
trec	37.9709205	
distan	8.00000000	
segdist	0.00000000	
glycont	512.800292	
pctutil	1.69935226	Error Count: 0

paused>

# FREQUENCY DISTRIBUTION OF EXECUTION TIMES

Model: carry



I will point out at this time that the rectal temperatures encountered at the end of the workload are certainly all above 39° C and many of them are approaching 39.5° C, which is the cut off for continued performance. So at the end of this work bout, these people would not be in great shape to fight or carry out any other work that day.

Now, what happens to the people who had to rest? They begin resting in the heat of the day and the environmental conditions are such that they cannot lose heat. This is an important problem the model can tell us about. It tells us that under these resting conditions, it is not until the day cools off at about 800 minutes that the rectal temperature finally drops, and the people are able to continue with their work.

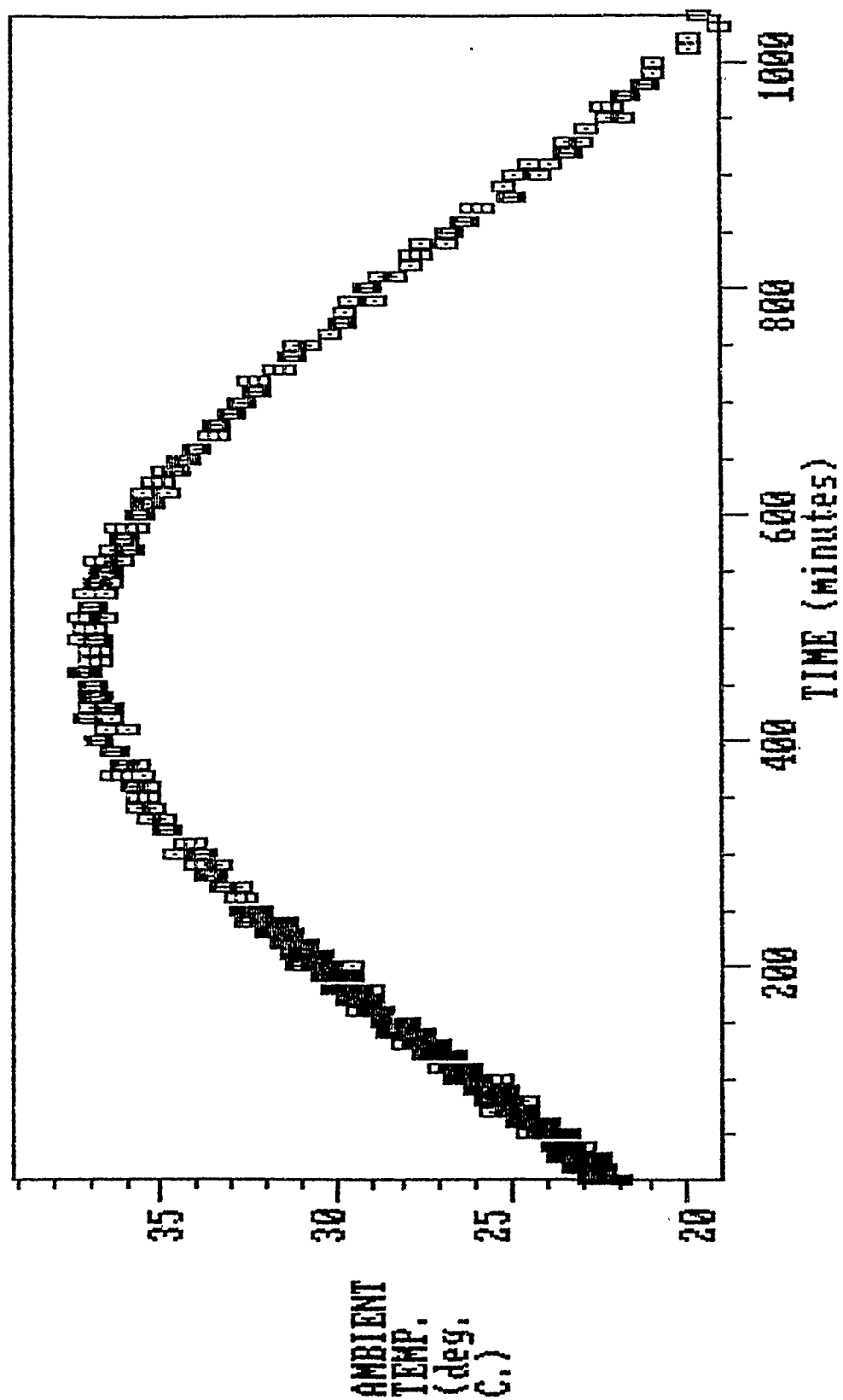
If we look at glycogen utilization as a percentage of total scores, you can see that at the end of this work bout most people have used no more than 8% of their glycogen. Early glycogen utilization is not a factor limiting performance in this kind of scenario, or at least the model says that. One of the things to note is that as you rest you still metabolize and you're working to get rid of heat and so some glycogen is used. But even with those men who rested, no one exceeds 10% utilization.

If we look at changes in body weight as a reflection of water loss, you can see that several things happen. First of all, everyone loses weight, particularly rapidly after the start of the uphill segment. Another thing of interest is that it is only the heavier people who heated up so rapidly that they had to rest. This makes sense in that as you get larger your surface to volume ratio decreases and your ability to transfer heat in either direction goes down.

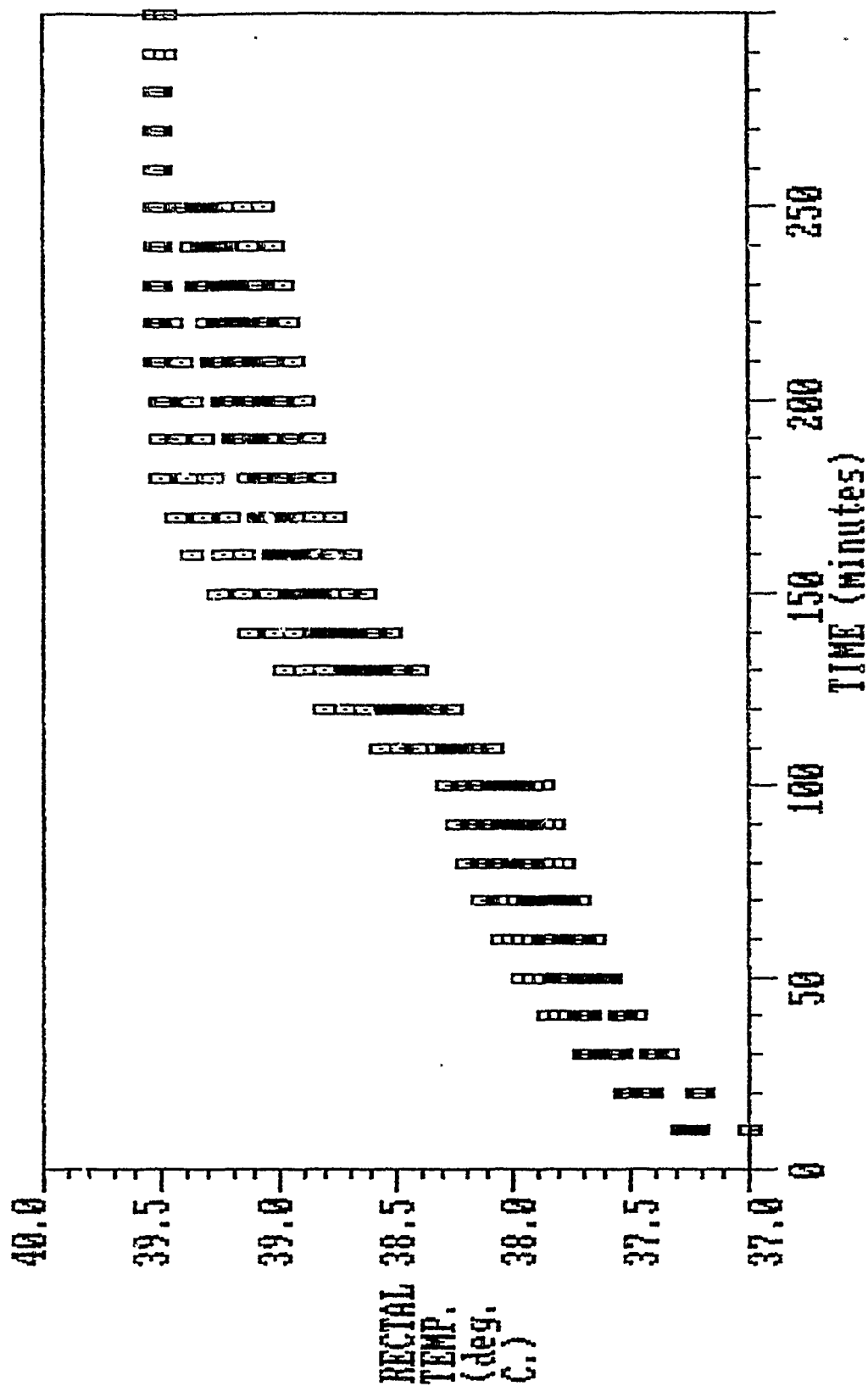
One of the important limitations of this model is that the men don't drink to replenish water losses. That's a later evolution. It's easy enough to put in, but right now it's not there because this is still embryonic.

If we look at weight as a percentage of initial body weight, you can see that routinely, by the end of the work bout, people have lost approximately 5% of their body weight in water. This would leave them severely dehydrated and quite ill-equipped to carry on with any other work. And, you'll notice in the hot conditions, even in the resting condition, they continued to sweat as one might well expect, even though metabolic rate has gone down drastically.

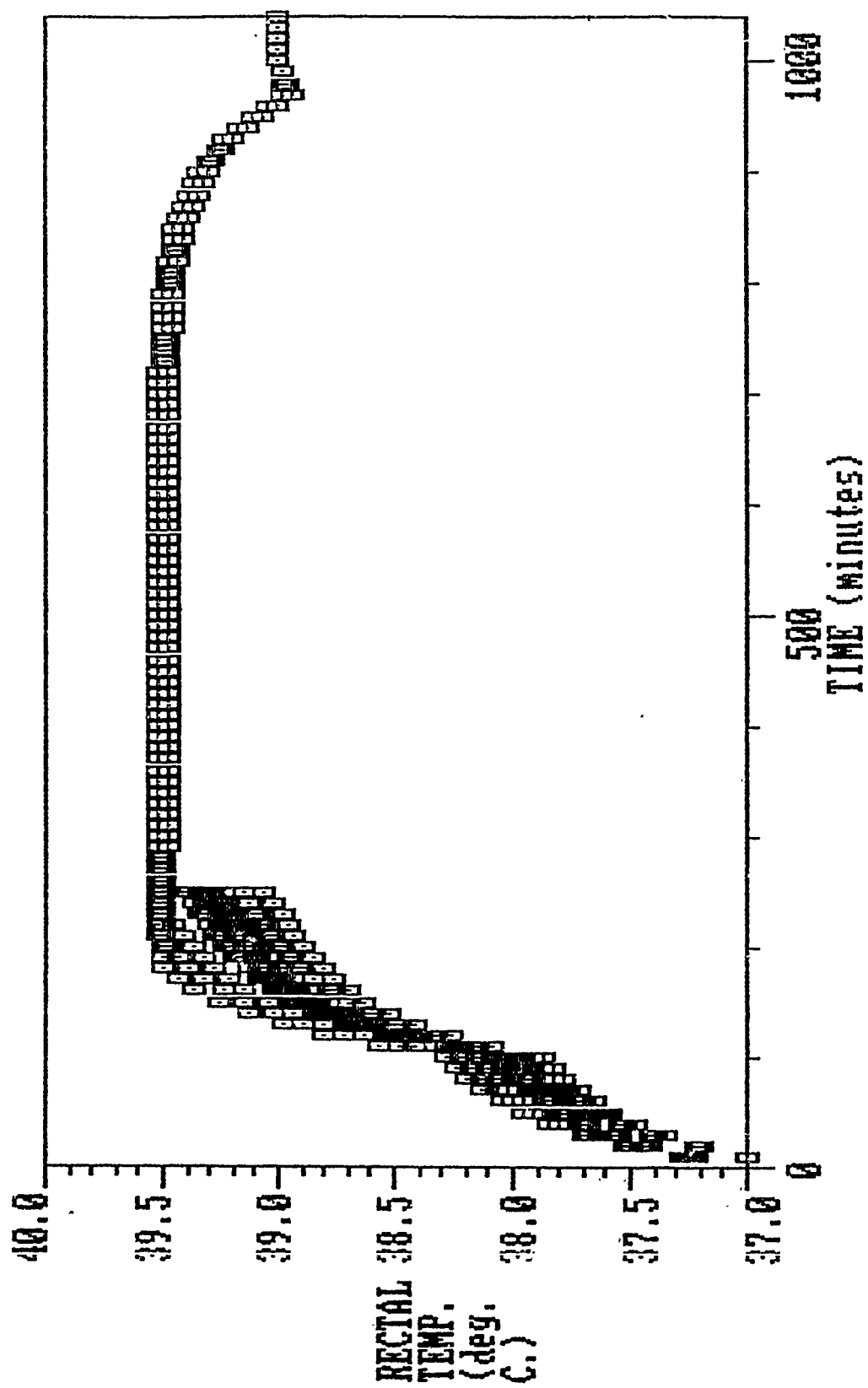
# AMBIENT TEMPERATURE PROFILE



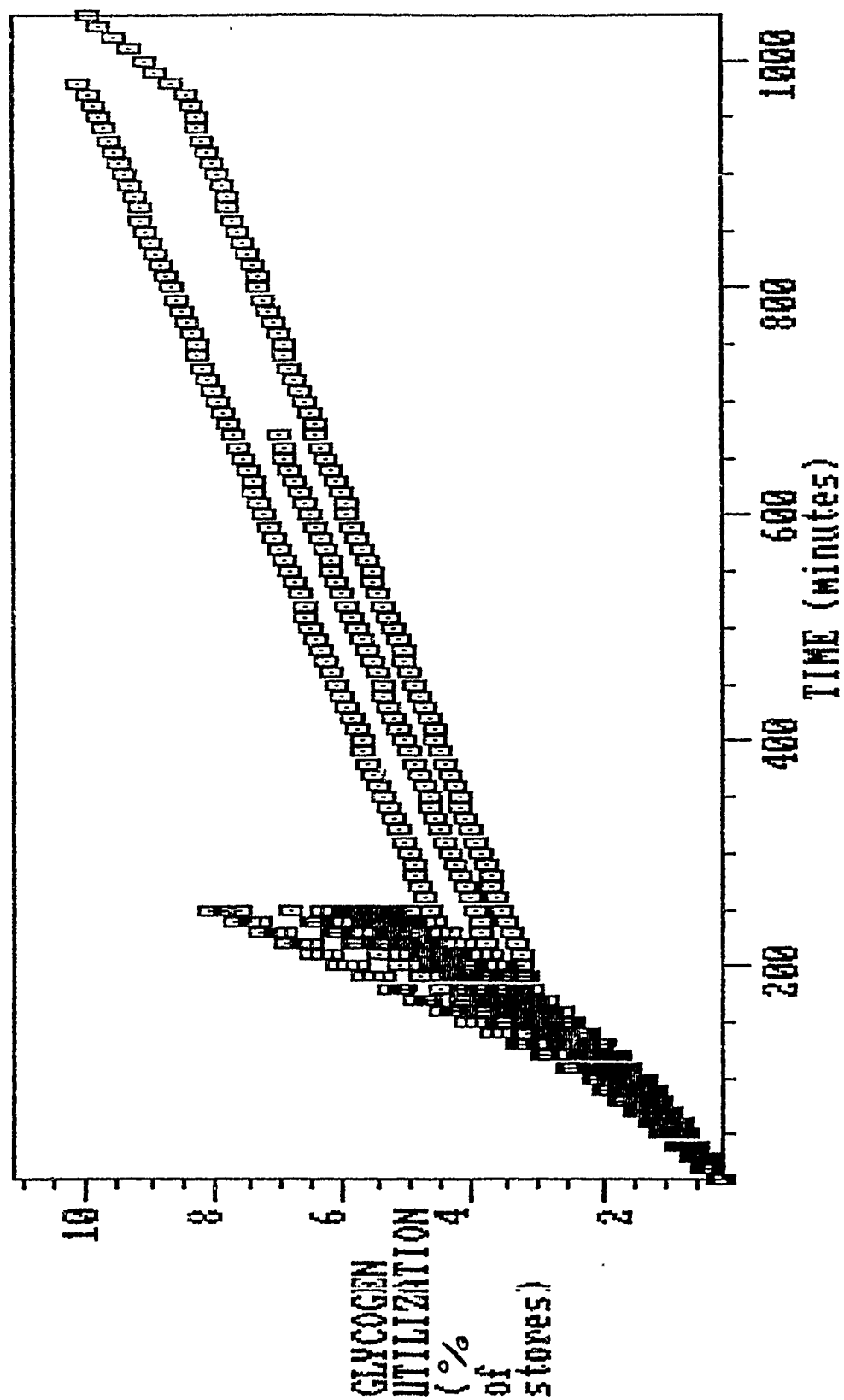
# RECTAL TEMPERATURE PROFILE



# RECTAL TEMPERATURE PROFILE

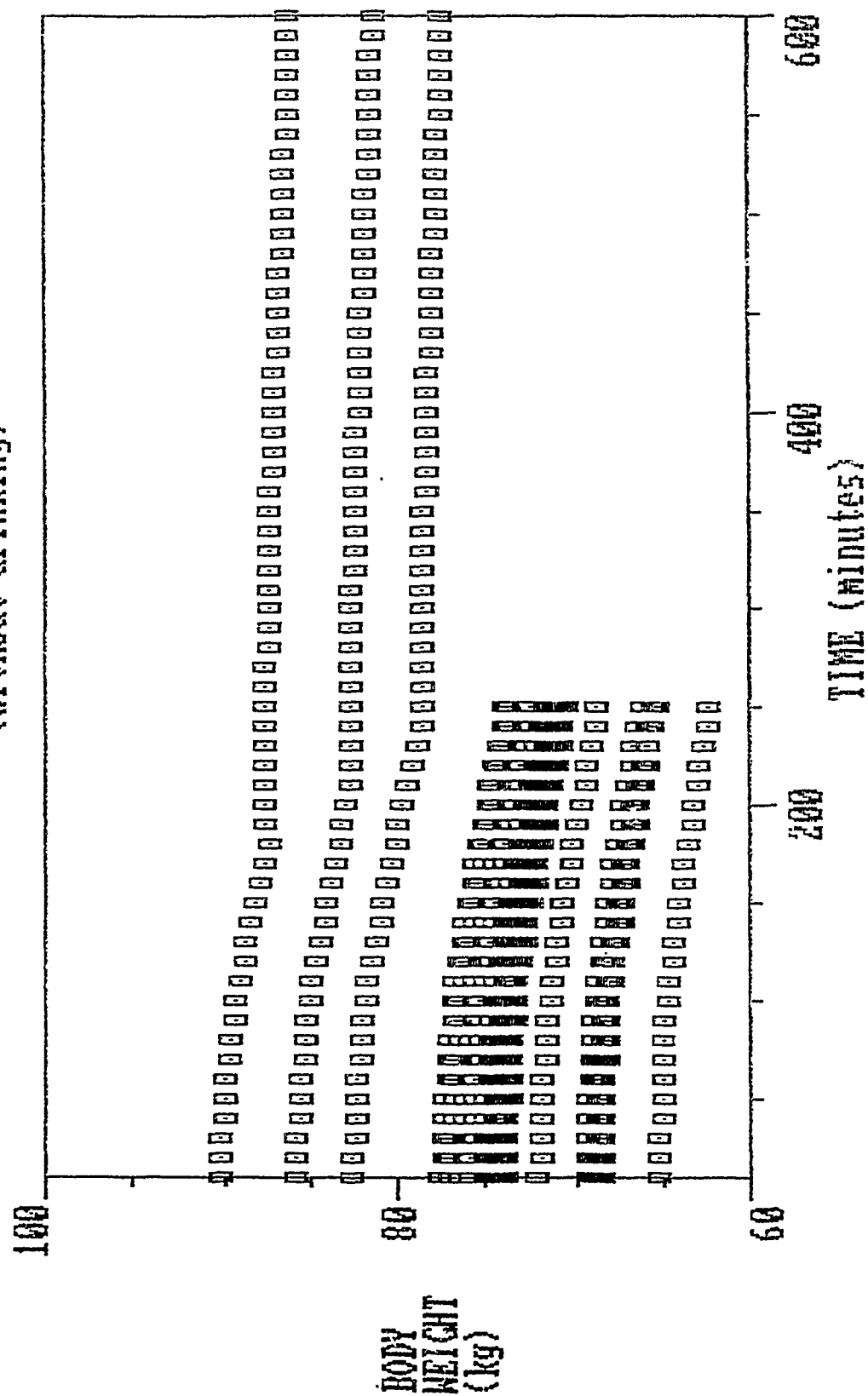


# GLYCOGEN UTILIZATION



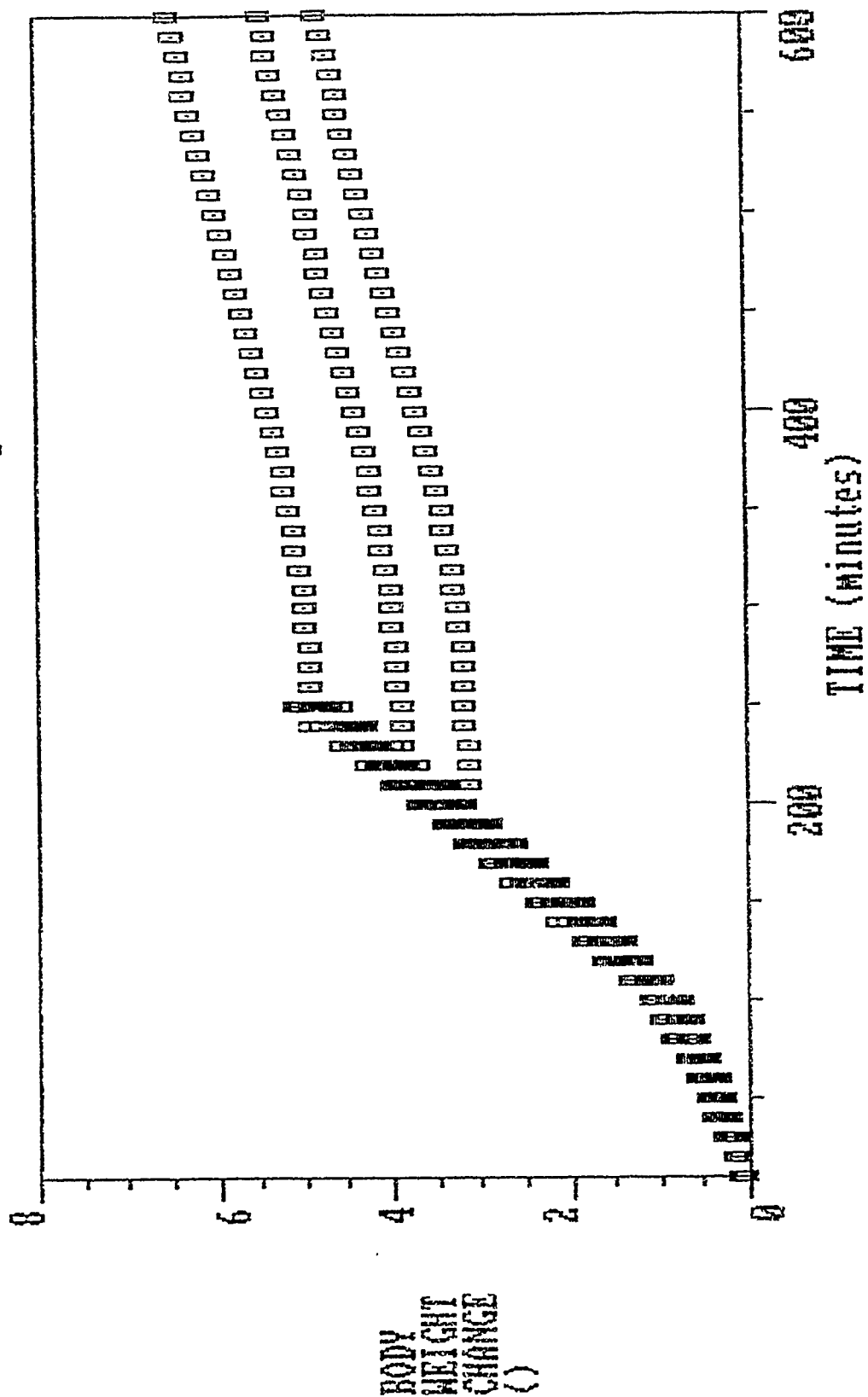
# BODY WEIGHT PROFILE

(without drinking)

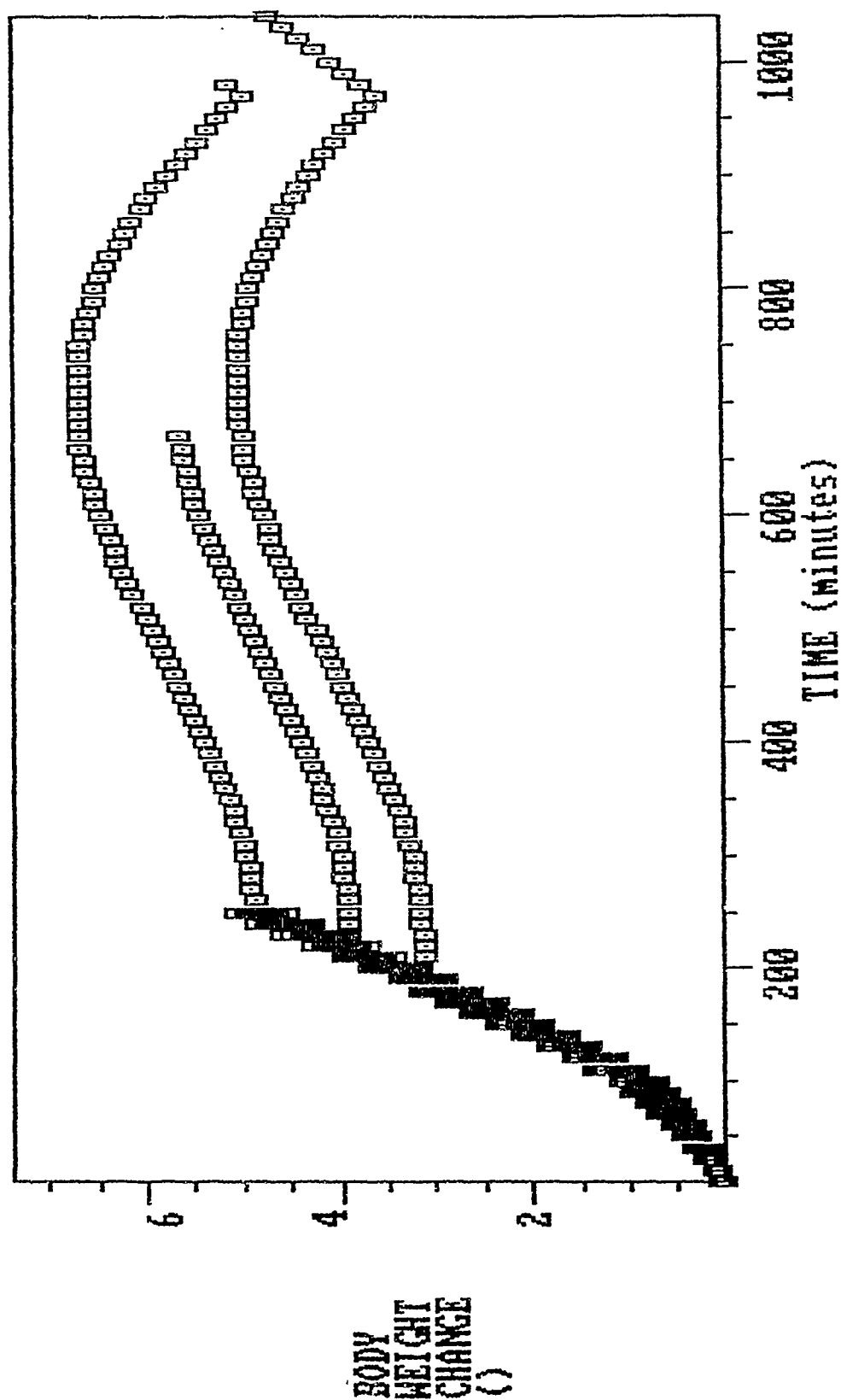




# BODY HEIGHT PROFILE (without drinking)



# BODY WEIGHT PROFILE (without drinking)



Now this all looks pretty lovely, but if we look at the rest of the body weight change curve, you'll see that those people who are still resting at 950 minutes begin to gain body weight. What has happened in this particular instance is that environmental conditions have changed such that the heat required to move out water has dropped below the maximal absorbence capacity of the environment, and the function to predict sweat rate has gone negative. This model tells us that after awhile we can begin to absorb water from the air. Right? This is pretty good. I haven't seen this yet, but it's a neat phenomena if we could pull it off. This is one of those dramatic examples that show you have to be careful to use the equations in your model only to the limits prescribed for their utilization. Runs like this point out, every now and then, that things are not quite as rosy as one might think.

There are many obvious limitations to this model. I'm sure all of you can think of at least four. I've done this primarily as an exercise to see how easy it might or might not be to use MicroSAINT and to use a network shell to accomplish this. Certainly, MicroSAINT isn't the only way. One could write raw code and do it almost as easily. Because of the decision points, it might actually be better to work with an expert system that called in surrounding functions. It would allow you to keep track of the environmental conditions a bit better, I think. I'll leave it at that.

For anyone who is interested, I did bring a computer loaded with MicroSAINT and this carry model. If anyone would like to see what it's like to run it and how it works, or how the functions are incorporated into it; feel free to come back and see me at the back of the room when I finish talking, which is in about two seconds.

AUDIENCE: Has anybody thought to do a history on the use of the acronym SAINT?

DR. HODGDON: This one grew out of SAINT which is an Air Force product. I think that's the one by Chuck Jorgensen. It's just an implementation of that particular software for PCs.

AUDIENCE: I would like to make a point similar to the one Commander Hall made earlier. The only thing that comes out of the model is an orderly description of whatever you put into it. And so, if you intend to use the model for some practical purpose it is very important that you investigate carefully the source of your numbers and not include in the model any variable that you cannot validate and quantify.

Because, the odds are you are going to reduce the validity of the model when you do that. I saw that demonstrated a number of years ago as part of a Joint Chiefs group that was developing a model for predicting target acquisition. It was very important. Two models were developed; one was a very sophisticated model and included just about every variables that could possibly evolve, including the ice maker and air coolers and had 30 different variables. The other model had basically only three variables which actually had some information. Sure enough, the simplest model was the one that validated, and sure enough, the model that included only the things you actually knew about, was the one that predicted. The other model had many swags so it was much less accurate. So, it really is a serious point and I support that. I think that one needs to give careful consideration to the variables used with an attempt to keep a few valid relationships.

DR. HODGDON: I agree. In fact, part of the reason for selecting ARIEM for sets of equations is that they only deal in variables that we have measured in the field. In the models of heat loss and heat storage, such as Wissler's model, the number of variables involved is quite large and will include things we will not routinely measure in the field. If you can't predict the essentials, why are you trying to predict the minutia of the performance? Thank you.

CDR DEAN: I was talking to Dr. Zornetzer and he said he usually comes last, so we're going to do this in reverse alphabetical order.

Dr. S. Zornetzer  
Office of Naval Research, Arlington, Virginia

DR. ZORNETZER: First of all, let me thank NHRC and especially Captain Bob Chaney for inviting me to attend and participate in this conference. It has been interesting and informative. My reason for coming was to learn. As Director of the Life Sciences Program at the Office of Naval Research, I have the responsibility for overseeing a number of basic research programs which could, potentially, contribute to better foundations of knowledge and understanding to this very difficult applied research area which was the focus of this conference. One of my goals in attending, was to try to identify some holes, some areas of obvious lack of knowledge, which would help me formulate basic research issues that ONR's basic research programs might focus on and that might contribute to a better understanding of applied issues in the future. That is clearly my charge for the Navy.

So, what I want to do today is offer some observations and thoughts and distill my comments as briefly as I can, to try to give you some insight into what I walked away with and some thoughts I'd like to share with you. These thoughts are not meant to be critical, particularly, or inhibiting to the effort, because I think it's an important effort, but I do think that some of the comments and thoughts I have might be useful, and I'd certainly like to hear your reaction to them.

While I fully appreciate the desire and need to develop models capable of predicting combat performance, I believe you might be jumping the gun in the sense that, perhaps, there is not enough baseline data available to make these models accurate, robust, and of course, useful at this time. The real danger here, is in raising expectations of potential users of these models, particularly in the operational community, only to come up short and thereby undermine future competence and credibility in the programs. In order for the models to work, you have to have a reasonable qualitative and quantitative picture of the important elements that make up the factors in this model and their relationships to each other. There were some discussions on that yesterday. Based on what I heard, you have made a good start in identifying a number of qualitative factors. Accordingly, a number of dependent and independent variables which eventually should be incorporated and included in such a

model or models are being identified. At the quantitative level, however, I think there remains serious problems and deficiencies. For example, if I understand correctly what the thrust of the modeling effort is, you are trying to develop models of group performance rather than individual performance. One of the most obvious issues that comes to mind for me is how you're going to account for all the individual differences that will be incorporated into such a group model. We saw yesterday that such individual differences can be dramatic. At this point, I'm reminded of a series of psychological studies and experiments that were conducted back in the 60s by John Lacy and his wife. These experiments to me, conveyed a very important message. Let me just try to distill the essence of some of those experiments for you.

What the Lacys found was that there was tremendous idiosyncratic differences in the stress response of individuals to given stressors. Within a given individual, the response profile to a variety of stressors might actually be rather coherent. But across individuals, the amount of noise and variability in the response profiles, a variety of physiological and psychophysiological measures, was incredibly different. So, to begin to pool individuals and form group data bases that you would then hope would serve as a foundation for a model and then to develop quantitative and qualitative variables based on those group data, I think is a very dangerous and difficult undertaking. You're going to have to have very strong signals to eliminate the noise if this is going to be an effective approach. Frankly, I don't see a great deal of hope in that. I think it might be more fruitful to focus on the individual, and I think this is an area that clearly deserves a lot of discussion. I invite commentary and discussion. Perhaps, we can use this as a discussion issue this morning. I must emphasize again, I see real problems in developing group norms of stress responses, especially to complex stressors of the type we're dealing with here, when we have data like the Lacys' suggesting enormous variability between individuals.

The good news is that the stress response pattern can actually be rather predictable and coherent for a given individual. In fact, there may be families and clusters of these types of response patterns and perhaps we could begin to identify individuals that categorize themselves into such clusters. I don't think there has been a lot of work in that area and this is something I think might be useful for us to pursue in the future.

This provides a transition thought to me that I'd like to share with you. At ONR we supported a program in organizational psychology for many years and one of the interests in that program was small group performance. It was a conscious and deliberate decision a few years ago to de-emphasize our investments in organizational psychology. Our program, I felt, at that time, had already contributed a great deal of information to the group performance data pool, and I believed we should be putting more emphasis and resources into understanding the individual, his cognitive and perceptual dynamics and the performance characteristics of the individual under controlled, stressful conditions. The goal of our ONR program is to develop a deeper understanding of the stressors' effects on individual performances, what can be done to minimize the deleterious effects of such stressors and contribute to the foundation of knowledge about the effects of stress on an individual which, hopefully, we can use to build upon and project from into more complicated situations. To de-emphasize group research was a very deliberate decision, consistent with the message I have just indicated and frankly, from what I heard yesterday, I still think I made the right decision. I think the best way we can contribute to some of these difficult problems is by understanding the individual in a stressful situation, his performance in a stressful situation and how we might buffer that individual to minimize the deleterious effects of stress on individual performance. I think that's where we can have the best handle and the best ability to make a contribution.

Let me tell you where we are at this point. We've now put together a new funding package that has emerged through intense internal ONR competition in a zero sum game. So, we've just put together approximately five million dollars of new 6.1 money to study these issues and our approach will be interdisciplinary. We're going to be incorporating the efforts of cognitive scientists, neurobiologists, physiologists, endocrinologists and mathematicians. Some of the issues we will be addressing in the next few years as this program evolves, will be to understand better, individual response profiles under stress, individual buffering capacities to stress-induced degradation of performance, training strategies effective in minimizing stress-induced degradation of performance and possible neuroendocrine and neurohumoral makers for stress-resistant versus stress-susceptible individuals. These are the goals of our program, and we feel if we had a better understanding of some of these issues we would contribute to some of the needs you have in trying to extrapolate from the individual to the group and to much more complicated situations.

MALE VOICE: Is this for FY90?

DR. ZORNETZER: We're starting this in FY90 and all of this is 6.1 that I'm talking about. Stan Collyer is parallel with us and is trying to put together approximately the same size program in the 6.2 arena. So, if he is successful and we can work together, we'll put together a significant amount of money focusing on these issues.

Well, let me just summarize with the following thought. If we can get a better handle on the individual stress response and develop some training strategies to help buffer that individual from stress-induced performance degradation, then we will also be contributing in a generic way, to some of the needs you have in the more applied arena. By helping to strengthen the foundation of knowledge in this area, I think we'll all benefit.

Those are my observations, some of my thoughts and comments, and I invite any thoughts you might have.

MALE VOICE: You suggested that we might be setting our expectations too high in this type of effort. I would suggest to you that there are people actually using these models already without our input.

DR. ZORNETZER: Well, that's all well and good if the models work, but what if the models don't work? What if the models are misleading, erroneous and actually cause more problems than they solve. Then where are we and what have we gained? It's difficult for me to imagine that the line's going to come up with sophisticated and accurate models without the knowledge foundation necessary to allow those models to develop. They're not going to pull them out of thin air. Where are they going to come from?

MALE VOICE: That's the fact in point. They have been pulling them out of thin air.

DR. ZORNETZER: Do they work?



MALE VOICE: Let me give you some examples. I run a computerized war game center, and for human factors, I swag the hell out of them. Does it work? Talk to a couple of generals up at Camp Pendleton, and they'll tell you hell yes, it works. It's super. I need something else. I'm tired of swagging. Provide it, please.

DR. ZORNETZER: I agree with you and that's what we are trying to do.

MALE VOICE: You said your approach was multidisciplinary. Please don't interpret this as critical but I did not hear you mention a person from the field participating in the basic research effort. I think that's very critical to have people like Major Anderson, who know what stress is about from a reality factor and to work hand in hand with the scientists who do not really know the kind of stress that Anderson observes.

DR. ZORNETZER: You make an excellent point and implicit in the development of our program and explicit in the selling of our programs at ONR, we described the scenario in which the subject populations for many or most of the experiments we would hope to support in this program would, in fact, be active duty personnel that we would work with in conjunction with our 6.2 friends and colleagues and in conjunction with the operational Navy and Marine Corps to try to capitalize on the real life stressful situations that exist.

MALE VOICE: Typically though, at university settings you don't find Major Andersons walking around.

DR. ZORNETZER: Now, your point is very well taken. We've had limited success in the past, and we would hope to have success in this program as well in explicitly encouraging and selecting university investigators who have an interest and a desire to work in conjunction with Navy facilities, Marine Corps facilities, etc., where they have this kind of subject pool available. So, we'll be focusing on that as a main theme in our research program.

MALE VOICE: One of the things that occurred to me in talking to people about this sort of thing, is the people who have a formal model and swag it now; obviously they have a problem, but if we don't do something to try to integrate something into what you already have on hand, in essence what we are leading to is the informal model that everybody carries around in their heads and tries to apply it in a nonsystematic

fashion. It depends partly on how you evaluate these different models. If you take them against perfect prediction, we're probably going to come out rather short. If you use a realistic alternative with the limitations of the computer and the limitations of nonartificial intelligence or biological intelligence, perhaps we'd do better if we used that as a prerequisite rather than attempting perfect predictions. It's the ideal kind of situation. If nothing else, we should be able to come up with something that would systematize what we do and point out the problems.

DR. ZORNETZER: Yes, that's very important and I certainly want to encourage you to continue that effort. Don't misinterpret my comments. I think you need to continue what you're doing. We are looking for ways to help you get a leg up on it. It's a difficult problem; it's a serious problem; it's one we need to solve. We're going to try to help you from our perspective, but certainly you need to continue doing what you are doing.

MALE VOICE: You made an excellent comment about the signal to noise ratio. When you deal with small groups of people, what is the variability. As you were speaking about it, it reminded me of a conversation I had with a group of theoretical physicists at the lab. There were two groups. One group was saying, every time we try to measure these subatomic particles there is so much damned variability we just can't seem to get a handle on it, number one; and number two, every time we measure it we think our measurement itself is affecting the behavior of the particle. Another group says, I don't believe we should be doing this. Okay? The other group said the role of the National Laboratories, specifically Livermore, is to pursue high risk research. When an organization gets so conservative that they miss their mission which is to take on very serious problems, the high variability problems, then I think you're kind of hedging your bet. In other words, you are getting so conservative as to preclude the possibility of breakthrough or to see a thread of commonality. So, I caution ONR to be very careful that they don't get so conservative that they are reducing the probability of some kind of breakthrough.

DR. ZORNETZER: Your point is well taken.

MALE VOICE: You mentioned Lacy. He also talks about specificity.

DR. ZORNETZER: Well, the primary theme of his research as I recall it was that the individual differences certainly predominated over any kind of coherent predictable, stressor-produced specific response, and I think that's a serious problem for people who are trying to deal with group analyses of these kinds of phenomena. So I still think the message I'm trying to convey is a valid one. I think that's the primary theme of this data.

MALE VOICE: The specific response to the stimulus in the individual was always the same, but between individuals there were differences in responses.

DR. ZORNETZER: You know, there were a couple comments you made yesterday that Commander Petho and I thought were kind of interesting. One was that you didn't think that research into selection aspects of this problem would be very fruitful because of the limited manpower pool we are dealing with. I'm not sure that is necessarily the case. I think if we did have a good handle on how to select the people who were stress tolerant vs. stress susceptible, we might very well do a better job of assigning people within the given manpower pool than we do now. Not to exclude people from service, but to provide them with positions where they could most effectively contribute to their needs. So I'm not sure the selection issue should be short circuited up front. I think if we could come up with a good battery to select and screen individuals that might be a very significant contribution to this whole effort. If you can put 35 people together in an AEGIS CIC, all of whom had been selected to be stress resistant, I think you may have a much better team performance than otherwise.

MALE VOICE: That may very well be, but when you raise the specter of selecting individuals who are stress resistant and put them in various environments, what about the other people that are not stress resistant and how do you translate a nonstress resistant warrior. What do you do with those people and how do they interact with the more stress resistant--those that have been inoculated somehow? To use the medical model, those vaccinated against stress.

DR. ZORNETZER: Well, I'm not sure that the criteria for selection have to be transparent to everybody out there. There are all sorts of ways of doing that.

MALE VOICE: That component of our assignment is invisible today.

SECOND MALE VOICE: When you think of an application phase, you are wondering about the cost of screening for many kinds of situations. If we find these individual differences are so great can we afford to spend that kind of money?

DR. ZORNETZER: That's a priority issue. We screen everybody for HIV now. Can we afford to do it? Well, it was decided it was a high enough priority, and therefore, we could afford to do it. Well, if this is a high enough priority, we'll afford to do it.

MALE VOICE: I'd like to just make a point to Dr. Carroll's statement regarding the classifications as being invisible. I think that's a pretty good term to use, being invisible, because there are many times that we don't even use it. If the Navy says we need 10, we get 10. They have to be pushed through all the time, so I'm not sure the selection is efficient because we don't adhere to it.

DR. ZORNETZER: Well, that's another problem. I still think it could be useful and maybe something else has to be changed to make it more useful.

MALE VOICE: If I understand the thrust of the overall program from what you described, it is to do away with the need for the selection criteria in the first place. I think you are looking for methods to enhance stress resistance in the long run. That would be the more desirable solution and that's really what the overall program is about.

DR. ZORNETZER: If it were completely effective, then of course, you would be correct. I think we probably have to approach a complicated problem like this in more ways than one, so we thought we would approach it both from a screening perspective as well as a training and buffering perspective. This is a multifaceted, complicated problem and I think we need to deal with it in a number of ways and that what we're going to try to do.

CDR DEAN: Our next speaker will be Dr. Bob Carroll from OP-01.

Dr. Robert Carroll  
Office of the Chief of Naval Operations, Washington, DC

DR. CARROLL: I want to thank Captain Bob Chaney and Commander Larry Dean for inviting me to this conference. Larry and I used to be colleagues in OP-01 and had a good friendship that has continued through the years.

Obviously, I have to mention Bill Banks, the most influential student I've ever had. I had him in an undergraduate introductory statistics course, and he was an outstanding student then, but I might add that he was a senior student at the time and I was actually younger than he was, even though I was the professor.

This conference is extremely timely. Captain Chaney and the Naval Health Research Center are getting into pressing Navy issues and I believe that R&D should be requirements driven. Even R&D that is tech base I think needs to be driven by a requirement. At least, the link should be obvious to everyone, obvious to the military line and obvious to the researchers. Stress is an important issue today because of the operational episodes we are all familiar with, and there have been several incidents in training also in the last year that we are all familiar with. CNET Vice Admiral Disher is interested in developing research in safety related to training and I think it's a wide open arena. What are the limits of training? Can we teach reaction to stress in training? Do we need to select better? What's the contribution of better selection vs. stress training? All these issues need to be researched by your community. Obviously you have to be concerned with tying it to medical concerns and I think always using the word stress is your link.

When I took over as the assistant for research and planning in OP-01 I thought we needed to have the requirements identification process determined by the line. It shouldn't be determined by a staff office. I was there and could have been a czar for R & D, determining requirements, moving money around, all of this. Line involvement from the beginning of an R&D project is necessary so that they will procure and use the R&D which is eventually developed.

There are many things where organizational boundaries impose constraints. We have to overlook these boundaries sometimes if we want to accomplish something. If you don't, you won't accomplish anything of significance. You need to get top down driven requirements to accomplish much and that's why the congressional hearings on stress are probably now leading to ONR, OST and even OP-01 to put more money into human factors and stress related research. I was happy to hear this morning that ONR is going to establish a new five million dollar research program in this area. The only way we are going to get resources for our efforts is to take advantage of leveraging these key issues when they come up. When they do it creates a lot of noise and fervor, gets your research funded and then goes to work on the problems we face.

All the findings presented yesterday by research personnel from the Naval Health Research Center should be of great value to the Navy. Now, you have to make sure the operational Navy gets these results. We need to package them in a way that they can use them. It doesn't do us any good to publish a research report and mail it to them, if they don't have the time to read it and probably will not understand the research terminology anyway. We need to put the bottom line on the findings we think are reliable. We need to put it down almost in bullet type formats so they can use it.

The students you use here at NHRC--what an opportunity for them. There's no better place to study stress than in the military. We can manipulate stress. We do it all the time in our training; it's really a rich research environment. So if we're having a hard time retaining our researchers because of the lack of pay, then we should sell the advantage that we have the best research opportunities in the country. Much better than a university professor. He can manipulate his freshmen, but what kind of stress can you generate with a freshman.

We need to do more cooperative efforts and again I want to laud the NHRC. Their research in cold weather operations with the Norwegians, their research on sleep deprivation with the Canadians. Cooperative research is a big area today. As a matter of fact, U.S. foreign military sales over the last five years has declined from 17 billion to 7 billion. The U.S. is concerned about this because of the deficit. The foreign countries aren't buying our products. Well, there are two thoughts here. One, we want to engage foreign countries in cooperative efforts so they can assume some of the defense burden which will help use reduce our deficit. Two, cooperative efforts may encourage them to buy our products. You know, they are not going to buy our products if they are not

involved in the development. OSD has issued guidance to all the service that by FY94, 10% of the total R&D budget of each service should be devoted to cooperative efforts with foreign countries. By the turn of the century, the guidance says each services should have 25% of their R&D budgets involved in cooperative efforts. I think the Navy and services need to get together and prioritize where do we want to share and where don't we? Do we want to share our Stealth technology, or do we want to share medical technology, personnel technology? Where do we want to share? The guidance is telling us to do it at this point so I suspect medical and behavioral sciences will be one of the areas for cooperative efforts.

I think there is another reason why our foreign military sales have gone down. I think you have alluded to it in this conference. Frequently we put all the bells and whistles on our hardware systems. It is that extra capability, the new technology we put on the system, the technology we frequently turn off in the field because we don't know how to operate it, that is the cost driver. I think that's another reason why our foreign sales have gone down. We've made our systems so complex, elaborate, and difficult to use without extensive training that foreign countries can't effectively use our systems anymore.

With World War II we developed a strong manufacturing capability; we were one of the few countries that had a strong manufacturing capability after the war. The European manufacturing capability was devastated from all the bombing. We thought we were good managers because our foreign sales went up, profits went up and, in reality, we were dealing in a monopolistic environment. Anyone can be a good manager in a monopolistic type environment. Now we have to face true competition. So, now, I think that's where we need marriage and cooperation between hardware engineers and psychologists. I hate to hear comments by behaviorists that it's the engineers' fault and by the engineers who say the psychologist gets in his way. We really need cooperative efforts. That's the only way. We need to have common purpose between the engineer and the behavioral scientist. We need to work together up front. We need to quit saying it's their fault, pointing both ways, placing the blame elsewhere. We need to cooperate up front and share in the benefits, too. I think this requires basically a national agenda, top down driven again.

I think we need more interlab and interservice cooperation. Today, defense agencies have 22% of the defense R&D budget. Five years ago, defense activities had 10% of the R&D funds. So, in the last 5 years, defense activity funding has gone from 10% to 22% of the DOD R&D budget. If what's programmed in the out years comes true, by FY94 defense activities will have 37% of the defense R&D budget. Why is that happening? One reason is that we don't see enough cooperation among the services, so anything that cuts across service lines ends up going to a defense activity. Of course, there are things like the Strategic Defense Initiative that are helping to promote funding of defense activities such as DARPA.

Within the Navy I understand the ASBREM is working fairly well. That's the joint service coordination within Medical R&D. I think it's working well with the Army and Navy but not with the Air Force. We've been directed by OSD to establish a similar mechanism in manpower personnel and training research. We were using the ASBREM model modified to our needs, but the Air Force was refusing to sign it because they didn't like the way ASBREM was working. We are still working that initiative right now at the Air Force secretariat level, trying to resolve the differences. I know when ASBREM was first formed, the Navy didn't want it. But I understand now you can correct me if I'm wrong—that the Navy is quite happy with ASBREM.

I heartily endorse the efforts to include behavioral performance variables in war gaming models or other combat models of various types. Addressing the point that was raised this morning, a lot of the time we cannot predict individual behavior, but we can predict group behavior. Even with our selection instruments, when we assign a person to a particular rating in the Navy, we know he might be a failure or washout. We know we can't predict individual behavior that well, but we can predict group behavior quite well and the errors in group behavior are much smaller than individual behavior. Dealing with group measures sometimes is the solution to individual differences. Someone said yesterday that sometimes models that have just four variables versus complicated models with many variables predict just as well. That's true but I think behavior variables should be one of the four variables. When you look at outcomes of combat frequently it is the better trained outfit, sometimes with similar equipment, that completely demolishes another outfit just because of the training and personnel factors. So I think we have a lot to offer, but I think we need to show people we have a lot to offer. We need to prove our point. We need to actually do research. One of the things I'm always promoting is that I think you need to get involved in fleet exercises. We



need to start manipulating personnel variables and determining its impact on combat effectiveness. We need to start manipulating training. I think imbedded training and networking of simulators will facilitate doing this type of research. We should start measuring the personnel component of combat effectiveness. I think it's going to be hard to model this unless we can measure it. Actual exercises are needed to obtain data to help us build good models.

Modeling today is becoming even more important in the Navy. A lot of our weapon systems are outgrowing our ranges. We don't have the capability now to test or evaluate some of our new weapon systems because the range just will not accommodate them. So how are we going to evaluate it. Well, the Navy's policy now is to develop models for T&E of various systems. It's hard to validate war gaming models. One of the things I told Bill in my class was you always need to validate your models. But in war gaming models there are no criteria. We aren't having enough wars to really say we are producing the right results. So, whether we like it or not, there are going to be models out there to some degree which are not validated. I think we should become a player.

By including personnel variables in these war gaming models at least we can start teaching the line that personnel variables are important in war gaming training. Within OP-01, we run many models where we can't predict individual behavior, but the aggregate we can predict. We forecast strength planning. We tell the recruiting command how many people and what ratings to recruit. We cannot predict who's going to leave the Navy in advance, yet we can predict fairly accurately how many of a given rating will. We can predict that given a pay raise of 4%, this many will leave; given a pay rate of 8% this many will leave. We can make these types of predictions but we cannot predict at an individual level which ones will leave with certainty.

A final thought I'd like to leave you with is that I hope something concrete will come out of this conference. As I say, I've heard all kinds of interesting findings on cohesion, leadership, team training, operations under heat and cold, and many others. We need to package those things into some guidebooks, and I'll offer a funding source for you. It's not mine, it's Earl Alluisi's. I think we need two types of guidebooks. I would like it to be an action item coming out of this conference, because you really have some valuable research findings. You have an outstanding laboratory here, and you know what's going on elsewhere because you gave a beautiful summary of other

peoples' research, but I'd like to develop a guidebook for the commanding officer—a commanding officer of a ship. Here are the findings we've gathered over the years. A very simplified guidebook, not a tech report; just these findings we think are reliable. I think we also could use an engineers' guidebook, as LCDR Frank Petho brought up yesterday. We have some findings that could help design a system. We have a committee for R&D line where each service is represented. I'm the Navy rep on this committee. I asked someone yesterday how much it would cost to produce such a guidebook and they said about 50K. I told them Earl gives you 50K just to develop a good proposal. You send in a preliminary proposal and he gives you 50K to work on enhancing your proposal. We probably could develop such a guidebook. You wouldn't even need to do it in house. In house your researchers are busy, and you could hire a contractor to do this and just tell him what articles to review, what findings to put in and then you just oversee the process. I think we need to take that further step. Our research is now driven by requirements. We are doing good basic research and coming up with good findings, but now we need to package our findings in a way that the operational Navy can use. I've already plugged the NSIA conference where we have Navy speakers coming up in May. The Navy will host that conference probably in a few years. Let me know if you'd be interested in something like human performance in combat as a future theme for the conference. I think we could have a conference bringing in NSIA, the other services, DOD and industry participating as well. I believe it's a high visibility thing, and we can pull it off if you're interested.

Those are my comments. Any general questions.

**MALE VOICE:** One thing about how well joint technology coordinator groups work. The structure at the top is the flag officers. They meet once a year, they basically plot out whatever they can think about, including the weather, but what actually happens with the guys below that—the 05, 06 level guys. It all depends on how well those three people get together and work.

Some are working terrifically and others don't work at all. A lot of that has to do with who the service assigns, because I don't really see at that level very much in the way of the services being unwilling to cooperate; it's just that the guy doesn't get there. The other thing I would ask and you can talk to me about in private, probably, because I don't think everybody else will care, but just a question: what is the Air Force

unhappy about with the system? I would be curious as to whether it's a systematic thing or whether it's just simply that they don't want to play.

DR. CARROLL: Well, that's always tough to find out. I have my ideas on that too. We have the same thing; we have an Interservice Personnel Review Organization (IPRO). You've probably heard of ITRO, Interservice training review organization. ITRO can quickly get together and get a joint interservice position on issues. IPRO is run the same way. We have 10 panels, one on accession policy, one on MWR, and so forth. Some panels are doing great and other panels react like you mean we have to meet again.

MALE VOICE: You can't go after a problem that has arisen and then everybody gets together and does it. It has to be a continuous process for it to work. You have to meet regularly.

I have a question or comment. I was thinking about your idea about a guidebook in line with what we have been talking about. We're looking at decrements in performance and in our earlier discussion were thinking: should we also look at places where performance is unpredictable? I think this in our models is one of the larger criteria that would be of interest to a good commander. When are conditions such that you are going to reach that human variability, so that you don't know what's going to happen. Are the tanks going to be driven to the correct place? Are they going to forget what they're supposed to be doing? We might be able to look at models in terms of predicting those places where behavior is unpredictable.

DR. CARROLL: Right, I agree with that.

MALE VOICE: You mentioned about various models and one of which is the stress model. I wonder if you could give us any information about medical sustained operation where the medical corps is involved in actual simulated operations. Medical doctors cannot function 24 hours a day, over five days. I was wondering how much was included in these models of personnel.

DR. CARROLL: I don't know. Does anyone know of any research on how long a doctor could work effectively? I do know doctors supposedly can not work under extreme stress; that's why they don't let you operate on your own family members.

MALE VOICE: One example was doing cardiac catheterization on his own mother. At a major conference a physician got to his feet and said, well, I did it because I was the best guy, and I wanted to give my mother the best shot.

DR. CARROLL: Well, there's a lot to say to that. Other comments?

MALE VOICE: There is a dim patch of literature on doctors involved in continuous duty. There's a relatively short time period that their performance is maintained—less than 12 hours. Once you push them beyond the 12 hour area, their performance deteriorates.

MALE VOICE: I think it has something to do with lawsuits. In New York State they passed a law where a maximum duty period for an intern is 18 hours. Traditionally it has been 36. The literature I've seen does show performance degradation in reading electrocardiograms and things of that nature, not counting mechanical performance which is probably worse, but after having been sued and seeing lawsuits taking place, the state of New York set time limits. It's going to cost a lot of money to do that because essentially it is slave labor and state hospitals will have to come up with the money to do it, but it's probably going to follow in California.

I do know lawyers are basically driving our business now. Professional organizations used to set ethical standards but now for all practical purposes they are actually driven by the lawyers. Lawyers like these big settlements too, because with settlements like the Texaco settlement of \$10 billion, they just raise their fees another \$100 thousand. The bigger the settlement, the higher their fees can get. So, I do think we, as a country, should set limitations. We're spending all of our effort, instead of dealing with productivity and quality sorts of things, on these lawsuits while our foreign competitors work on improving their products.

MALE VOICE: Thanks for telling about the two guidebooks. The first type you mentioned would be for the COs. We considered guidelines or guidebooks, but I'd like to hear your input on how we get these implemented. How can we get them to read them and apply what we put out?

DR. CARROLL: Well, the first step in getting them to read the guidebook is to develop the product. As I always say, you've got to get the user and researcher together from the start. I think if you develop a guidebook, and I'm not talking about a long

technical publication but just some of the findings we have. You bulletize the findings. I don't know how long it would take, but make it simple and I think you will find people reading these sorts of things. But people are very busy obviously. The CO on board ship won't read it or delegate reading it to someone else, unless it's quick and unless it gives valuable information, but that's the challenge to us.

MALE VOICE: I found from my cohorts in Washington, trying to get the fleet to make use of tech based research takes an advocate, even if you put it in bullet format. You have to walk it through each office, and, yes, they may read it, but then they do not have the time or interest to pass it on and you have to walk it to the next office. It turns out to be your full time job, just trying to get a small piece of research into the fleet.

DR. CARROLL: I think, if we had this type booklet, today, if we had produced it two years ago, we could have gotten a lot of leverage for it in congressional testimony. We should develop a guidebook, right now while there's a lot of interest. CNET would love to have such a guidebook. I'm sure, related to training.

MALE VOICE: Dr. Carroll, in reference to our conversation about that guidebook last night, the lights just went out.

DR. CARROLL: See, that's what always happens. They find out how much money you have and then they raise their cost to what you have. I just said 50K was no problem, and now the price has gone up.

I don't have the answer on top of my head, but I think we can have leverage right now to do all kinds of things related to stress, training, cold and all these things. You know things go in cycles. If nothing happens for a while the peak of interest is going to go down, but right now, it's these episodes we have got to take advantage of. It's these things that make people aware of issues but with time they'll forget them.

MALE VOICE: I would point out that our mere presence in the field doing our research is an awareness process. We are in the field with the battalion; it's not just the 16 subjects we are testing that know we're there, it's all 700 members of the battalion that know we are there, and after two days in the field, they all know why we're there. So, the fact that we do field research, even though it's not the absolute controlled environment, is in fact a technology transfer, just doing the data collection.

MALE VOICE: There is a very important thing called credibility.

DR. CARROLL: Right. I've seen it in OP-01. We must develop products with the user in mind. Our products should be tailor made for the user. We must not develop products and then market them. Our products should address user requirements from start to finish.

MALE VOICE: To Commander Banta's comment, I know what you're talking about--trying to get something out of a laboratory to OP-01. How do you transition the technology from the R&D community into operational use? My message to you is develop the product, the handbook, and I'll take the necessary steps to get it under review.

DR. CARROLL: You can't beat that. Thank you very much.

CDR DEAN: Dr. Lorentz Wittmers, our next speaker, is from the Hypothermia Lab, University of Minnesota.

Dr. Lorentz E. Wittmers  
University of Minnesota, Duluth, Minnesota

DR. WITTMERS: I'd like to thank everybody for the invitation to come and talk and participate in the conference and maybe give you a little history on my involvement with models. It goes back into the early sixties when as a graduate student, I was modeling the fluid transport across capillary membranes in isolated rabbit lungs. I thought that was a lot of fun. The model worked relatively well.

In retrospect I think I should have stuck with the capillary model. I had a better chance of winning than with human models. In coming to Duluth, which is cold, we were interested in cold stress. We got interested in modeling in comparison to human experimentation with respect to some things we did for the Coast Guard in evaluating hypothermia protection devices.

It has become very popular, at least in the modeling community, to try to get rid of human subject studies because 1) models are simpler, 2) models are cheaper, and 3) models don't have to go through committees in order to use them. So there was a push for a long time to use models for hypothermia protection capabilities of items like helicopter suits, for example, or deck suits used by crewman working oil rigs. We got into the business of testing these on human subjects and found that the individual variations given the same suit and same condition were so drastic that we spent many years fighting the people with the models. In other words, the response to stress of these individuals when put in say 10° C water, varied so greatly that any model constructed would probably be either ridiculous or leave you open to a few lawsuits, because the model underpredicted or overpredicted what happened to the individual when put under that stress. And so, I've had a few discussions with Dr. Wissler on his model and a few discussions with the people who use the copper manikins and it's always fun to talk with them. But we're sort of stuck with human subjects.

The problem with respect to stress is, that among physiologists, I cannot get the same definition of stress from any two of them. So you are more or less stuck with whatever stress definition you wish. I find that in building a model, I cannot, with the limited number of subjects I have, produce enough data to with any confidence that I

would build a model with that data. For example, in the next two years, I will probably test 30 or 40 subjects under six different multiple stress protocols. Now, what we are planning to do is hypothermia water stress, hypothermia air stress, add the two together so we have a water/air stress on top of each other, and then make life more difficult by adding either exercise and/or sleep deprivation. So, we're going to do multiple stressors.

But, the problem is that we won't turn out all that much data from each of the protocols. And, my question to you is, in order to make models better or to make them more accurate, do we need a standardized protocol? If not a standardized protocol for stress, at least a standardized protocol for performance? If we take people and put them under a stress, give me a standardized protocol so I can evaluate their performance. If you evaluate somebody's performance under your conditions, at least we might be able to put the data together to give us enough numbers to make the model usable.

Secondly, there is one modeling sort of joke—at least I haven't seen here and I'm happy that I haven't—and that is to use the data to create the model and then use the same model to test the data. I haven't seen that and I hope I never see that, but I think that would be another effort we could well do. That is, if you create a model, create it in such a way that you can give it to me, and I can develop a protocol that's different but will fit the model. In other words, I can gather all the data and then try to test the model. I think that kind of cooperation would do well for everybody to think about. In other words, I want to run my own protocol, but if you have a standard protocol for stress and a standard protocol for evaluation, I would like to add that at either end, so that in the end when we bring the data together, we can pool it and see what happens.

I like models, but I'm the human subject type of person. I like to put people in water and watch their responses. Models do not roll over in tanks, models do not hyperventilate when you stick them in 10° C water, and models do not have different patterns of sleeping the night before. So I'm sort of a human subjects person, and I'll stick with that for a while.

Thank you.

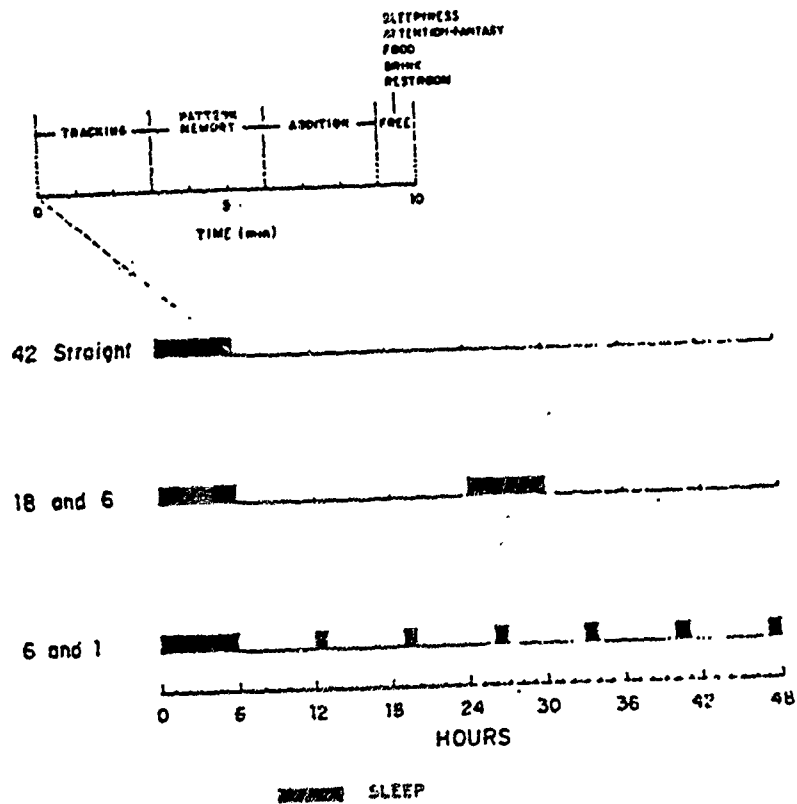


CDR DEAN: It is a pleasure to introduce Dr. Kripke, University of California, San Diego.

Daniel F. Kripke, M.D.  
VA Hospital, San Diego  
University of California at San Diego

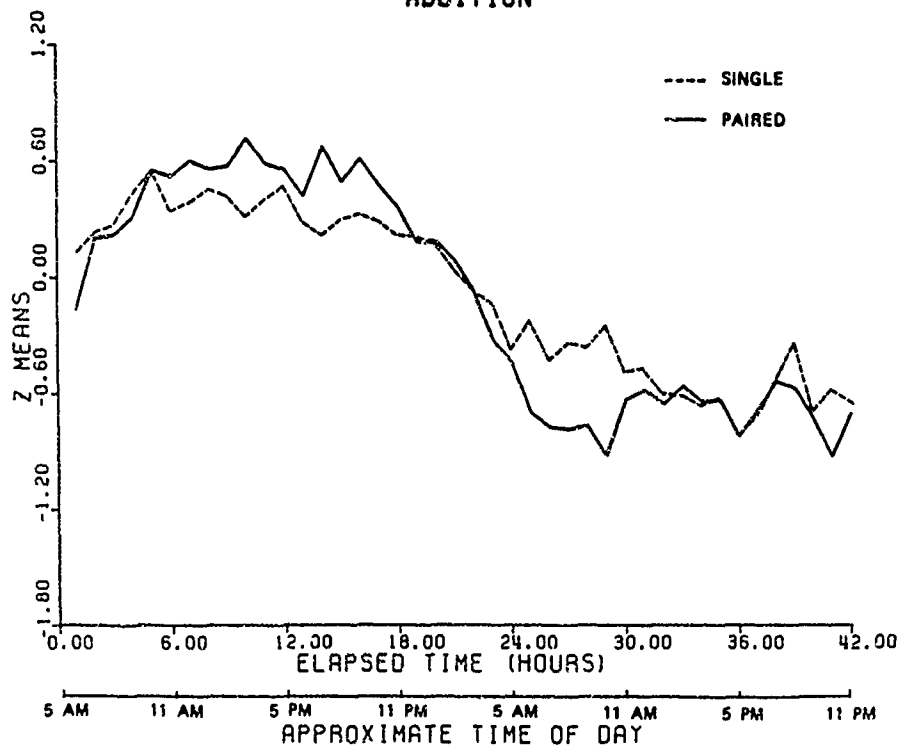
DR. KRIPKE: I have a confession to make to you. I used to be an Air Force aeromedical researcher over 20 years ago. It's interesting that at that time I met Paul Naitoh, who was a University of California researcher, and also people at NHRC. I really came to San Diego and joined the University of California partly to be with friends at NHRC, and I'm glad Paul Naitoh is now a Navy man. I'm very pleased to work with NHRC and Captain Chaney and Commander Banta. We really appreciate the chance to work with you.

I'm going to talk, not about my usual expertise (which is in putting people to sleep) but about light. I want to start with this figure. This was an experiment we did with Dr. Johnson at NHRC on a unique kind of continuous sustained performance. We put people to work on computer tasks, continuously for 42 hours. One group never had a chance to rest. One group had one eight hours of sleep. One group had some naps. As you might expect, the groups that had rest performed substantially better than the people who had to work straight through. What was remarkable is that the people who had to work straight through suffered a variety of illusions, distortions and even hallucinations, and many of these people simply could not work continuously for 42 hours. So, the more sustained the performance, the more difficult it was to perform. Here's an example of performance on an addition task for 42 hours, and after an initial learning effect you see a steady deterioration. What's most peculiar is this dip here about 5:00 a.m. and then some recovery as fatigue gets worse. This is, of course, the circadian rhythm, the circadian dip which has even a stronger effect than fatigue in determining performance. We've seen this repeatedly in our data, and I think you're all familiar with the circadian effect. It's important. There were some guys on the graveyard shift at Three Mile Island who made some really silly mistakes and melted down that reactor. There were some guys on the graveyard shift, about 1:30 a.m., at Chernobyl who made some really silly mistakes and blew up that nuclear reactor. There were some guys who had been on shore leave during the day who decided to take a tanker out from port of Valdez after midnight last week. The Coast Guard said that a



Diagrammatic illustration of experimental group protocols plus 10-min testing sequence.

# ADDITION



10-year-old could drive through a 10-mile wide channel but these guys conned the tanker onto the rocks after midnight.

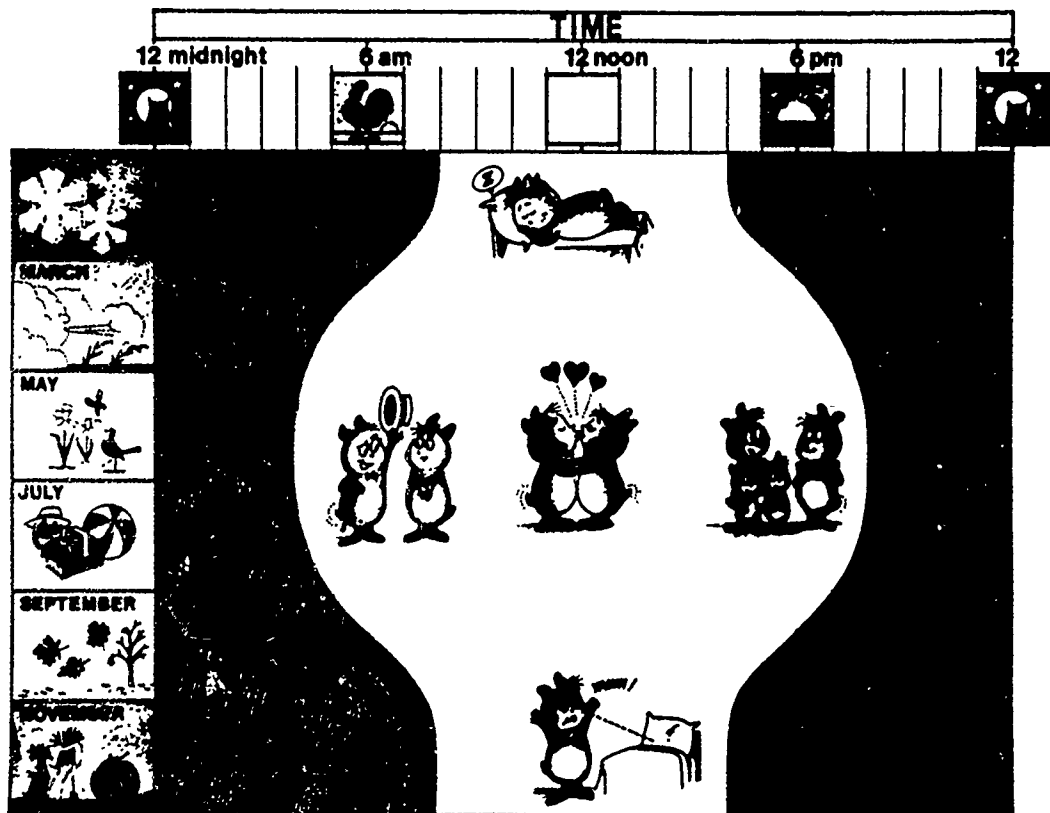
The circadian effects are very important. What's exciting is that we have a new way of dealing with circadian impairments of performance.

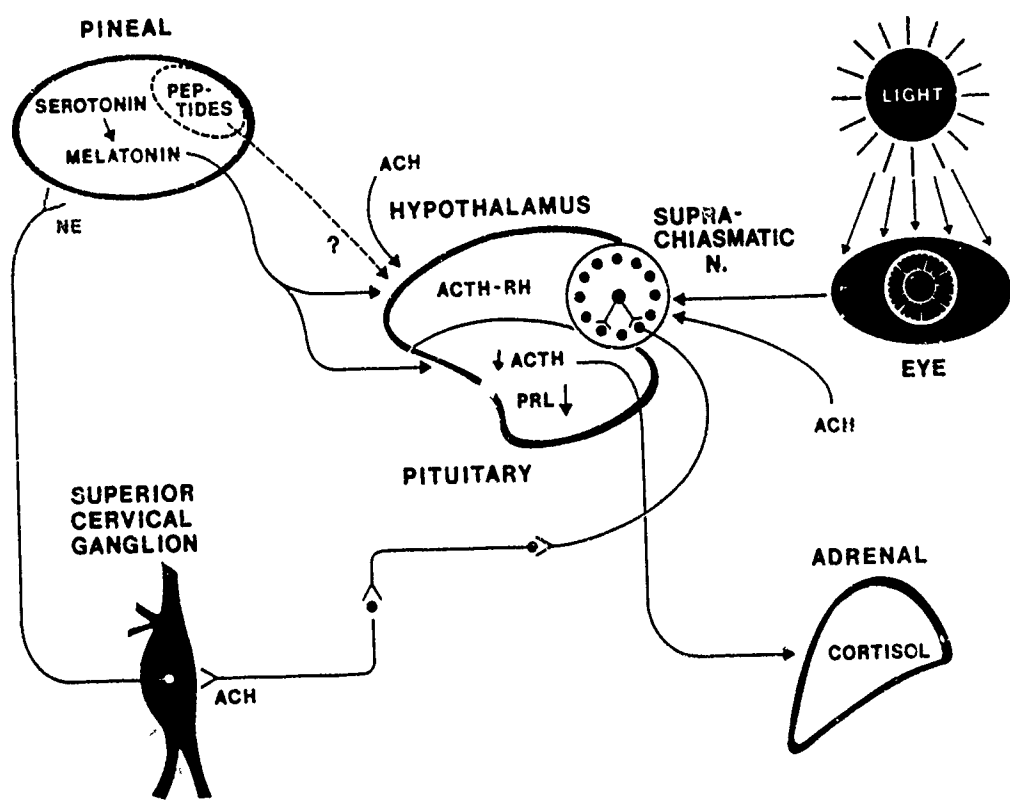
The theory is based on well known animal theories of free running circadian rhythms. Flashes of light in the early morning will advance rhythms and in the late evening will delay rhythms. What is produced we call a phase response curve to light. In animals, even candlelight will shift an animal's clock, but candlelight does not work for human beings. We are diurnal animals and we require very bright light. We need about 2000 lux or even more to have substantial effects on our body clocks.

Dr. Cole has been using light for jet lag in people flying from Hong Kong to San Diego. That's an 8- or 9-hour advance, the most difficult jet trip you can make. The time of treatment with a dim, red light placebo had no effect on how much people were able to sleep at night, which was our measure of jet lag. When we used bright light, you can see a .89 correlation between the time of treatment and sleep fragmentation. That's a powerful effect. The timing of the treatment accounted for 80% of the variance in jet lag in this experiment. I'm showing early preliminary data that light can have a very power effect on jet lag, but it's too complicated to explain in detail. I can tell you that this timing is not what we would predict from the phase response curve. There are some peculiar human factors that are not yet understood and for which we need more empirical data.

The experiment we're doing at NHRC right at this moment—we have two subjects running in an experiment—is an experiment in night shift work. Bright light will help the night shift worker adjust, so that nocturnal performance will be more reliable. We're also looking at endocrine parameters, and I'd like to show you why.

We can start with some animal work. The abscissa is the hours of the day and the ordinate is the months of the year. The period of light is broader in summer. Small animals like hamsters breed in the summer. In the winter, they lose interest in sexual behavior and, incidentally, in aggression also. The reason is that their gonads atrophy. We know something about the mechanisms. It's controlled by light striking the eye, the suprachiasmatic nucleus, the pineal gland and the melatonin affecting the





hypothalamus, hypothalamic factors regulating the pituitary and regulating the peripheral endocrines. It's a very beautiful mechanism.

The way it works in a hamster is that if light strikes a critical photosensitive interval (CPI) then the hamster feels great and reproduces. If no light in the winter strikes the critical photosensitive interval, the hamster's testicles atrophy to 10% their former size. What relevance does this have to human beings and performance?

We have recently recognized there is a syndrome called winter depression that is rather like this. Recent data, not yet reliable, suggest that as much as 5 or 10% of people in northern cities like New York City have some impairment of energy and performance in the winter, due to lack of outdoor light exposure. It takes bright, outdoor light. Indoor light is not bright enough in humans to produce this response. It's amazing that this syndrome that may affect a million people in New York City alone had not been recognized until recently. And, although we've only been experimenting on this for a few years, we are now quite sure we can rapidly treat this condition with exposures to bright light.

How is this relevant to naval operations? There isn't much outdoor light for people down in submarines, and I would guess that the people on the lower decks of a battleship or aircraft carrier often don't seem much daylight from day to day either. We do not have proof that this sort of mechanism occurs in operational naval personnel, but everything we know about the physiology suggests it well might be treatable with light.

There are some data from our own lab, showing a week's light treatment in major depression, not just seasonal depression. You see light has dramatic effects in major depression. It does work more promptly than antidepressant drugs.

I noticed there are mainly men in the front of this audience, and I guess the Navy didn't used to be much concerned with women's medical problems, but that is becoming more important. My colleague, Dr. Perry, has recently shown that bright light will treat premenstrual syndrome very rapidly. We have some new data that rather dim light, a single 100 watt light bulb by the bedside at night, can cure menstrual irregularities. Now, that needs to be studied much further, but what it means is that rather dim amounts of light have very powerful endocrine effects.

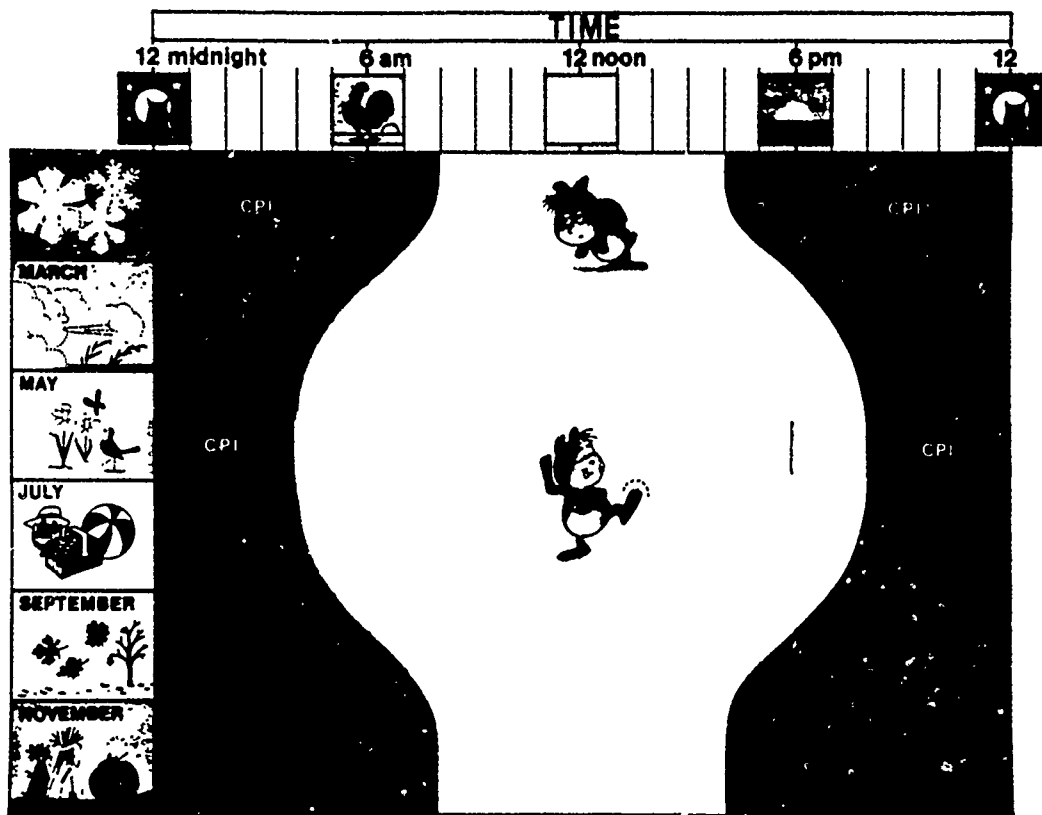




Figure 1

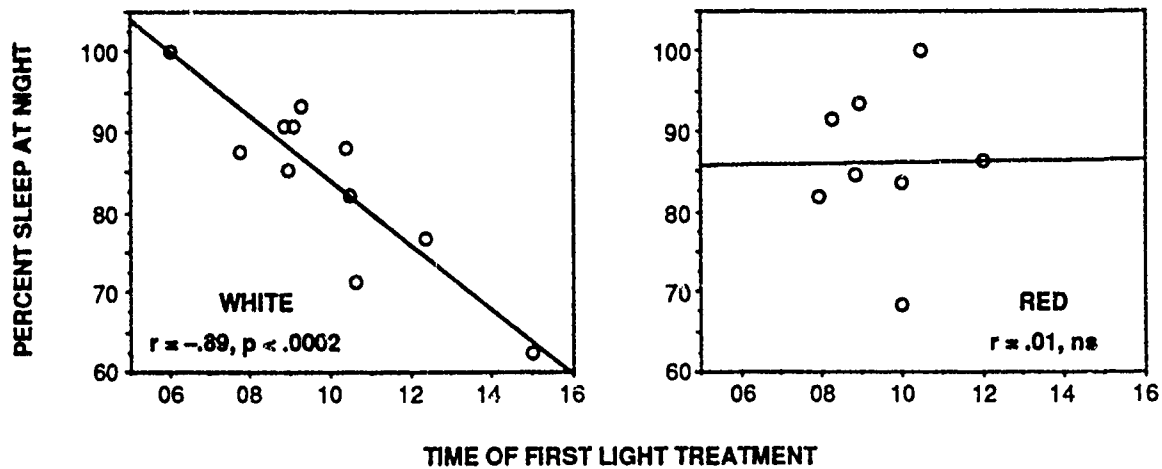
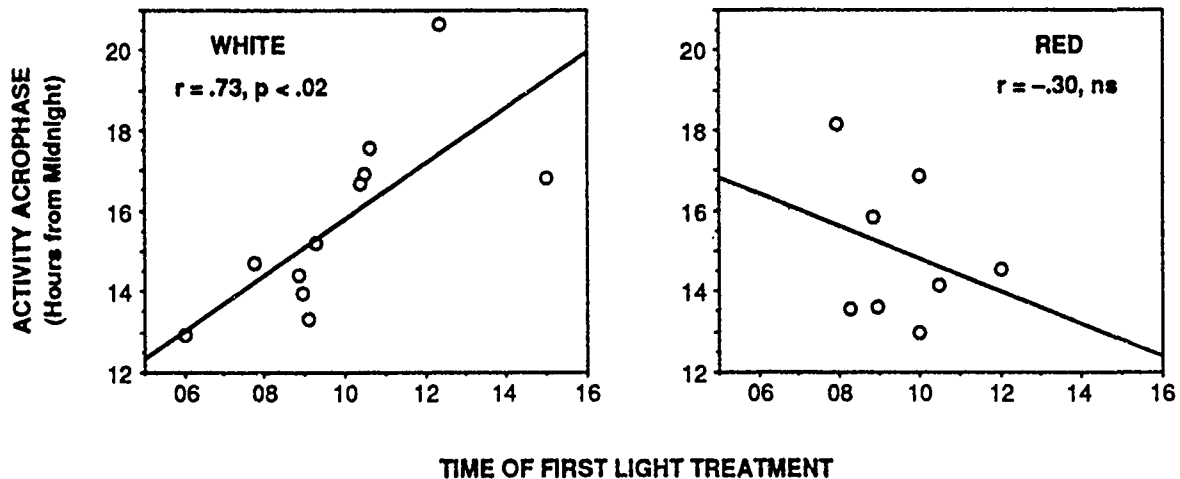


Figure 2



Effects of bright white light treatment (approximately 2,500 lux,  $n=11$ ) and dim red light placebo ( $<100$  lux,  $n=8$ ) on sleep fragmentation and circadian acrophase of rest/activity after eastbound flight. X-axis in each figure shows midpoint in time of 2–3 hour light treatment on post-flight day 1. Fig. 1: Y-axis shows Percent of self-reported total 24 hour sleep occurring at night (2200–0800), averaged over post-flight days 1–3. Fig. 2: Y-axis shows acrophase of daily rest/activity cycle, as measured by Actillum accelerometer, averaged over post-flight days 1–3.

How could this be applied operationally? That kind of light box might not fit too well on a Navy ship. My colleague, Dr. Cole, has recently invented a kind of sleep mask, goggles, that can be used at night and have little light bulbs in them. We're testing this now. It needs a lot more testing. This is the sort of device that is very small and uses very little power and it might be practical in an operational situation for adjusting people to shift work, for adjusting people to jet lag, for preventing some of the endocrine impairments that may occur in people who aren't exposed to outdoor light.

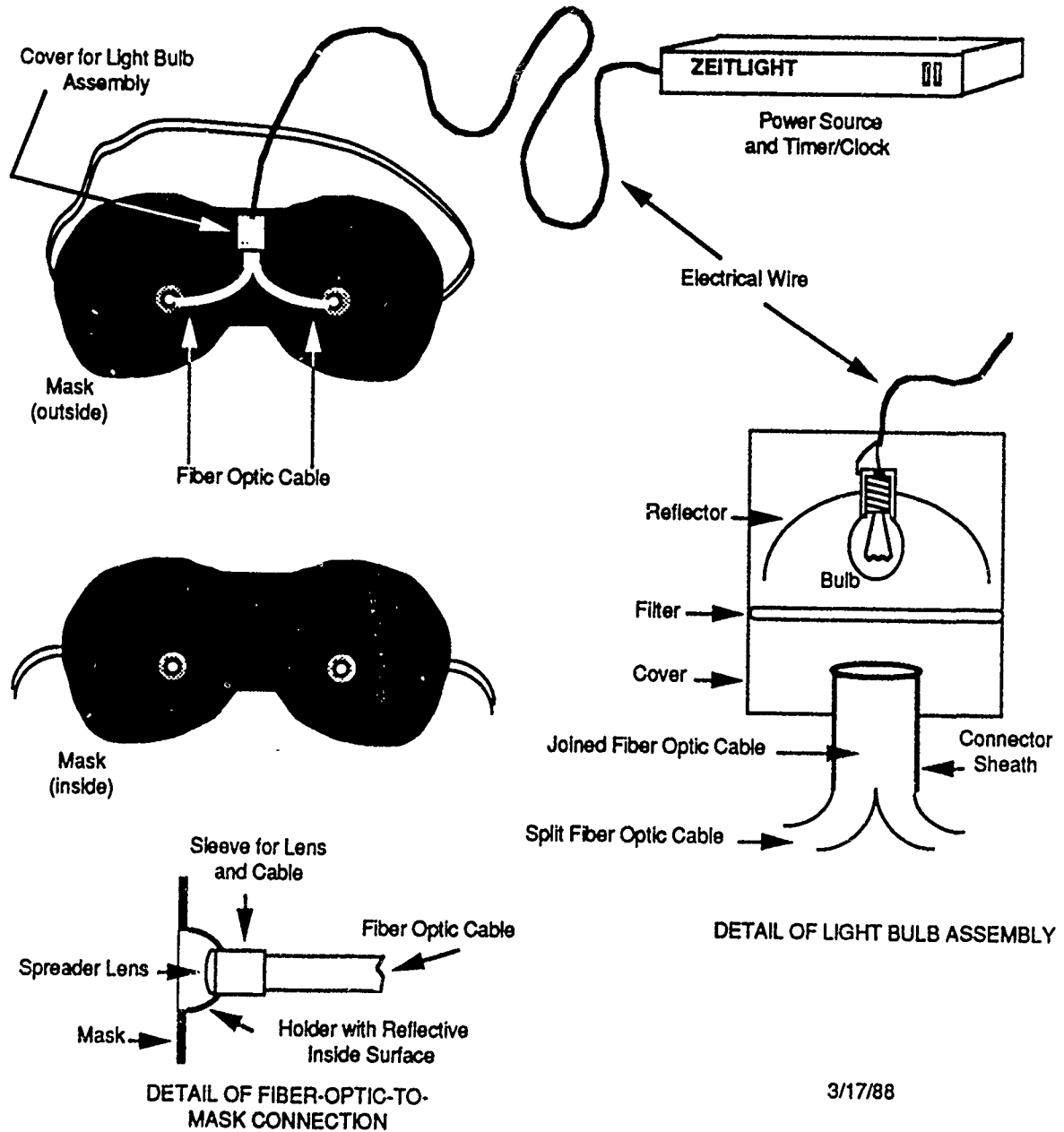
We have another instrument which we're very excited about. We call this an Actillum. It's a little computer that fits right on the wrist and probably can go anywhere, except that I don't think it would withstand what a SEAL goes through under water. It measures light and activity for as long as a month on a single battery charge. This is the sort of data which it collects (figure 10). This is on a trip I took from San Diego to Helsinki and back. You see the shift in the activity pattern and the measurement of light exposure on a log scale. With this kind of instrument, we can begin in real operational settings to look at what people's light exposure is, to see how that affects their biological rhythms, to see how it affects their sleep patterns during the day and whether they are falling asleep, taking naps when they should be awake as I do in dark conference rooms. With this technology, I think we can very rapidly move toward understanding the effects of illumination levels in actual performance settings. I was very impressed by Commander Banta's video tape and evidence of people falling asleep on duty. Dr. Akerstedt in Stockholm has been recording train drivers and Swedish nuclear plant operators. He actually records them sleeping while they are operating nuclear plants or driving trains. We have to become more aware of these impairments and how we can regulate them with light. Thank you.

**MALE VOICE:** Can you comment on the effects of melatonin on jet lag?

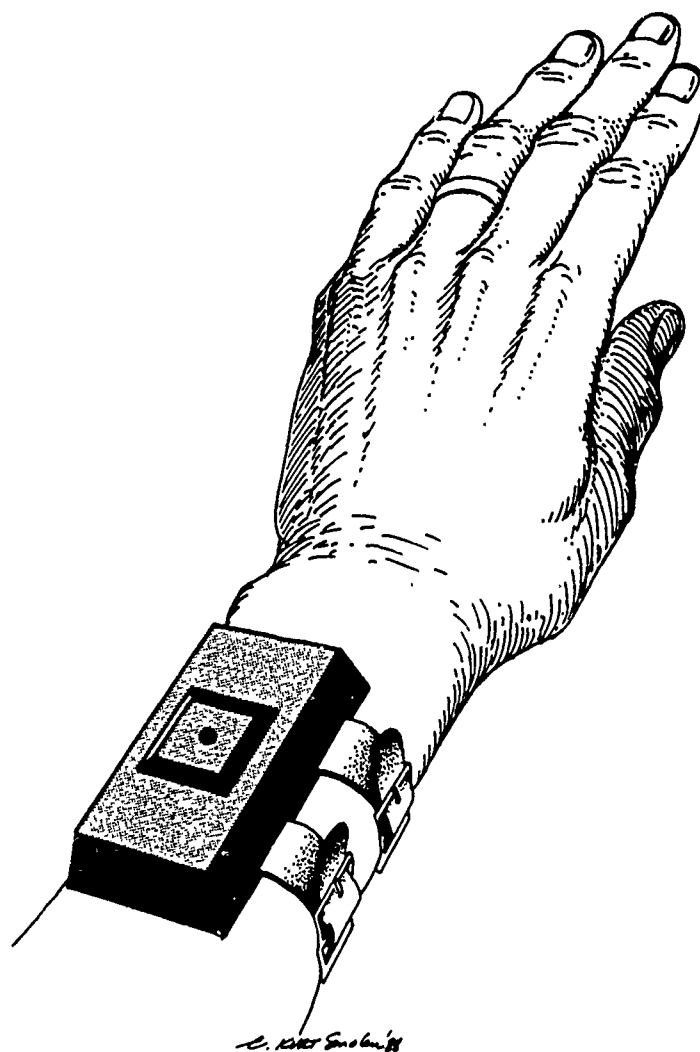
**DR. KRIPKE:** Well, the effect of bright light is to suppress melatonin, so they have opposite effects. In the animal work, light has more powerful effects on rhythms than melatonin. In human beings, there is early evidence that melatonin may be useful for jet lag, and it is really attractive. You just slurp some down. It tastes good. It's easy to take orally. It's a very promising chemical, but it probably will not be as effective as light. The two may be used in combination, so I think they are both worth testing.

# Bright Light Mask (Zeitlight™)

## Fiber Optic Version

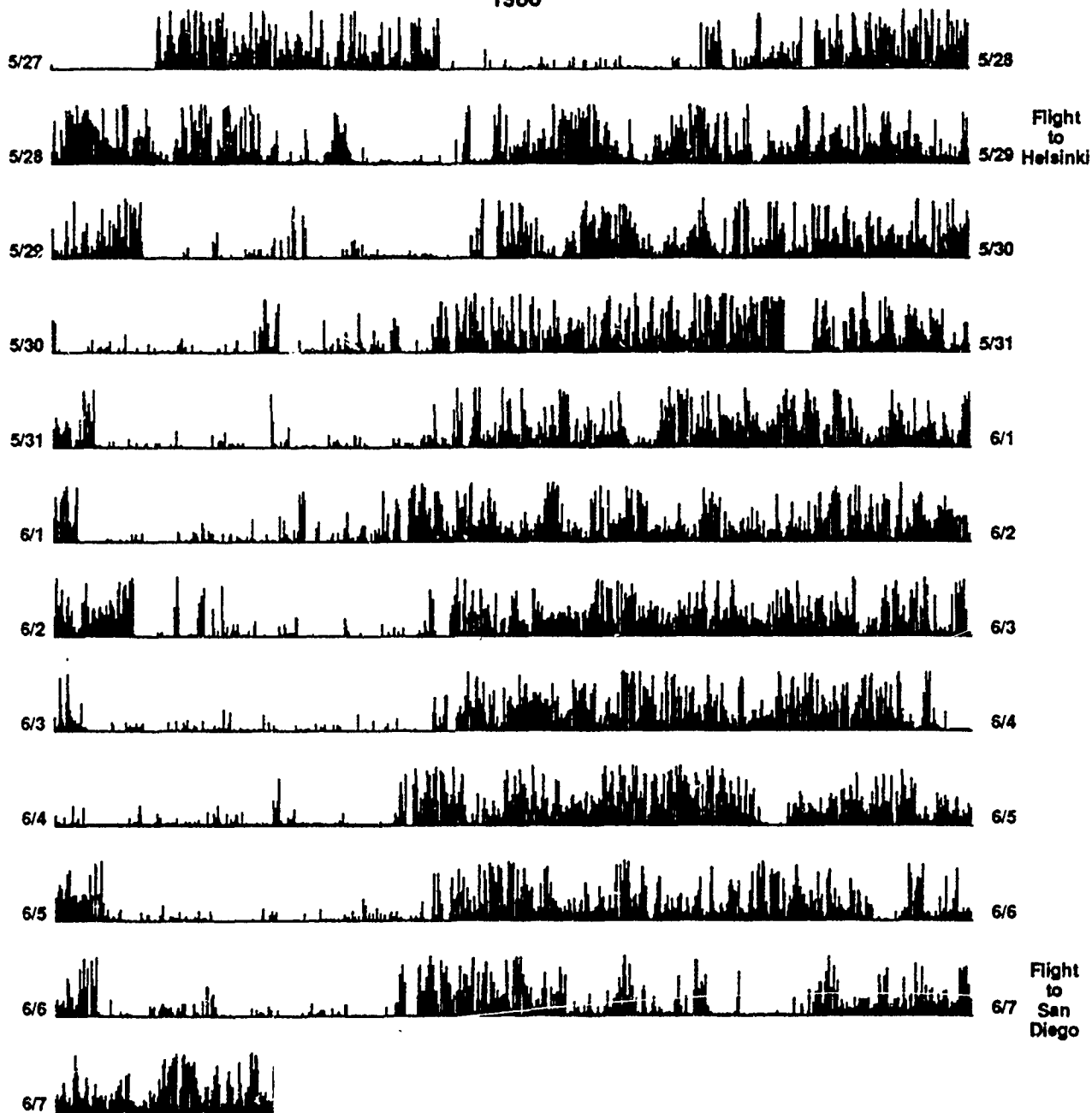


Copyright © 1987 by Roger J. Cole  
Patent Pending



# SUM ACTIVITY

SAN DIEGO—HELSINKI—SAN DIEGO  
1988



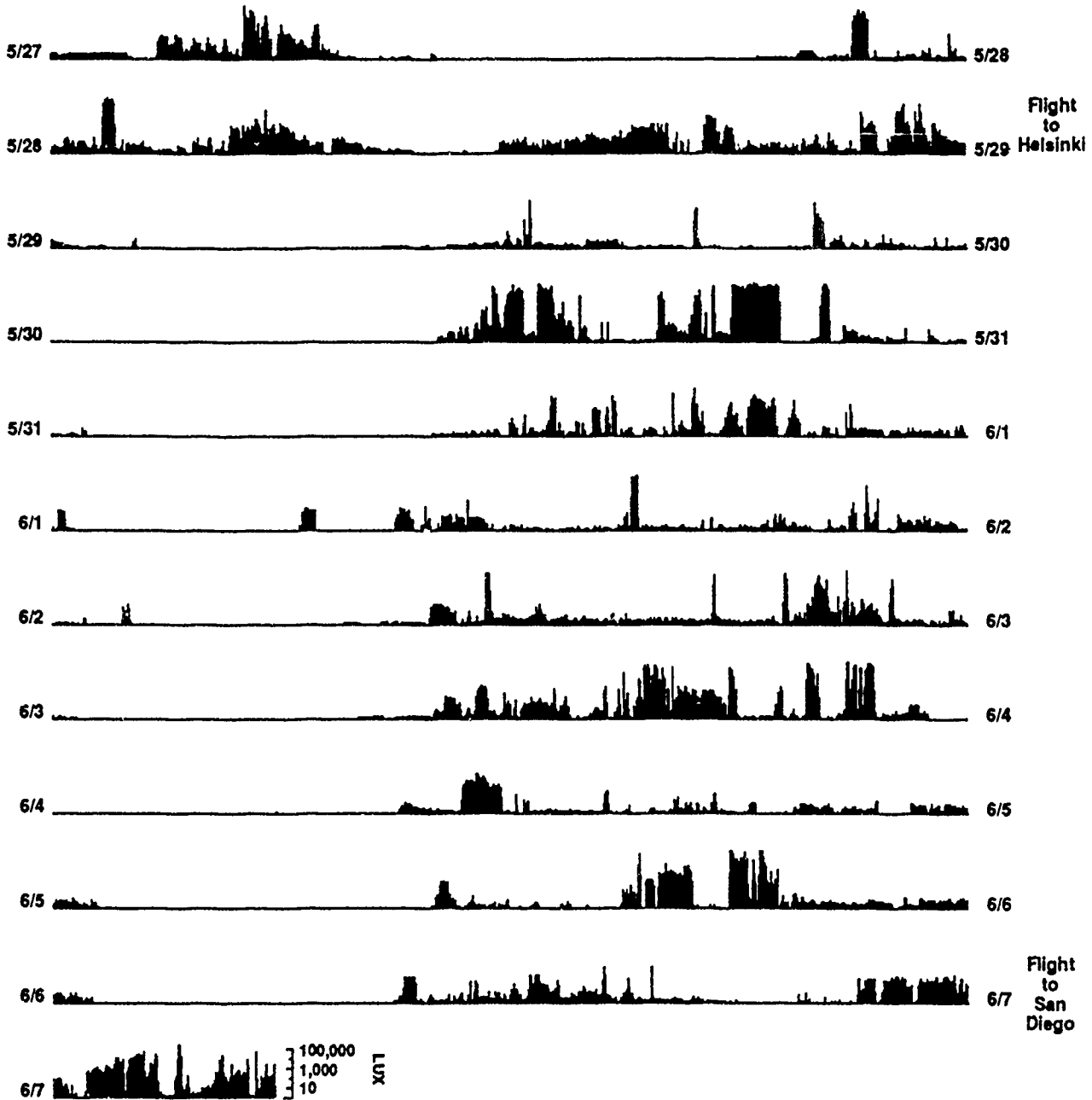
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# LIGHT EXPOSURE

## SAN DIEGO—HELSINKI—SAN DIEGO

1988



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TIME (SAN DIEGO)

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TIME (HELSINKI)

CDR DEAN: Next I would like to introduce Dr. Dobie from Navy Biodynamic Research Lab in New Orleans.

Dr. Thomas Dobie  
Visiting Research Scientist (Great Britain)  
Naval Biodynamics Laboratory, New Orleans, Louisiana

DR. DOBIE: Well, I too, ladies and gentlemen, would like to thank Captain Chaney, Commander Dean, and Commander Guy Banta for inviting me to this meeting, which I found most interesting indeed. At the same time, I would like to apologize to Captain Gaugler and also to Guy Banta, they've heard before a lot of what I'm going to say. I hope they'll bear with me.

Since I've got a captive audience I wanted to take the opportunity of telling you what we are doing in the Naval Biodynamics Lab in New Orleans, and what we're proposing to do. I think a lot of it will, in fact, fit in very much with what we've been discussing in terms of sustained operations and I truly believe, as I have for many years, particularly when I was in the military--dare I say in the Air Force--that interlaboratory cooperation both within a country and internationally is very important and very fruitful. In fact, I came to the Naval Biodynamics Laboratory from the United Kingdom's Ship Motion Working Party, and I'm still a member of that Working Party. I think we can learn a lot from each other, and there's no point in designing the wheel all over again when there are people with all the experience that may well be required.

Well, in our ship motion program we are trying to improve human performance in ship motion environments, as you might well imagine.

I want to just run briefly through the program. I'm not going to bore you with a lot of detail, but you'll see it's divided into human factors or motion effects and motion sickness. In the motion effects, we're trying to tease out those variables which are, indeed, pure motion effects: fatigue, motion sickness, and the interaction of all of these particular variables. We're also trying to look at environmental interactions, work space, training schedules, and so on. Now, in the motion sickness area, I've been particularly interested in cognitive behavioral training which I developed so many years ago. Working with air crew trainees who were permanently grounded with apparently, intractable motion sickness and by using a cognitive behavioral training program, I was

able to return 86% of these people back to flying training. At the same time, we are conscious of the fact we have to look at antimoion sickness drugs, partly as emergency measures for people who may well be on the threshold of death in dinghies or coming out from submarines into dinghies, who are not worried about unwanted effects of the drugs, but simply trying to stay alive. We're also trying to look at drugs which may well help in preventing motion sickness. We're trying to break away from the usual idea of using Hyoscine and Scopolamine and using Scopolamine and dexamphetamine which already has a lot of information published about it. We're particularly interested in looking at calcium antagonists as possible new avenues of drug therapy in the field of motion sickness. We're also interested in looking at antimoion sickness devices, not just things like Malcolm Horizons which are familiar for orientation in helicopters, but we may be looking at Sea/Sky Analogs which we hope we might be able to develop with Chuck Holman at MIT. Here we will have inertially stable analogs of the real world, rather than just horizons, and then an operator could have his work area or his TV screen or whatever in the middle of this analog screen. Effectively we take them from below deck up onto the deck. That is an exciting possibility.

I'd like to tell you about the equipment we have, such as the ship motion simulator at the Naval Biodynamics Laboratory, an 8 foot cube which will hold up to three people in the seated position with VDTs in front of them. We can reconfigure this in half a day to any particular layout we wish. The door leads into a seated area in front. At the moment it is configured to run one subject; there is a VDT and a performance box so he can either use a key or individual keys or a control handle for doing tracking tasks. We can keep an eye on him through our own TV camera above his VDT display. The control room of the ship motion simulator is in a cab.

The performance is really quite impressive. It has three degrees of freedom in heave, pitch, and roll, and it can actually heave  $\pm 11$  feet up the wall of this large test cell as part of a NASA test cell. It also has  $\pm 15^\circ$  in angular displacement pitch and roll. We can carry 5000 lbs. of equipment onboard, or people, or an admixture. Personal computers are onboard and data collection is with an HB9000. We are, at the moment, not just driving it with sinusoidal motion, as has happened in the past, but with our ability to record ship motion at sea, we then drive the ship motion simulator with those tapes which we have recorded at sea. We can look at particular ships or particular classes of ships and plug that in and say this is what will happen in a real world



situation. In fact, the experiment we're just starting this week is to look at the independent variable of roll stabilization in a particular class of frigate.

The other equipment we have is a rotating, tilting chair. The base frame rotates on a motor and another bed tilts  $\pm 40^\circ$  in the lateral plane and chair within that roll plane tilts forward and back  $\pm 40^\circ$ . By using all three together we can produce cross coupled choreotyped vestibular stimuli. At the same time, we have a screen on top with a slotted cam above the subject's head, whereby we are able to induce visually induced motion sickness by rotating black stripes through the visual field in the horizontal plane. It's a modified Dischkensen Bran type of drum which normally is a rotating drum. On this one we use a fixed screen and a slotted cam to produce the same stimulus.

We've been using these as a way of doing a lot of experiments which do not require the sophistication of ship motion simulators, but at the same time allow us to use the SMS to validate or bioassay the results we may get on much simpler equipment.

This is a Dischkensen Bran type drum with a mirror in the ceiling which I have in my Department of Psychology at the University of New Orleans. We do quite a lot of work in that department also. We've been particularly interested to look at various types of stimuli to reinforce cognitive behavioral training.

The Naval Biodynamics Laboratory has a long horizontal track for doing impact work; it also has a vertical track for looking at vertical accelerations, and we have a shaker for vibration work. Indeed, a lot of work is currently going on with the tracks, but I won't get into that field.

What we've been trying to do is to say why cognitive behavioral training of these air crews worked. Was it basically, as many people thought, purely the behavioral area that was significant? In other words, were they getting better simply because of the repeated exposure to a stress stimulus or motion stimulus?

So what we did was look at four groups of subjects in a factorial design. The combined group, so-called, had both cognitive counseling which is a kind of confidence building counseling, ten sessions only and also had reinforcement in the Dischkensen Bran type drum, whereby they were getting stimulus up to their threshold of motion response. We don't take them beyond threshold early motion sickness because I feel that has an adverse effect on confidence building. If you blow the individual away, he

gets more depressed, and he's never going to get over the problem. Another group of subjects had desensitization only. They got this reinforcement with absolutely no counseling whatsoever. The control group were simply given experimental interaction entirely unrelated to the experiment.

The two groups that received cognitive counseling, either with reinforcement or without, did significantly better than control and, indeed, significantly better than those who had, if you like, behavioral training. Also, the combined group had a significantly improved performance in terms of mean tolerance score than did the confidence building only. That is to say between the second pretest and post-test where they had ten sessions, we had these significant improvements in terms of their ability to tolerate visually produced stimuli. I should add we have set an arbitrary limit of 20 minutes, and if the individual was still going strong after 20 minutes, we terminated the particular exposure.

Now you could say, of course, maybe because of the counseling these guys were simply trying to be nice to the experimenter and they sat in there longer, bit the bullet and tried to do something to impress the experimenter. So we reported symptomatology scores, because there's no point in just staying in there longer if your symptomatology is worse and your performance is degraded.

The combined group and the cognitive therapy group not only showed an increased tolerance to the visually induced motion but a reduced symptomatology score. They stayed in longer, and they felt better. The other groups showed no significant improvement. There was a slight improvement in the control group but not significant.

This is the classical accepted diagram or model, if you will, of motion sickness, if you believe in sensory mismatch as a cause of motion sickness, whereby the input stimuli are active or passive motion stimuli which affect the receptors in the eyes, the semicircular canals, and the autolous or other gravity receptors. Depending upon the internal model or what the individual expects, in other words, the conflict can be between the eyes and ears, or within the ears, or even maybe within the eyes. If you believe in the mismatch, then neural centers mediate what we classically know as the signs of motion sickness.

This, however, is really a very basic input/output, Pavlovian type model. I think it falls far short of reality. We've modified this model, simply by adding what we choose to call the cognitive overlay. I'm not trying to suggest that motion sickness is all in the mind. What I'm saying is that this kind of model, if you like the physiological part of it, is perhaps what occurs in the early stages of motion sickness. When you are first exposed to these motions, I believe, it is relatively a simple input/output model. Very quickly I believe that with your exposure you can either be sensitized or, perhaps, protected over your early years. By the time people come into the military, they fall into diverse groups, because of their previous attitudes, their memories, past motion history, and conditioned fears.

**MALE VOICE:** This system has a cognitive overlay.

**DR. DOBIE:** Basically we say that our cognitive behavioral training will demolish this cognitive overlay before the individual will habituate to repeated reinforcement stressors. It doesn't seem unreasonable. If you've been car sick all your life and simply say okay, for the next three weeks I'm going to give you ten more trips in an automobile, it would seem a bit naive to think that will help you get better if the last 3000 trips you've felt yucky. So we basically are suggesting that you remove or change this attitude, and you can then bring down the individual's heightened arousal before he gets into the reinforcement situation. These people have a lot of anticipatory anxieties because of well founded previous experience.

Just to show where we're going with this, and I don't want to get into any of the detail, we're looking now at undergraduate and graduate counselors. We're doing a counselor evaluation program, giving them subjects to see how well they do. We're also looking at optimal reinforcement training programs. How many sessions do you need on average for individuals to gain this type of protection? We've also been looking at IR generalization. Many people have suggested that adaptation of this type is highly specific. If this meant you needed a ship motion simulator as a training device for ship motion, then forget it, because it's too complex and too costly. I believe that you can use the response as the stimulus. In other words, just provoke a motion response, however you do it, and you can use that in a reinforcement program.

When I first tried this, people said cross couple choriostimulus will not work for air crew because it is not typical of the stimulus you get in an aircraft. That was shown to be false. When I wanted to do it with our UK Navy, they said, we know you're wrong

this time, because you don't have a heave component and that is critical in the production of training. I believe, however, we already have evidence to show not only can you get generalization by going from cross coupling into a heave provocative environment, but more importantly I believe you can use cross coupled reinforcement to protect against visually induced motion. That is to say you can use that as training against simulator sickness. I would like to be able to say we had equal success using visually induced motion to protect against vestibular stimuli. We haven't achieved that yet, but maybe the reason is that we've found the magnitude estimate of motion using a vestibular stimulus was about 2-1/2 times greater than the estimates using visual motions, so maybe there was a gross disparity in the severity of the reinforcement stimuli. Maybe if we equate to those a bit better, we might get generalization both ways.

So what we're really aiming to do is to try to get the simplest, cheapest, most effective way of producing a fleet training program. I'm pleased to hear that eventually we'll get some funding for documentation to put it into fleet use. I've already mentioned drugs and other factors so I won't pursue that any further.

I believe motion sickness is a typical stress response. It's not anything different. I believe it is a protective response of the human animal. It's simply that we weren't designed to ride around in high performance vehicles. I believe that some form of cognitive behavioral training, suitably adapted but not very different from what we use for motion sickness, could also be used to teach how to handle various other stressors, whether they be work overload type stressors or environmental stressors such as temperature and so on.

Incidentally, we did some work with colored lights and showed an interesting phenomenon which is difficult to explain other than by generalization. Halfway through a series of runs with these subjects when we switched color from red to green or green to red, they increased in their motion sickness response. They got a startle effect when we first changed it, but then it flattened off in the subsequent runs. What we're now going to do is put up a performance battery on board the turntable, so we can get individuals to carry out a task whilst we train them to handle external stressor—confusing noises, bad RT procedures—to teach them how to selectively address their task and at the same time pick up or reject extraneous stresses. Although we use the United Tri-service Performance Assessment Battery at the moment we hope one day

to replace it with a much more realistic type of task which is fleet-oriented. For sustained operations, we could drive our simulator, either with UTC tests or shipboard tasks, for at least 48 hours. We have plans in hand to drive it for 72 hours, so we can get beyond that stage where people usually habituate to motion in 48 hours. We want to look at work-rest cycles and the interactions of sleep enhancer drugs, stimulants, and antimotion sickness drugs. It may well be, for example, that the advantage of Scopolamine/dexamphetamine, is due to the fact that the stimulant, dexamphetamine, helps to focus attention. It may well be that part of the counseling which we have found very effective, isn't necessarily confidence building, but is teaching people to focus their attention on what they're doing and that gives a busy signal to the sensory mismatch stimuli which come in. Many guys in Louisiana will tell you when they go out fishing: If the fish are biting, I don't get sick. Focus of attention is obviously very important. You can do a simple experiment by turning somebody on a chair and asking them to give you a magnitude estimation of their dizziness after two rotations. If you then ask them to focus on a finger when they stop, their magnitude estimate of dizziness drops. If you ask them to go down the alphabet backwards, the magnitude estimate of disorientation or dizziness usually is zero.

In other words, I believe these are all parts of what we call "bricks in the wall" that we're trying to evaluate. What is the important thing about counseling? How many reinforcement sessions are needed? What kind of reinforcement is necessary? How do you train counselors? How do you get people going in the field? That's basically the way we are trying to tackle it, and I think it has a lot of parallel with what we were discussing yesterday. Thank you.

**MALE VOICE:** I noticed about halfway through, Doctor, you mentioned you were going to be looking at some of the frigate ships and it reminds me of what we did ten years ago. We had data from the 1050 class and found that they had roughly three times the motion sickness aboard that class as opposed to other type ships. Furthermore, the total information from those ships indicated that it was the more experienced people that were having the problem with motion sickness, and they attributed it to the gyroscopic stabilization on that type vs. other type ships. I don't know if you were aware of that data.

DR. DOBIE: No, I wasn't. When you talk about more experienced people being affected, this is classically what you get in the simulator sickness story. The naive subject doesn't know what to expect and so, if you like, the comparator in his brain hasn't already been organized to any particular response in a flying situation or a simulator situation. He doesn't notice anything particularly, or, certainly, he does not respond to it. Whereas, if you put experienced pilots in this situation, they feel a bit different. This may account for the fact that we used to quote 50% as the incidence of motion sickness in average conditions for about 48 hours. That was also the figure for the astronaut program. Chuck Holmman has published recently, as some of you may have read, for the present shuttle program, the incidence for space adaptation syndrome, or space sickness is over 70%. Now, if you go back to the old days when there were test pilots, they're in a totally different environment, an environment where they are less in control than they were of their airplane and also they have a lot of cameras looking at them. There is a lot of stress there. They're being beamed around the world and who wants to be seen being sick. That raises another interesting issue which we are looking at also and that is personality. When I did the first 50 air crew trainees, I worried very much that I am simply delaying the issue. When I put them back to flying, will they be poor trainees? Will they subsequently get sick later? I crossed my fingers, literally, for six years and then reviewed these people. To my joy, not only were they all going still, but they turned out to be above average in terms of winning prizes, doing aerobatic jobs for the squadrons if they were fighter pilots, and so on. It struck me that if you are a high achiever or if you are that type of person who may be as affected by performance decrement, then maybe you are more likely to have this problem. In other words, if an individual's career is at stake because of motion sickness and he says it doesn't bother him, he's either a liar or a cabbage. It must have a profound effect which enhances anticipatory anxieties.

MALE VOICE: A question about counseling strategy. Other than focus of attention, is this an outreach of some theoretical point of view?

DR. DOBIE: Basically people who have a lot of problems with motion sickness tend to feel there is something strange about that. In other words, they fear that they have some defect, physical or whatever, that's causing them to be different from others in the population. In a nutshell, the whole thing is the idea of demolishing this thought by starting off the first session not talking about the individual at all. You talk about motion sickness as being a normal, healthy response and that the people who are never

sick, if anything, are probably the only ones in the population who do have a defect. You try to set the scene of normality and then you go from there by simply discussing the individual's history, and when you get into the history, you have already covered all of these variables as being typical of the population as a whole. So, individuals start to relax a bit. You will notice in that first session, they are on the edges of their chairs, literally, and they gradually relax when you show them they are not as strange as they thought they were. So, the rest of the time is confidence building counseling. You never, for example, measure symptomatology after a reinforcement run because that in fact, would be negative. Everything is in terms of how well you've done--you must be very pleased, that's unbelievable, look at this. You are getting them to draw out their performance themselves; that's another reinforcement sign. Basically, it's confidence building.

I mentioned the business about whether or not focus of attention was very significant because we want to tease that out and see how important it is in the training protocol.

**MALE VOICE:** Has anybody in New Orleans had any input from the fleet saying that sea motion is a significant operational problem?

**DR. DOBIE:** Well, like a lot of this stuff, it's kind of anecdotal. I can tell you from long discussions with the physician who is head of the Coast Guard in New Orleans that 50% of the Coast Guard were sea sick to the point of detriment to the job. Again, that's the usual sort of figure.

**MALE VOICE:** The reason I asked the question was that I was doing a survey on human factor problems in the fleet. I specifically included sea motion and rode lots of ships and identified over 500 complaints. Sea motion was not one of them, was not recognized by anybody. There were cases such as electronic maintenance workers who had a problem with motion and got sea sick, but there was no general recognition by the seagoing Navy.

**DR. DOBIE:** I think there are two observations I would make very briefly on that. One, is that it is also typical of the air populations. If you go around to training schools and ask the instructors, have you much trouble with motion sickness, they say no. Then you look at their own reports, generated by themselves, not questionnaires put in by researchers, and you suddenly find there is a major problem. They say I had forgotten

about him, or it's so much part of the scenery. That's one problem. The other problem is a lot of people don't like to admit it because they think it's some sort of weakness. I think the last point I would make is that I think you can get performance decrement without emesis. I think emesis is a red herring in this problem. I'm sure all of you have noticed that some people barf and feel better; some barf and don't feel better. Many people don't seem to really barf at all, but they are so yucky they're absolutely useless. Those variables also help to hide the significance of performance decrement caused by low grade what I tend to call PYF--Personal Yuck Factor.

As ships get smaller and the number of people doing a particular task gets smaller, it is important when one person is blown away by motion sickness; that has highlighted the issue. We are doing some work at the moment. Commander Morrison is going to sea, and we are going to get some more hard data on that. We've certainly got it for air crews, helicopter pilots having visually produced motion sickness using night vision goggles. We're getting simulator sickness problems, and we're trying to do a lot more performance measures and degradation measurements.

MALE VOICE: You mentioned stimulants. Have you chosen stimulants?

DR. DOBIE: No, what I was just saying was that dexamphetamine was added to the Scopolamine/amphetamine classic mixture which is still the best antimotion sickness drug, and it may be that the dexamphetamine is not only a way of offsetting the side effects of the Scopolamine, namely, the sleepiness, but it may be that it helps focus the attention of the individual and that in itself is protective.

MALE VOICE: Did you consider methamphetamines?

DR. DOBIE: We're at the stage at the moment of looking for any comments from individuals as to what particular drugs we should use. I'm interested in calcium antagonists because there have been the anecdotal reports that individuals being treated with Procardia, which is nifedipine, for hypertension have suddenly anecdotally said since I've been on your program, I don't get seasick anymore. When we look into it, there may be good physiological reasons why this is so. So, we would like to start looking at different classes of drugs along these lines, including maybe even some of the drugs used in treatment of sickness in deep x-ray therapy.

MALE VOICE: I'm somewhat concerned about the use of amphetamines.



DR. DOBIE: We're not suggesting using dexamphetamine. What I'm saying is we're interested in it because it is part of an existing mixture. Secondly, if people do wish to use it for keeping people awake for other reasons, we would like to know beforehand what the interactions might be in terms of other drugs. We know so many occasions where different drugs are being used for different purposes and people are not looking at the summations or even the synergistic effects among them.

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CDR DEAN: Our next discussant is Captain Bob McCullah.

Captain Robert McCullah, MC, USN  
Naval Health Sciences Education and Training Command, Bethesda

CAPT McCULLAH: I would like to thank Captain Bob Chaney and Commander Larry Dean for inviting me here.

I have learned a great deal from listening to everyone here. I probably have a lot less to contribute than what I've heard. I am currently at Health Science and Education Training Command, Director of Educational Programs Management. Essentially, we deal with continuing education credits, duty under instruction, sending people to out-service training for fellowships, master's degrees, and doctoral degrees. We control the money for that kind of funding and I have a physician, dentist, nurse, corpsman, and Medical Service Corps officer who process the paper work. They dust me off and tell me where to sign and that's basically what I do. My background is in clinical psychology. For six years, from 1976-1982, I was the specialty advisor in clinical psychology, and then from 1982-1985 I was the detailer or assignment officer for all of the health care and science people in the Medical Service Corps. Since beginning with that position, I have not been in clinical psychology jobs. I can say in 24 years that being the detailer was my favorite job by far, because I really can't stand point papers and I like this kind of meeting.

I don't like office meetings where people bitch, complain, whine and manipulate. I really like making decisions and then seeing something happen. That's my own immaturity and my own impatience, I guess. But that job afforded me the opportunity to meet a lot of interesting people, namely the scientists and clinical care providers in the Medical Service Corps which is a tremendous group. We have 21 different specialties in health care and science—often under appreciated, often not well known among certain circles in the Navy. I passed out a list which I hope all of you have. It's simply titled "Navy Clinical Psychologists," it's two pages. Does everyone have that? It's just a list of 12 names. These are people I know, of course; I was involved in assigning them to their jobs for nine years and was also involved in the creation of some of the billets. The positions I'm going to talk about have more to do with the topic of this conference than other jobs that clinical psychologists typically do, such as working in a naval hospital or clinic. The positions I'm going to talk about are places where we

have clinical psychologists full-time on the staff of operational units where, essentially, their job is consultant to the command. They do a whole variety of things, screening instructors if it's a training command such as the SEER bases, dealing of course with individual dysfunction and family dysfunction. They definitely are involved, and of course, all clinical psychologists are basically involved with evaluating stress on a day to day basis. The clients they see, particularly in these commands I'm going to focus on, are certainly involved in stresses that relate to degradation of performance. I might add that these are people stationed there full-time. They are not people who come in and study and then leave. They are there with the command.

I'm going to be talking in a minute about SEAL Team #6. I'm no expert regarding SEAL team activities in the Navy, but I was involved in the creation of the billet. I'm going to tell you a little bit about that and the psychologist with SEAL Team #6, Lieutenant Commander Peter Graham Mest, who is only the second psychologist ever stationed with a SEAL team full-time. He travels with them. Wherever they go, he goes, so he faces some of the stresses that they do.

Okay, the role of clinical psychology or even behavioral science, I think, from the health care provider side of the house, has been very hit and miss. Many of these jobs I'm going to talk about have only been developed in the last few years.

Today there is no Mental Health Division in Navy Medical Command, the headquarters of Navy Medicine. Back in 1980-82 there was a division and I was in it. Then back in 1976 when I became the head of Clinical Psychology in the Navy I was in the Mental Health Division, which went away but came back in 1980-82. The Navy Medical Department, not because of its own choosing, often spends so much time reorganizing and restructuring, it is hard to maintain continuity at times. By the way, the opinions I express are my own.

Basically, I think the question we are trying to examine is how can people who are clinically trained contribute and work in concert with research people of various backgrounds. It has been a very murky area and very hit and miss because of organizational problems and not always having headquarters program managers for their activities.

I thought I'd give you a little bit of the history of how we got involved in some of these commands. These are not going to be chronological because of the amount of time we have to discuss this and I'd rather get on the ones I think are a little more important. Back in approximately 1980, a Commander Mersenko who was then the CO of SEAL TEAM #6 came to then BUMED, now NAVMEDCOM, and expressed an interest in having a psychologist full-time on the staff. I was never sure exactly what the genesis of this request was. I thought it was a great idea. Another individual who was key in developing this billet along with myself and Commander Mersenko, was Captain Paul Nelson. He's now retired, and many of you know him. He's the Director of Accreditation for the APA, and it's unfortunate he can't be here today because he could also shed some light on this. Well, Captain Nelson and I were strongly supportive of the idea, a billet was created, and the first psychologist on your list, Lieutenant Commander Tom Mounts was assigned. If you were going to contact anybody he would be one of the first people you would want to contact as far as a clinical psychologist who has really had a close view of special forces and operational forces in terms of the stressors they face. Tom was not only the first person with SEAL Team #6, but he is now with the Naval Investigative and Security Command which is another job function which I'm going to describe here in a minute. He is the only person to have occupied both those jobs. You recall NIS is now part of the Naval Investigative and Security Command which is in Suitland, Maryland.

What SEAL Team #6 does, of course, is classified. It is not classified to say that the psychologist functions in whatever way the CO wants him to function, which is basically looking where SEAL Team #6 is--around the world, basically. LCDR Mounts gets into things such as profiling and measuring stress. How much stress can these people take? The family stress is enormous because the families don't know where the people are. That alone is a big stressor. So, basically that's all I want to say for time reasons. I could spend the whole time talking about SEAL Team #6. I don't know whether Dr. Goforth has been working with the psychologists at Norfolk, because SEAL Team #6 is in Norfolk. I assume you are dealing with folks here in Coronado/San Diego.

DR. GOFORTH: Yes sir, SEAL Team #6 is probably not home.

CAPT McCULLAH: Next, I wanted to talk about the SERE Team (Survival, Escape, Resistance, Evasion) otherwise officially known as FASOT Group Reliant and FASOT Group Pack; that means Fleet Aviation Specialized Operational Training Group, Atlantic which is NAS, Brunswick, Maine and FASOT Group Pack which is NAS, North Island, Warner Springs. Those are the actual camps. How many people are familiar with this program? Okay, Frank have you been through SERE training yourself.

FRANK: Yes sir.

CAPT McCULLAH: Of course Frank and Guy Banta, who is an aerospace physiologist, know a lot of people who have been through it. I've see the course. I was smart enough to be an observer and not a student in the course. If you want to study induced stress, I would advise you to go and visit the SERE course which is also a classified course. It's not classified to tell you that the course is based on the inoculation theory for those who have a high risk of capture, namely, aviation personnel. You inoculate them to the stressors they may face as a POW. We have a psychologist in station full-time with each of those programs. This began in the late sixties or early seventies. Some of the people on your list are people who were stationed there full-time, and they screen instructors and screen students in vivo. I mean they go there, they are on the compound throughout training, night and day, and they have authority to advise the officer in charge that a certain individual is not doing well. This is very stressful, realistic training, I believe, and very useful. Aviators I have now have said they get a great deal out of the course and feel it's very valuable.

MALE VOICE: I have been through that, not with the Navy but with the Air Force in support of Viet Nam. It was run by ex-POWs, and it was very stressful. You left there completely convinced you did not want to be captured.

CAPT McCULLAH: I'm amazed at the people, primarily enlisted people who staff the SERE bases and who actually induce the stress. They are just incredible people. I don't know where we find these people. Being a clinical psychologist, I'm a fairly cynical person and you may think that we look for sadistic people, but actually these people exercise incredible judgment, incredible professionalism and control, and create a very excellent training environment. It's the most amazing training course I've ever seen, anywhere, any time. Not that it doesn't have flaws, I'm sure, but I'm very impressed.

Another job function where psychologists, clinical psychologists certainly see stress and degradation of performance is a billet which came on line in 1984, Naval Investigative and Security Command. Again, I was involved in this and the line actually gave up the billet. They came to me because of my background of having been the head of Clinical Psychology, and on your list you will see LCDR David Highland. He was the first person there and now LCDR Commander Tom Mounts is in that position. Parts of what they do is classified, but it's not classified to say that again they have gotten into profiling, training of agents who face tremendous stressors, assisting witnesses in recall of events through hypnosis and other techniques, and almost any function you can think of that a psychologist would do as a consultant. I would caution you that some clinical psychologists have a great deal of knowledge of statistics and experimental methodology, those primarily trained under the Boulder model such as I was. We have in my opinion, too many graduate schools of psychology, and we have some people who are very long on the practical applied intervention end of things but not so knowledgeable in experimental methodology. So, some of these people may understand what you are talking about but they don't have the hard science background that some of the other people do.

For about the past two years, we have had a full time psychologist in Quantico in charge of the Marine Corps Security Guard screening program. You are all well aware I'm sure of the problems of the embassy guards in Russia and other places and the stressors they face and how they manage these stressors. LCDR Forrest Sherman is the psychologist there, and he is also on your list. He is the first person in that position and that is a full-time position.

Starting in about 1984, the Naval Military Personnel Command (NMPC) created a full time department for physical readiness, physical fitness, and health promotion, so this office essentially is the program manager for the PRT (Physical Readiness Testing) and for health promotion programs such as smoking cessation, weight control, and stress management. Officially, this is the Navy's office for stress management training programs. For a lot of these billets there's no logical pattern, but really a lot of it was networking. I happened to attend various conferences, and somebody said I met that guy McCullah and I think we need this so I'll call him. A Captain Bill Jackson, line officer now retired, used to be program manager for Alcohol and Drug Rehabilitation Programs in the Navy and he knew me because I put a lot of psychologists in the alcohol rehab centers. So we got to know each other and he came to me one day and

said, you know, this is my mission. I'm now put in charge of this physical readiness, physical fitness program and these other health promotion programs. I'm a line officer and I don't really know what I need. What kind of people do I need to do this? I said you need some scientists, but I can't tell you what type until you explain your mission more clearly because then I can tell you what kind of scientists do what. Once he did that we put in an aerospace physiologist who was a member of the American Academy of Sports Medicine and had training in exercise physiology, and we put in a clinical psychologist as the head of this who was Commander Jim Scaramozzino. He is on your list and is now a Captain Select and the head of Clinical Psychology in the Navy. He is the senior psychologist at the Naval Hospital, Bethesda as well. So these billets were created. I was the detailee at the time, and I was able to make the final decision. I could promise people to fill those billets and so that's how we created these science officers in NMPC.

Also in your list is Commander Steve Kelly, who is now in a position to relieve Jim Scaramozzino.

Next I want to get to the Naval Academy. To me, the Naval Academy would be a very fruitful place to expand the contribution of not only psychologists but other science personnel to the knowledge base of our new line officers who graduate from the Academy. But unfortunately, what is true is that the midshipman men are exposed to the following. They have active duty Navy chemists who teach basic chemistry. They don't get into R&D and that kind of thing. They teach introductory chemistry. Starting in 1969, the first Navy clinical psychologist was assigned, Buzz Inman, who is now retired. I relieved him in 1972, and we have now five full-time clinical psychologists who are involved in the counseling center. It took, by the way, many many years before they had a formal counseling center. I used to have to take mids into a classroom to do counseling with them because the Academy did not want a formal counseling center. It is part of that problem of not admitting that human beings are fallible and have problems. But now they have a formal counseling center, and, in addition, they have people who are full-time in the academic department, which used to be the Behavioral Science Department but is now called Leadership and Law. When I was there behavioral science was an elective that we used to take a lot of heat as the "bull course." The mids loved this because they were so tired of all the heavy duty physics, chemistry, calculus, weapons systems, and computer science that they signed up in droves to get the "bull course" from the psychologists. It was a required course, then an



elective again, and so it depends on who the superintendent or commandant is and other powers that be.

I would suggest that it really would be a lot better if we had a full-time research psychologist as part of that department which we have never had. The billets are coded for clinical psychology, but I think we should have at least one or more, not only research psychologists but physiologists and other people teaching. I say you should have, but I don't have control over converting those billets. I think the midshipmen would get a lot better broad based training so that when they become OPNAV program managers, COs, and XOs, they've already been exposed to experimental methodology and you don't have as much of a hard sell. They are exposed to hard core curriculum but not to those things.

We, of course, have been heavily involved in the U.S. Antarctic Research Program and we still evaluate applicants. John Madison was very much involved in the screening of people for Antarctica. I'm not going to go into that. Larry Palinkas is really an expert here. I know Larry's here today. I'm not going to talk a whole lot about that. I think you're familiar with the literature.

I just want to mention one more thing and that is direct consultation to ships. Clinical psychologists and psychiatrists have been involved in that--leaders, in fact. The person who probably had the most to do with creating that relationship where psychiatrists and clinical psychologists would go aboard ship and do stress management consultation among other things, was Admiral Sears, who today is the Commander of Navy Medical Command. He really got that started in Norfolk when he was Chief of the Psychiatry Program there and then continued in San Diego when he was Chief of Psychiatry, and they did it through the 32nd Street Clinic here in San Diego.

Those are my remarks. I've enjoyed it very much. Thank you for inviting me.

**MALE VOICE:** We established a chair at the Naval Academy and hired just recently a couple of researchers. The research chair can teach in any area, economics, leadership, or law, etc. I don't know if you know Commander Burt Speir. He has been in the clinic and worked for us in 01 for years in R&D, and he might be a good person to deal with. He is in Hawaii still, I guess.

CAPT McCULLAH: Yes, he's the XO of the clinic in Pearl Harbor. As I said, this is McCullah dealing with the stress of flying coast to coast along with all of my other many stressors, and it's just the beginning.

MALE VOICE: Do you have any suggestions on interaction with the stress management program people who are responsible for that? We work quite a bit with LT Curley and others in that program, but I don't think we really understand too well what stress management means to them, what they're trying to do about it, whether there is anything we could do to help. It doesn't seem to be very clearly formulated.

CAPT McCULLAH: Actually, I think part of the problem is that many of these people have so many collateral duties, and Jim is one of those people, being Specialty Advisor in Clinical Psychology, at Bethesda, in the internship program and having many other collateral duties.

A person I should have put on the list and I didn't is Commander Pat Crigler, who is Code 34, at MEDCOM. I have her phone number right here and I'll give it to you. She has the Health Promotion Division at MEDCOM. She's not been in some of these other operational billets and I guess that's why I didn't list her but she is a very articulate, very bright person, in stress management programs and even medical department programs are her baby at MEDCOM. She is the person responsible for them. She interacts with NMPC's Physical Readiness and Health Promotion people.

CDR DEAN: We have a unique circumstance. In the entire Navy there are two Mateczuns and we have both of them present here. They are brothers, and we are going to hear from John now.

Commander John Mateczun, MC, USN  
Naval Hospital, Portsmouth, Virginia

CDR MATECZUN: My brother is here. I'm the younger and more handsome one. I'm with the Department of Psychiatry at Naval Hospital, Portsmouth, and I'm also the Specialty Advisor for Psychiatry to the Commander of the Naval Medical Command. I'm very happy to be invited here to participate in this conference. It's an important subject. There is a Stress Study Center at USUHS in Bethesda that is starting to take a look at stress related issues and may also be a resource for some people.

One of the things we have in Navy psychiatry is SPRINT Teams which are in Departments of Psychiatry where we have the ability to provide clinical intervention after disasters. This is probably an area where we have some expertise to deal with what goes wrong at the "end of the line." I'd suggest that when you are thinking about the target audience for publications, when you're thinking about who it is you'd like to direct things towards, that you look at the "end of the line" because that's where things happen; that's where individuals and groups become dysfunctional and have trouble, not here at the Research Center.

A thought occurred to me about the manual you are thinking about writing. Most guys aren't going to read it out there. Most line COs don't have a whole lot of time. Who do they go to? In the Navy they go to their Medical Officer; their battalion surgeon, GMO aboard ship or senior medical officer. When it has anything to do with physiology or psychology or anything that looks like a health related science, that's who they go to.

You might want to aim a publication at that person, who has to have the expertise to provide to their skipper to be able to go and say, "Skipper, here's something about sleep." That's because they're the persons who are going to be identified as being the experts while they're out there. COs are not generally going to read these kinds of things. I found that most COs are immensely interested and adept at human resource management, but they have about a hundred other jobs as well and a new manual is

probably something they're not going to pick up and read unless it is an area of specific interest for them.

I'd like to talk about three things that I've heard at the conference that are important to what we're doing.

Modeling is first. Modeling is important because everyday I'm required to predict things, about individuals in particular, that I see in a clinical status. I'm required to predict whether or not they're going to be suitable for certain things such as to go to the Antarctic, to be a submariner, to do all kinds of things. Just because modeling is difficult doesn't mean, I think, it shouldn't be tried, because I have to try to predict rare events clinically and if I don't do it, I may be subject to suit. Okay, that doesn't mean we can't try to improve our modeling just because statistics are not particularly on our side. I'll give you an example; suicide is a rare event, very difficult to predict. If you know anything about statistics at all, you know with a rare event, any time you try to predict something and include all of those people who are going to be in that category, if it's rare, you're going to have a lot of false positives. In a group of say, 10,000 people or so, generally I'm going to have, if I try to predict a one person event with 95% certainty, about 500 person false positive rate. Nevertheless, I'm held responsible. In court, if I fail at that prediction, if I do it in a negligent manner. So, modeling has to be done. Modeling might help me do that.

Models are extremely important; every Marine and every sailor has a model in his or her head that they carry around with them, and they are going to interpret events based on that model. The archetypal Marine has the idea that they are essentially without fear, that they can go limitless amounts of time without food or without sleep and that they have infinite capacity for sex. It's a model. It's a model that people carry around with them, and I think as you've seen in Dr. Dobie's presentation about cognitive expectations that people have, that part of the work we do is working with those cognitive things and saying, hey, being seasick and being afraid and those kinds of things are normal sorts of behaviors. We have to remember we're working with "servo mechanisms," if you will, that have given enough stress, 100% failure rate at some point in time. We can predict those kinds of things. I think models are important. I think it's important for us to look at them and that's one of the reasons I'm glad to be here at this conference.

The second topic I want to take a look at is the difference between individuals and groups. It's true that individuals have idiosyncratic reactions to stress. One thing I might do to illustrate this is as follows. I'll do this briefly and if you have any questions afterward you can ask them. I'd say think about your job. What is stressful to you on your job? And, you would think of something. It is an event that is idiosyncratic to you. You'd say, "This is stressful to me on my job." Then I would say, "Now, I want you to think back, I want you to think back about what your earliest memories are of something that was stressful or bad, of something that happened to you." And, you would think back and you would remember a memory of something that was stressful to you in your early life. Then I would connect the two for you and you would be able in some way to understand part of why you have that idiosyncratic response to certain stressors in your life. This is why I can predict, given your idiosyncratic responses, what you're going to respond to. Knowing those things about you, I can make a prediction. Without knowing individual history we can also predict what's going to happen in the aggregate sense. I go to court to testify frequently and people say, well, "What about this individual, doctor? Isn't it true that this individual could have done this or should have done this?" or one of those kinds of things. And, I say, "Given a group of individuals, a percentage of them will do this or that. I cannot say with certainty about this individual whether he or she would have done that." We can predict about groups. I think we have a better ability to predict about groups than we do about individuals and I think we should focus there, to some extent. I don't think we should separate individuals from groups any more than we should separate the body from the mind. I think these can be fruitless endeavors. In the clinical sense, we like to dichotomize, categorize. We like to put them in different places. You have a mind that's in a body and you have an individual that's in a group. I challenge you to separate yourself from all of your groups, if you can, and see how it is that we could determine your functioning in other than an idiosyncratic sense. You can't do it. So if you dichotomize down that far, you're going to fail, I think, at predicting individual behavior. Every Marine and every sailor has a model that they carry in their head about what their role is and about what the expectations are of them. Most of these models have errors that I think we can do some things about that will improve performance.

Fear is an emotion and when we work with individuals aboard ship, it is one of the big things we see in groups. Groups are far more powerful modifiers than individuals

are. I think we should try to work with those powerful groups in research in trying to find out more about them.

For instance, if you've never seen or been in a group that has panicked, or in a mob, or in any of those kinds of things, you can't understand, I think, the power of a group. Group panic is a terrifying situation, and it will overwhelm most individual defenses. The strongest individual in the world could be overwhelmed by group panic. These are extremely difficult situations to deal with.

What can we do about that. These are clinical questions I'm asking. I'm not pointing towards any specific research efforts. I think we can use this knowledge. I try to deal with affect, with emotion. Emotion is a subjective experience that is extremely difficult to measure, so we get into quantification difficulties. What is this stuff? Nevertheless, emotions and groups are what people deal with. One of the things that stressors result in is an emotional response. One of the buffers and the biggest buffer you have when you are at "the end of the line" is the group. If you have a functional group when you're at the "end of the line" your chances are enhanced of staying alive. "I would like to stay alive," is generally what most people are thinking. If they have a functional group, they're more likely to do that; therefore, they're going to like a functional group. People are willing to give up a lot of individuality in those situations to have a functional group.

Screening is the last area I want to look at. We have to make predictions, and we have to screen people for all kinds of things. It's very difficult. In Judges, Chapter 7 or so, Gideon is faced with a battle with the Midianites and they're crossing a little valley. Gideon has about 10,000 people with him and he says, "Gee, I don't know what I'm going to do. I don't think the people are ready to go to war here with the Midianites." The Midianites are pretty tough, and they have a lot of people, and the Lord whispers in his ear. The Lord says, "Go and say--those of you who are afraid depart the valley." Gideon does this and about 90% of the people leave. A few other screening measures like that and Gideon is ultimately left with about 300 people. So even with divine guidance, it makes it real difficult to not screen out a lot of people. Given large or fat manpower pools, you can come up with some people, and they too can succeed through surprise attack at night by blowing horns, setting fires and other kinds of things; 300 motivated people in a night attack surprise operation. Screening is not easy; it's not an easy thing to do. Nevertheless, we're required to do it. Any kind of information we can

get that's helpful in being able to do that is good. I would suggest that with screening measures, you have to look at the least common denominator; i.e., who's acceptable, not who's perfect. Because you never get who's perfect. You're more likely to get who's acceptable. I can screen out all kinds of things. I can screen out pathology very well. I can tell you if somebody is crazy or not. After that, we're pretty unrefined about what it is we can do with screening. Can we screen in individuals? Not very well. That's the caveat—it's easy to screen out. Selecting someone for a job is much more difficult.

Those are just some of the thoughts I had. I think it's an excellent conference, and I'm glad to be here. Any questions?

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CDR DEAN: Our next speaker will be CDR Mike Fraser of the Naval Medical Research and Development Command.

Commander L. Michael Fraser, MSC, USN  
Naval Medical Research and Development Command, Bethesda

CDR FRASER: One of the jobs I have at R&D Command is buying the tools you guys are going to end up using to develop your models. As I've listened to the sessions over the last two days, I've come to two points that I think need to be brought up. I want to talk about two specific issues that I think need to be reinforced. One is the appearance of a model. It's a lot like a kid's kaleidoscope. What it does for you depends on how you look through it and where you point it. As you tweak it and turn it, your ultimate goal—what you're going to use the results for—depends on how it transforms the light that goes through it. What you put into it is going to affect substantially the information you get out of it whether you're concentrating on the predictability of individuals or small groups. I'm going to be very brief, because I can't add a lot to what's already been said.

The other issue is group predictability. It's very much a quantum mechanics issue, and the Heidenberg principle is very much in effect. Our measures cannot help but modify the effects we're trying to look at. We're trying to predict what's going to happen in a real working relationship under stress, either short term or long term, and those sorts of things are very difficult to simulate no matter how good we are in trying to replicate our environment. You've talked about a variety of ways to do that, but we can't put people under the sorts of stress that they're going to see in the Persian Gulf under combat conditions, long periods of time, under high heat loads, and lack of sleep. We can implement various pieces of it; we can try to build the test situation so it stresses them, but that's an imperfect correlation.

I want to talk a little bit about the end use of what we are trying to do. I spent a fair amount of time a few years back living in a vault, reviewing war plans, and I will tell you that the guys who write the war plans don't care about individual variability. They want to know about group dynamics; they want to know about performance of large bodies of people. The guy that cares about the individual and the small group is the line commander. You need to address both of those groups. The planner has to know what he can expect in a very generic sense from large groups of people. If I have

10,000 people I'm dealing with, scattered among a large number of units, how is their performance going to degrade over the scenario? What can I expect in terms of lowered performance, in terms of increased error, in terms of decreased reliability in what they're doing? Someone talked about lapses. What happens is the accuracy does not change as much as the variability. That's terribly important.

The other aspect of it is in the small unit organization. You've got the 35 people in the CIC. As individuals and as a working group, how are they going to operate after the first few days of high stress? After a week? After a month? What sorts of adjustments in the manning and management of these people is the commander going to have to make? Can he do anything to ameliorate the impact of the stress he's putting these people under and still get his job done? What can he do to make it better? What can he do to work around the unavoidable aspects of the long-term stressors? The commander's workbook is a terribly important thing. I think this has got to be one of the action items that comes out of here. Corresponding to that is a planner's workbook. What can you do? What can you tell about the long-term performance of large numbers of people in the combat planning scenario? Thank you. Questions?

DR. HELMREICH: I would like to make a more general comment. I'm really pleased with the emphasis by the panel this morning on the group issue, and I think it's right on target. From my own perspective of trying to review research and do it, I would say our knowledge base is much less at the group level than with the individual and that's where we need basic research. I'm a little bothered that the basic research emphasis is on the individual and the more applied research emphasis on the group because we need it at both places. I also feel that for understanding group behavior, research needs to be done in operational settings. I don't think we can build very good models of group behavior with bored freshman. I think this lab has great access to the right kinds of groups, and I just think they need more work at the basic end of things. In fact, I'm not sure there is a real distinction between basic and applied research. All good basic research is applied.

CDR FRASER: I absolutely agree with you, and it's obvious from the things I've heard this week that translation from individual performance to group performance is non-linear. There are synergistic effects that take place, and it's obviously not a simple additive issue, but for the guy involved in the planning process, he really doesn't care

about the individual. That's at the small unit level or the ship level, and we've got to provide the tools for predicting at both of those populations.

MR. BANKS: Do you see from your perspective more of a trend to focus on individual differences as opposed to group performance, let's say in the last 5 or 6 years. Is there any focus you have or perception you have of those trends, let's say.

CDR FRASER: It depends on which way you point the kaleidoscope.

MR. BANKS: For example, some folks commented that from a psychometric point of view, sometimes group performance is better predicted because you have less variability as opposed to individual performance which is more variable. Steve Zornetzer gave an excellent talk earlier indicating that the Office of Naval Research had kind of discarded group studies in lieu of studies of individuals or models directed towards individual performance: Are there various trends in the Navy with regard to these kinds of issues?

CDR FRASER: I really can't answer that except that from the planning perspective, you don't care about the responses of the individuals because you don't know what individuals are going to be involved in any of these scenarios. The only place that comes in is in determining the variability and the certainty that you have in the group measures that you are dealing with. That gives you the size of the variance you are going to have to build in. If you want some sort of uncertainty factor to build into the planning process where you can tell the line commander that if you keep these guys going full tilt for 72 hours, they're going to be down to 40% of full performance  $\pm 10$ . That gives him a handle on what he's got to do. If you tell him it's going to be down to 40% of full performance  $\pm 40$ , he knows he's got a real problem.

Any more questions? Thank you.

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DR. GUNDERSON: I would like to ask Dennis Kelleher and Bill Banks to summarize our efforts and suggest conclusions.

#### REVIEW AND WRAP-UP

LCDR KELLEHER: Bill was trying to convince me before he left for lunch and left me here that the risk has both advantages and disadvantages for those of us who set about forcing this issue about six months ago now. There are some risks and benefits to accrue from having that issue forced. We, somewhat independently I have to admit, based upon some of our own staff members' previous experience and the like and with the availability of some funds, we were able to finally get off dead center with respect to the issue of importing or not importing human factors' effects into realistic models of combat performance that are out there. They are being used. We can't deny that fact. So, this is actually the third of a series of three meetings. Eight of us have been to all three; most of you have not. Each of those meetings actually differed in how that meeting progressed, what came out of it, and what was learned. The first meeting was really only one of awareness; i.e., to get biologists back into the room with operational research types, so that biologists could be retaught, and I really do mean retaught. The first meeting at Livermore was an educational meeting, not just for us at NHRC but also for other members of the Navy Medical R&D community and for all the other services because we did, in fact, have appropriate representation from other services. Everyone asked where's the Army and Air Force at this meeting. Well, since this is the third of that effort, we're concentrating on really increasing the awareness of the Navy as to what we'd like to do.

What was the requirement we thought needed to be addressed by that Livermore meeting? Well it's the same requirement that the Military Operations Research Society felt needed to be addressed when they put together their program for this year, quite independently from what we were doing. That is, there is an increased awareness within the DOD that sometimes you have to take people into account when you're talking about military operations. There just simply are going to be critical jobs that need to be performed that stretch the limit of the performance capabilities of man to the point where equipment issues are no longer the relevant issues—man is the relevant issue. We don't know what those limits are. So that Livermore meeting was one of re-educating

and increasing the awareness within Naval Medical R&D Command based on our own personal interest in terms of where we thought it needed to go.

We did leave that meeting with an increased awareness, and I think we left it with some positive expressions by Dr. Alluisi in terms of the fact that not only were we interested, but the people who were eventually going to task us, perhaps, to do this work are extremely interested in that effort. But most importantly, we left there with an understanding and agreement that we were going to continue this dialogue, and this was not an effort that should die. This is one that we should continue to talk to each other about and, maybe, get to the point of having a real, organized, focused effort underway.

So, that leads to what we're going to leave here with. Are we going to leave here with an effort at the DOD level or at the SECNAV level to come up with a tasking requirement? Is there actually going to be a program element defined that needs to address the importing of data into TWSEAS or the importing of data into other combat simulation models? Is the awareness at that level so high that now they're going to come back to us and say, yes, this is a valid, identified R&D requirement that can be addressed in some ways by the medical labs? If that requirement is identified and it is addressed to us, then we have to go about a much more rigorous effort of goal setting and program identification.

From this meeting I think that we can probably do a better job of goal setting now than we could after the Livermore meeting, and we'll get to some recommendations that are partly a fall out from the contract that we had with Livermore.

Another thing that was again expressed at this meeting occurs at every meeting where we put biologists in the room talking about basically operational questions. There is a tremendous disagreement in terms of definitions of what do we mean by modeling and at what level are we talking about importing data. Everyone goes away with their own impressions of what they heard at the meeting, because they came in with a cognitive background of what they expected to get out of it.

Models or systems are on a variety of levels. Operational research types talk about models much differently than we as biologists. When we speak of models, generally we talk about functional relationships which describe some natural occurrence or we talk

about an analogue to the real world, something we use in the experimental sense. The operational research types talk about models as predictors of the behavior of a system. Well, they're not all mutually exclusive, but we just have to make certain which level we're talking about. Certainly, at some level of operational research, it almost becomes irrelevant to import human factors information. When one is talking about the capability of a division to be resupplied, it may or may not be relevant to talk about the individual performance capabilities of an infantryman. The level of sensitivity at that level might be one which you don't need to worry about. The people who work on that level don't care about human factors. However, if you're talking about a company commander who wants to know whether a given concept of operations that he has selected for a given mission will be successful, given a variety of environmental stressors or time stressors or the like, it may be quite relevant for him to import human factors information into his decision making. What should a model be at the level of an operational commander? He goes through a decision making process, and that decision making process is a model. If he's not incorporating all relevant information, his model will not work perfectly. He will come up with a decision, but it may or may not be a successful decision, based upon the input data that was provided to him.

What should be the products? We heard a variety of ideas as to what should be the products of a modeling effort within the Naval Medical R&D Command, that is, whether we should come up with some equations that we would hand over to the engineers. Of course none of us want to do that and that's the kind of reluctance that has pervaded our efforts; i.e., we're very parochial as biologists. We want to control how our data are used. We want to control how are interpretations of the data are used. We want to control it so much, sometimes, that it becomes less than useful to people who need to use it. That does not mean that absolute sensitivity and absolute validity of all of our research is required to make it useful. The product can be improved guidance to the commander, and it doesn't have to be a very sophisticated guidance. It can be appropriately imported data into an operational training model, so that a commander has an increased awareness of the potential effects of human factors in his operations. It can be as simple as that. So, training is a place where we could be importing our product. If in our analysis of the information through some sort of organized model, we come up with an identifiable task that isn't being accomplished because of very specific things going wrong, that sort of problem might be attacked by identifying the requirement for a specific piece of equipment to be developed. So you can see that the potential value of the effort is one of not just directing our research but certainly

focusing the efforts of other people as well. We've also heard there is potentially a problem in the transitioning of the continuum of R&D efforts that are supposedly the whole reason we are supposed to be doing research; i.e. we look at this as a continuum. Well, it's not just a continuum of top down; it's actually a circuit which is supposed to be at work and that circuit is one in which there is not just basic research which looks for an application some place, but there is also the operator out there who is doing test and identification, who identifies a problem and then is able to intervene by going into the R&D cycle. So the idea that there has to be perfect basic data which is then related into somewhat less than perfect application of that data is not necessarily the way to go either.

And, the 6.1 effort shouldn't necessarily be the driver for what should be the sensitivity requirements for the 6.3 effort or the 6.4 effort.

So what do I think are the recommendations? It's purely my thoughts on the Livermore recommendations you received when you came in--their professional opinions of what the Navy should do. Possibly NMRDC does not need to take the risk to address the requirements generating folks to say we think we're at the level of identifying a requirement to insert a program element on modeling of human factors in combat simulation. And that should be a limited effort right off the bat, one which tests the concept, i.e., we still have to test the concept of importing human factors information into combat simulation models. Necessarily it would be a limited set of models and a limited set of variables. There is no sense trying to model the world and failing; we're not trying to model the all inclusive performance of man, as an individual or as a group. We should probably select from a matrix of dependent and independent variables a subset that are of the most interest and based upon our collective professional opinion have the highest payoff in terms of validating the concept of importing human factors information into the models. Then go ahead and go through the whole spectrum of validating such a concept; i.e., taking it again to the field and selecting an intervention based upon the predictions and then looking at the validity of that model as a predictor of performance.

Whether or not that process eventually leads to a decision that it should be done, it will produce several products that will have value beyond whether the modeling effort itself has value. First of all, the process will once and for all, force a rigorous review of the literature to identify strengths and weaknesses in the data bases. We've all been



saying among ourselves that we have reasonably good ideas about what the data look like in our area of interest, but as a collective whole, we don't have a good feeling for what the data bases look like under a variety of stressors and a variety of performance outcomes, both individual and unit performance. So, that will be an enduring product, i.e. there will be that rigorous review of the literature. If we're going to test a model, we will have to come up with an agreed upon protocol for testing that model. Each of us within our own R&D efforts want to have our own models and that's the way it needs to be. R&D Command can tell us how they want that to go, but there will be a protocol we will agree upon as the validating protocol for such an effort. That, also, will be an enduring product because so many times we ask, does a system work, or does something help the performance when, in fact, we have no cross validity among our own measures as to what standard performance measures should be. We probably do need to agree upon a standardized way of viewing performance, both in laboratory measures of performance and field measure of performance. There should be some sort of focusing of our effort right off the bat.

It's been suggested that one way to focus right off the bat is to come up with some commanders' guidance type products. That's probably good, but I would also introduce the point that a lot of commanders guidance has already been published. If you look through the field manuals, you'll find it in each one of the field manuals that relate to each one of the stressors we're talking about. That commander's guidance has not necessarily been imported into research information. A classic example at the Military Operations Research Society meeting, a commander's guidance model was produced by the folks up at the Army Research Institute of Environmental Medicine labs by Rusty Warren and his group under the MANPRINT Program which was a specific product to put on a PC, an expert system to assist the commander in deciding how to accomplish his mission with respect to load carriage. It was a very elegant model, very nicely done. The question from the audience was, "Well that's fine and good. You've got this nice computer model that will do that so why don't you just put it out there in the field manuals for the commander to get that information he needs?" The truth of the matter is, Rusty Warren's model was built solely upon doctrine that has been incorporated into field manuals for 20 years. Here was an operational research type asking a question about the incorporation of doctrinal issues, and it had been done for 20 years. He wasn't even aware of the degree to which that kind of guidance was already available to the commander. Maybe another revision of the type of operational guidance that is already in the field manuals would be appropriate.

MR. BANKS: I'm going to try to get a commitment from all of you. The first thing I want to find out from you is whether or not you think it would be a good idea to have a handbook of human performance data as it related to combat simulation models—in other words, the integration of medical data in a format amenable to the modeling community, the integration of physiological data. The integration of engineering inputs into this handbook would bring together a coalescence of information in a useful format. Then John Wiley could publish this; a couple of people even indicated that the Military Operations Research Society folks which is Army dominated, or seems to be, would be interested in publishing such a document. Let me see the hands of the people who think that's a good idea.

MALE VOICE: How different would this be from the engineering data already published?

MR. BANKS: Nothing like that. Let me tell you, I love the engineering data compendium put out by Boff. Am I pronouncing that correctly? Boff, I think is one of the editors or authors. The problem with that data is that you cannot transition from that data to a combat simulation model. Impossible. You know what you get. Heart rate. Show me how heart rate results in decreased effective fire. If you cannot transition, give me a transformation of that into decreased fire power or some operational measure, it's useless to me. I'm not saying it's not good data from a physiological or psychometric point of view—it's perfect, it's laboratory data. Here's a real question for you. An Army Colonel asked me this, Southern Army Colonel: "Bill, I want to know what the probability is for me to detect red forces on a sultry summer day with this type of terrain under this kind of luminance level. What number should I use?" What's the detection probability? Now, what I'd like you to do is provide Boff's data and give me that information so I can give it to that field officer in an effective way for him to model and use. You can't do it; you cannot transition. This handbook would try to take existing data and existing knowledge and where it is possible to transition the data into a form compatible with the modeling community, do so. Where it cannot, it would show there are big holes. It would point out that this page is blank on purpose. There is nothing we have that the modeling community can use. You're thinking of something.

MALE VOICE: I think the question has been raised in this area. Are we ready to put together that kind of manual?

MR. BANKS: I believe we are for the following reason: Number one, no such handbook currently exists. If you don't start somewhere, all you're doing is putting it off. I believe that you need some place to start. Even if the handbook is not a completed product; i.e., you have blank chapters because there are no data, it is better than no handbook, because at least now the people that come after you, have something to target and focus on and add more information to as it becomes available. I have a lot of operations research folks at Lawrence Livermore Labs that ask me every day: Where can I get this kind of data? I point out the Boff, and the comments I get back from the OR community are: I can't use this. How do I get this data in a format that's useful to me? So, that's the idea of the handbook, taking what is available and putting it in chapters, making sure each chapter and subsection is written up by one author, maybe one senior author, but then having two or three people from different disciplines make contributions to that, editing to press the data into a form that's most useful. Do you think that's a worthwhile effort? Let me see the hands of the people that think that might be worthwhile. Well, we have about seven. I have something for you. I have here the outline of the Handbook of Human Performance in Combat Simulation Modeling. This is a straw man; nobody's ego is involved in this. I would like to pass this out to you, have you take a look at it, and decide where you think you'd like to make a contribution in technical authorship. If there's something about the outline you want to change, change it and send it to us. You have about a month and a half to look this over and get back with either Dennis Kelleher, myself, Tom Berghage, Captain Chaney or Jim Hodgdon. Could you do that? Let me see the hands again.

Now I've got the rest of you sensitized. So what I've just done is request for author participation from those of you who are believers. I don't think I saw the hand of one physician. Let me tell you why it's important that physicians participate in this. Do you know what I've heard over the last ten years from the Navy Medical R&D community? Medical issues aren't as important as they should be to the fleet. We don't seem to get the same amount of attention and support that the line organizations get. Have you all heard that? Have you felt that at times? That's because the question is where are you? What are you doing? Are you really getting in there, pardon the expression, kicking ass and taking names? Many of you would like to be, and maybe the reason you're not is that maybe you don't see the opportunity. Here's an opportunity for you to jump in.

Next thing I'd like to point out is, that in order for this kind of program to take shape, form, and function, it's going to require a lot of detailed planning. I've heard a lot of different discussions on different aspects, and they're all important, but you cannot, as Dennis pointed out earlier, bite off more than you can chew. What we're going to have to come up with is some detailed programmatic schedule of what we're going to do. You might say, well, how can you do that when you don't have any money? Well, what I have found out is sometimes if you can get some momentum going, the money will come. But if you wait for the money to come first and say well I'm not going to do any planning until after the dollars show up, you can be disappointed. Am I correct? Well I don't know about every time; if it were every time I'd be head of the Medical R&D Command.

So, I would suggest and ask that you all try to get in touch with Dr. Hodgdon, Commander Kelleher, Captain Chaney and any of his command members and get in your ideas. Please put them down on paper. I don't care if it's one paragraph, one sentence or even something you can cut out of the paper and write a little comment on. Get some materials to these folks so they can infuse your ideas into this planning document so no one can say later, they never did one thing that I asked them to do or that I thought was important. At least it will be on the table that they can deal with. How many people would commit to do that? Let me see the hands. Do I see four people? Do I detect that this is not a worthwhile effort? Did I detect that you are all so busy that you can't write a one paragraph electronic mail message and send it off? Is that what I detect? What am I doing wrong?

Ideas, opinions. I think this is real important. This could be very useful if this was done. No? Let me see the hands again of those who would be willing, if they have an idea. Let me rephrase that. If you have an idea, would you be willing to put it into one paragraph and send it to the gentlemen? Ah good? I asked the right question this time. Thank you. Tom is writing your names down, because we're going to follow up folks. Remember I said we were going to have follow up? You'll be contacted within three weeks, and if you haven't sent it to us, we're going to ask did you commit to sending something?

Next thing I wanted to cover, seven people said they think this might be a worthwhile idea—at least the handbook. How many think the concepts of trying to get the biological sciences, the physiological folks, the psychologists, etc., to try to look at modeling in the context of useful problems to be solved, to save money, to save time, and to be compliant with the new directives you're going to be getting next year on reduced funding, would be worthwhile? Great. That's about 80%. I appreciate that. How many of you think it would be worthwhile for you to recommend to somebody that may control some funding that they put aside a couple of \$K and perhaps save that for Captain Chaney or for this command to initiate something like that? How many people would be willing to do that? Bob, raise your hand. We got one. Why am I only getting one hand? Is that because other labs may be thinking that should happen there? Should it? Should it be a joint multi-lab activity?

MALE VOICE: It already is.

MR. BANKS: Okay, it already is. Well, maybe we can go both ways. On certain issues, if you carved them up maybe NHRC can recommend that something be sent to you. I'm trying to get you to work like a team folks.

MR. PUGH: What might draw us together is what Dennis was talking about and that is the criterion. Let me throw out an idea. Engineers, physiologists and psychologists could meet to decide what are the performance criterion we are working towards. Is that something that will work to bring people together?

MR. BANKS: What are the goals?

MR. PUGH: Right. We have to decide what the criteria are. In other words, what measures of performance are we going to use that will bring everybody together.

CAPT GAUGLER: I may be really off the mark on this one, because I haven't been to any of the previous meetings. One of the things I see happening here that concerns me a great deal is, and I'm going to speak now from the headquarters perspective, the design of a research project that will be quite specific but for which we currently have no user.

MALE VOICE: I have use for it.

MR. BANKS: Two users. Another hand back there.

CAPT GAUGLER: Then I would say that what we're talking about is how it should be configured and what it should contain. This ought to be coming from your side of the fence, not necessarily from ours.

MALE VOICE: That's probably true. I can give you very limited, very narrow guidelines.

CAPT GAUGLER: Not that I want x-kinds of data. Rather that I want to be able to do your kinds of things. You need to be able to describe what it is that your function is and where you see that there are holes. Not what kind of data pieces you need. That, in fact, is our job. We need to know what the process is you intend to use and then recognize how does the data come out of our heads and into your process. Do you understand what I'm saying? In other words, from you we need a goal. From the rest of the crew here we need to know how to do that. I'm not so sure we've heard goal type statements. The reason you are having difficulty getting answers is because everyone is sitting here saying, where the hell are we going?

MR. BANKS: Okay, that's my fault. I've been to three of these things, and Major Anderson has given an excellent presentation on some operational needs, some problem areas, etc., and I have those in my head. I forgot that you have not been privy to that. I've heard from other officers their particular problems and I'm not sharing that.

CAPT GAUGLER: Let me go one step further. How many of the rest of you have, in fact, heard all of this stuff?

MR. BANKS: How many people have been to all three conferences? There's the problem.

CAPT GAUGLER: That is the other thing I wanted to ask is that you have the Marine Corps function. I think it's probable that more use would be made out of this kind of information if we were, in fact, talking Navy-Marine Corps use totally. We have one of the possible twenty users. By chance we have fallen upon one of the twenty users. Before we go designing what kind of a package we're going to make, I want to know what the other nineteen users look like. Who actually uses this kind of data?

Who is the modeling community that you talked about? There have got to be guys like we have in this room, who actually do those kinds of jobs and those are the folks we may need to deal with. Dr. Cherry who was here from the Army probably has an in with some of those guys. But those are the pieces we don't have.

MR. BANKS: The potential modelers--some are right in this room. One of our objectives is to point out that there are new models and methods, hardware and software that are available to scientists today, who are not trained to be operations research analysts. In fact, these tools could be made simple for them to use. Jim's example with the MICROSAINTE; there are other software packages like that. If you can get these packages into the hands of the end users, you will see more modeling automatically take place.

CAPT GAUGLER: That's probably true, but I'm not so sure we want to do that as a research project.

LCDR KELLEHER: The modelers you speak of, sir, within the Navy are really rather limited. That is, the type of people in the Navy who model things and then expect to be able to use that in some human performance setting are really rather limited. At the Military Operations Research Society (MORS) meeting we had the pleasure of speaking with some of the Navy modelers, e.g., the Monterey types. The Monterey types don't want to put the human in the model. The Monterey types largely are the Navy shipdriver type modelers. They look at battle group models and things like that. They are still looking at ships' systems as being the most relevant, most important thing that one must model. That is, what's the reliability of the AEGIS in terms of technical performance. They actually expressed at the MORS the classic view that man is an unimportant part of this equation. The MORS meeting was only a month ago. The Army types are basically in two camps. There are the folks who address the issue of small unit performance and unit reconstitution. They are extremely concerned with the element of imported human performance. There is going to be a DOD directive to incorporate MANPRINT protocols in terms of how we do things with the Navy. MANPRINT does nothing but make certain that the human element is incorporated into all acquisitions models, because that's how they make decisions on acquiring a system. They model that system to make certain it fits the threat and will be able to perform as required. They didn't appropriately model the Bradley, and they built a beast. They didn't appropriately model DIVAD, and they built a beast. So those

folks are extremely interested, and we specifically had those types of Army folks at the Livermore meeting. They made a very strong case, by the way, for importing human performance data in their models. They used models in a very specific sense. They want to address very specific questions, just as TWSEAS was developed for the Marine Corps to do a very specific thing, that is, allow commanders to exercise their command control function within a simulation environment. Models can serve as exercise drivers; they can serve as concept testers. TWSEAS is really a rather interesting model in the ways it can be used, probably somewhat different than the other models that are out there. There are literally hundreds of models that are still being supported by somebody within the DOD and most of them relate to weapons systems.

MR. BANKS: Dennis, let me inject something here and try to build a more concrete base to persuade. Are you familiar with the A-40 Douglas Skyhawk aircraft? Do you know when that plane was deployed, two Marine pilots were killed because they got a false fire warning detection. Education in the cockpit. Then later the Marine Corps changed and said before you punch out, even though you have a fireball warning, I want you to look at your tail pipe temperature and I also want another party to inspect you, another pilot to come and take a look and see if you've got fire before you bail out. That costs a lot of money. Do you know what that was traced back to? On the left side of the fuselage, there is an entry port that you pop open, lift up and you put your hand in like this through this little access in the skin of the aircraft, and there is a shock mounted fireball warning detector relay box on shock mounts. It has two butterfly mounts, and it's safety wired. There is no physical way you can get your eyeball and hand on that object at the same time. Why the thing was failing so frequently 100 times more than projected--was because when you took it out, you could take it out pretty easily--you could never install it properly. Have you ever tried to safety wire through an eye of a butterfly nut when you have to feel where the hole is? I mean, it just can't be done reliably. If this could have been caught way at the front end, we would have rejected that and saved two A-40s and two Marine pilots. I don't know if the Navy had any problem with that particular device. That's just one old war story, and I don't think they fly that anymore, do they? If you had that kind of data base and had access to these kinds of models, with rules of thumb that can be worked out in the decrement models, you could pinpoint flaws very quickly. Now, it's true you don't need a model to do that if you have a human factors engineer to tell you. Ask them to do the task one time, they'd say forget that, it's not going to work.



MALE VOICE: If this proposal were submitted to OP-01, the first thing that would happen would be a question, do you have a PDNJ, an OR or TMO or whatever you call them. The PDNJ (Problem Description and Needs Justification) is the research equivalent of an operational requirement which is the equivalent of a temporary medical requirement or whatever. Somebody's got to come to the sponsor and say we've got a problem and this is our problem. It doesn't have to be high falluting. In fact it could be one page, but it has to succinctly address the problem. The headquarters then looks at it and says, what laboratories do we have that could respond to this requirement. So we send it out to this laboratory, that laboratory or whatever and say give us a Technical Development Option--give use a high end, mid and low in terms of cost. That comes to the laboratory and you work out all those issues among yourselves. Before you send it up to the funding sponsor, send it back to the guy who initiated the requirement in the first place for an endorsement and then send it up top side. By the time you get all that done, you have the legitimate options, you've got an endorsement from the originator of the requirement, and you send it up top side. Now it's up to the resource sponsor to either fund or not fund. I think that's what we're looking at in terms of whether this is going to be used in the acquisition MANPRINT or the Navy equivalent or whatever; you may want to go to the ASN as the requirements are identified. Survivability and safety, for examples. Or the SG or whomever.

CAPT GAUGLER: The big thing is we haven't figured out who owns the problem. We simply have not figured out who owns the problem. Because whoever owns the problem is the only guy who will pay for it and who can describe it well enough to solve it. It may be three or four guys--that's possible.

MALE VOICE: I would think one of the owners of this particular effort would be OP-07. They are the coordinators of warfare, and they're the ones that basically drive our warfare models. If you could convince them by incorporating personnel components that would enhance their models, they're all for it, but you're going to have to do a little convincing.

LCDR KELLEHER: Yes sir, we would. I sat at dinner next to one of the prime contractors for the redo of the integrated Navy war gaming system, the Newport system, and he was, in fact, a Monterey type, who basically viewed from the top down what systems will define the outcome of the war. That currently is the kind of people at OP-07 who are not the type to view this as necessary.

DR. GOFORTH: When they get in trouble, speaking for the SEALs, they can never go see if they can do the mission. I believe I could get their support in a tasking letter. They will go ahead and take on these missions, and from what I can tell, without the model, I don't think they can complete them. They need to be able to pump this information in. So if they can't go 14 hours over that terrain at that temperature, carrying that load, they can say it won't work. A model for them would be very helpful, save a lot of people if you ever have to go on very difficult missions.

MALE VOICE: Hal, thank you for reminding us. That was discussed several months ago.

DR. GUNDERSON: Actually Bill, the emphasis if you recall, for a lot of our effort to date was Dr. Allusi's interest.

We don't know where that's coming from or why, but we certainly got a strong sense from him, repeated a number of times, that we want you to get interested in this, and we will do everything we can to support you. Now, I don't know what that means other than somebody upstairs thinks there are some good ideas somewhere that might be useful to the Navy. Now who's going to talk to Dr. Allusi and who's going to actually formulate what the problem is, who the users are, and so forth. I don't know at this point. We're in the laboratory being encouraged to do what we can, take a little initiative, and that's all we've done. We don't know where it's going from here, and frankly, Bill doesn't either.

MR. BANKS: I can tell you this that Earl Allusi did explain to me that apparently there are new policies and new directives coming out saying we have got to work smarter. We have got to understand phenomenon without doing very expensive testing. Take this for example. Do you know what it costs to test a nuclear weapon? Do you have any idea what it costs to put a device down a hole and let it go off and collect the data? We do not need to do that anymore. We have computer models that can simulate all the physics, all the important physics of that device and we can do test after test, collect statistical data, whatever, without ever having to drill a hole in Nevada anymore. We only conduct tests for what I call quality assurance, checking with reality periodically. That's why we've been able to negotiate with the Soviets, develop a new SALT III and several other treaties. What I'm trying to show you is that as models get more sophisticated, as we become more competent, as our scientists get more and more

familiar with the area, we can do more and more testing with the models to save money from having to do the real thing over and over and over again.

DR. CARROLL: I really believe in developing some models but what I'm not absolutely sure about is what we need to get a handle on it. I don't know what Earl wants to do. I don't know whether we could write a good handbook now or not. To me it's pioneering as of right now. Maybe the handbook will be something we develop in three years.

Well, I don't know. I'm just throwing that out. I'm not an expert at all. If we think we know something, then the people that know it can put it into the handbook. That's why I'm just throwing my hand up saying I'll give you money. We don't operate that way.

MR. PUGH: I hope we're not thinking about requirements that are at too low a level. I think we could be reduced to running around stomping out fires, and I don't think we're ready to stomp out fires. In the beginning we need a requirement that comes down from a relatively high level so that we can get the basic type research done; then we can address real-life problems.

MR. BANKS: You are saying that there may be a 6.1 component to this.

DR. CARROLL: 6.1, 6.2, or even 6.3, but I think that we need appropriate behavioral variables in the models, get a little experience with that and then write our handbook. Maybe we have already done that. But when we know what the models haven't included, then we ought to write it up and put our lessons learned in there.

CDR FRASER: I hear two different threads running through the conversation here. One is modeling for modeling's sake, and the other is modeling as a logical part of other activity going on—one more tool we can use to answer specific questions. If we are talking about modeling to answer questions we already have requirements for, we don't need new requirements. If we are talking about modeling as an end result, then we need a new formal need statement that helps us drive that requirement before we can get substantial amounts of dollars. We have a flat out statement from the Surgeon General that we will spend our money in accordance with his prioritization of medical requirements. So we have at least to agree among ourselves about these activities, and

the handbook we are talking about seems to fit more in the category of modeling for modeling's sake.

MR. BANKS: The idea behind the handbook was to provide a common focus, to bring in people of different disciplines to put down on paper in a coherent way what they know and to force different people from different backgrounds to work together.

That was the real motivator for the handbook. Make it very practical and make sure all of the communities that participated have access to that data, because right now it's very fragmented.

CDR FRASER: I agree with the concept of that but in a sense you've got to do it in the right context, unless we're going to go through a very complex requirements definition and approval process.

MR. PUGH: Can we come back and say there is a set of existing requirements that can be addressed by models?

CDR FRASER: Anything we've already got refers to that. Modeling is one more tool. The medical requirement, the operational requirement or any of the other statements of need that exist in the system, don't say anything about how you go about getting the answer.

LCDR KELLEHER: To give an example, our cold work unit as approved, has in it the use of small unit combat simulation models, and we know of the existence of two to help in the development of our simulated combat task performance course which is a FY90 milestone, so we already have within our program the identification of the use of the existing combat simulation models to help us do that research. We've already done that. We already have physically incorporated it into our work plan.

CDR FRASER: That's explicit. Your saying here is the answer I've got to provide. Models are ways of providing that information in a more usable fashion.

MR. BANKS: I'll give you two comments from Tom Berghage who has been participating very politely, shaking his head at me. He said I think it would be very important to get the tools in the hands of researchers. I know what he means by that.

As more and more techniques, methods, technology, etc., are made available, usually there is a transition time—it takes time. The Operations Research people have been holding on dearly to some of the stuff they have. They have not been sharing with you folks. I sometimes wonder if they don't make it difficult on purpose so you can never use that stuff. Now there are new software packages out that provide shells and frameworks. Tom is saying it would be very important to get the scientific community copies of those things. The second point, and I think this is excellent, Navy medical researchers need to have specific training in how to use these modeling tools; not only get them the tools, but then show them how to effectively use them to stay abreast. to cut costs down later on. I think those are two excellent points, and I think they tie back to some of the things you discussed earlier.

**CAPT GAUGLER:** To do either one of those things, we don't need to do anything. You're talking sharing methodology. Sharing methodology is not a problem. It is not a programmatic issue to share methodology. When you guys are sitting around in a room and say I just figured out a way to do this, you can tell somebody else. If it's really good I would suggest that you put it into one of your quarterly reports and give it to everybody else. You put everything else in your quarterly reports; why not something like that to share with everybody? That's information transfer only. We need to distinguish that from the need to generate something new. Whenever you want to generate something new, you're going to involve the expenditures of money and that means that all those other planning steps that Frank talked about have to happen first. You have to get next in line so you know where you're going when you talk about doing something new. It's the difference between the new and the used.

**MR. BANKS:** It was pointed out earlier in this case the request came from the Office of the Secretary of Defense and said get us a technical development option. This came top down.

**CAPT GAUGLER:** I haven't seen this.

**DR. GUNDERSON:** We're at a bit of disadvantage. Neither CAPT Jones nor Dr. Alluisi are here. They've had discussions about this issue and may have an understanding. This may not be a problem.

CAPT GAUGLER: If he's actually got a piece of paper that says this is something that needs to be done, and these are the users for it, then we don't have a problem. If, on the other hand, Dr. Alluisi is just saying that sounds like a great idea, and I think we ought to do that, and I'll support you as far as you want to go, he doesn't have a plan. There isn't anything there. It's empty. Then the result of that, if we act on it, is we end up with a "widget" with no one to give it to, and we have just spend how many millions of dollars developing a "widget" that nobody wants. You've got to distinguish between a guy who says I really want to help you or I think that's a great idea.

DR. CARROLL: I'm absolutely sure that Earl wants this. I've seen what is required of all the projects he funds. If he's offering you money, he makes you sign up in advance and go through the chain of command, the CO of the lab, the Navy point of contact for that pot of money. I'd then staff out to the appropriate office, whomever it may be, for review, and then we get a Navy position for OSD. I think it's just a little unclear what we're trying to develop here, but if Earl wants something, I'm not sure if what he wants is being characterized properly. I'm sure there are some users out there.

MALE VOICE: You've got to forgive me because I'm a real pessimist. I've seen too many guys out there at the Pentagon level, and it's the way they turn you off. They suggest you to death, and you go away and think you've got one on the line.

MALE VOICE: We can be burned by that, by somebody in a relatively high position, who says I think it's a great idea, why don't we go do this. The bottom line is they expect you to go do it out of pocket. It's a zero sum game and if they don't come up with extra bucks, somebody else loses, or you end up taking it out of hide.

CAPT GAUGLER: You may end up doing something that if you'd have your druthers, you wouldn't have done it.

DR. GUNDERSON: Well, we're not sorry we've done what we've done.

CAPT GAUGLER: Oh I don't mean to imply that.

DR. GUNDERSON: Because I think for those who are interested in the application of human factors knowledge to modeling this is a necessary learning step. Now, I think

it is an issue of where do we go from here and are we really going to start working on something that is going to happen.

DR. HODGDON: I noted Dennis was talking about wanting to develop a specific program element in modeling. Even if that doesn't happen, I don't see modeling disappearing. We see this as a very valuable way to express our results right now. We have a set of requirements for which the development of models becomes an appropriate and, in fact, very handy vehicle for representing our results.

CAPT GAUGLER: You already have tasking and money to do that.

DR. HODGDON: I'm not sure that a separate program has to be created. I think we just need to be aware of modeling as a reasonable thing to incorporate into some of our existing tasks.

CAPT GAUGLER: Maybe I'm misinterpreting, but I'm hearing more than that. I'm hearing that there are people out there doing things that have nothing to do with our research programs that might have reason to use our data or change their models to include our data and that I think is a different thing. That is the piece I'm very concerned about. Who's the user and how are we going to do this. To be very selfish, because it's going to be our job at R&D to try to figure that out. I don't expect you guys to do that.

MR. BANKS: You're right on. I'll tell you specifically, the JANUS community--JANUS is the strategic combat simulation model that the Navy, Army and Air Force uses--have come up several times to Livermore and said we'd like to use all that human performance data. And, I've said, I know the Navy has lots of it, and I don't know if the Army has lots of it. They come back and say I saw this, but it's not in a form we can use. I was thinking in the long term. The work that goes on here in developing human performance data would have a long term effect, but that's in addition to their original purpose.

CAPT GAUGLER: The answer to the guy coming to you and saying that is, you guys need to write a letter high up to get that kind of data. We'd be happy to provide it, I think. I don't think anybody here would be argumentative about that. If you got

the task to do that and the money that went with it, everybody would be happy. The problem is the guy who is saying that to you doesn't know where to go to ask.

DR. GUNDERSON: As a weapons system developer, he obviously is not asking for this specifically; that's where this requirement would come from.

MALE VOICE: I must be very honest. It's the thing Frank was talking about; it's the thing that says we must do this. If they have a "you must," they are going to try to get out of it. We're talking about a manipulative kind of behavior. You can cover the Systems Command with paper and if they want to do something that's not in there, it will happen. And another thing, even if you do have your ORs and TDOs, and on and on and on, you really have to monitor that program or you're going to fail to transition, because from the program manager's office he's going to want POM guidance and POM action; he's going to have to stand up 30 or 40 times to get those dollars, and he's going to look at you and say I'm going to have to eat this out of hide and I don't have the money.

MALE VOICE: I agree with most of the comments about the importance of defining some clear, concrete goals for the model, and I listened very carefully this morning and heard very clear statements about problems you've dealt with by using models. There are a lot of people here who obviously are model fans. I'm not at all sure as to what the problem of human performance under stress will need. For instance, there are tremendous methodological problems in the field that were not even mentioned in this whole meeting which is part of the underpinning of any modeling effort. So, I believe that in defining the goals for the model you should look for cases where humans are making decisions now, using the internal model that the psychiatrist talked about and determining whether or not we can support that decision process with a model, starting with the most parsimonious one. Another area in the war games, we are not so much concerned with supporting the decision process as you are with trying to describe the operational situation.

MR. BANKS: That's an excellent point. Let me refer something back to you that I think all of you may be able to appreciate. The most frequent question I get is what's the probability that a person will do this. Usually that question is given in the context of a nuclear power plant, a plutonium production facility, or a tritium production facility where people are very concerned about a release into the atmosphere. What



they've done, and I'll show you how models have been worked in the DOE arena, they've been able to model the probability of human error. We can replicate it or duplicate it. You say how have you been able to do that. We've run simulator studies and collected data off the nuclear power plant simulators. I'll give you an example which we can tell you. This is a meaningless one. What's the probability that you will misdial a phone number out of a hundred telephone calls. The mistake will either come because you misplaced physically the wrong finger on the wrong number, or you've reversed numbers in your head or whatever. I'll tell you what it is; 8% of the time you'll misdial a number. Now I'll show you how I can get that error to less than 2%. I'm talking about touch tone phones. I separate and space out the touch tone buttons at the same time. Now, I'm going to drop it immediately to 2%. We've actually done experiments where we can tell you exactly what the error is. We've actually gone into nuclear power plants and reported the number of mistakes made turning the wrong valve or opening the wrong vent or starting the wrong pump or whatever. We have been able to construct probability density functions for those tasks. Not for all tasks but for those we consider the most critical tasks. This is an example where modeling is now being fed back to two groups, the probabilistic risk folks who need to answer the question: what is the true probability of a nuclear power plant having a release to the environment under certain conditions? We have to tell you not only about the hardware failure, but we also can make statements about the probability of human failure. So it's very useful from a Department of Energy perspective. There is another use for that kind of modeling data. This is very specific and might not apply to the Navy, but then again if you think about it, it might. Another use for that kind of modeling data is for the guy who designs the plane. Wouldn't it be nice for him to know what tasks the human performs have the highest probabilities for failure? Which tasks that do fail have the largest consequences in lost time, dollars, or whatever? That's another useful application and example of what models can do for you. Some can be empirically based where you collect data over time. Others where you don't have data, you have to estimate until you get hard data. Are there any other questions or comments? I'd like to turn this back to Captain Chaney.

**CAPTAIN CHANEY:** Thank you Bill. Well frankly at this point I'm confused, but I think there are smarter people than me out there who know the answers so I'll find out later on what was going on here today.

I would like to acknowledge the people who helped put all of this together. Actually, I think they've been thanked already. I really didn't have much to do with this thing. Dr. Gunderson, the Chief Scientist, is the one who thought this whole thing up and got the list of names to invite. Commander J.T. Coyne is out there somewhere. He's the little short fellow in the back, stand up there. These are the guys who actually did this thing, along with Tina who sat up here and ran slides until she got a kink in her neck. Petty Officer Morosi is the driver. I think they all deserve a hand. Obviously, I'm very, very proud of the hard work and expertise demonstrated by my staff. There's a whole bunch of people, and I appreciate the work they did. With that I have nothing more to add.

Have a good, safe trip back. We'll let you know what came out of all of this. This will be regurgitated in print, as we said, and you'll get a copy of it. We're not going to give up on this thing.

Thank you very much.

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