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HUMAN FACTORS CONSIDERATIONS FOR THE DETERMINATION OF AUTOMATION POLICY

ANEP - 22

This ANEP belongs to a series of ANEP's that were prepared by AC/141 (IEG/6)SG/8 On the Influence of Human Factors on Ship Design. These ANEP's cover Human Factors/Ergonomics issues pertaining to manning automation, maintenance, habitability, environment, work space design, etc.

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NORTH ATLANTIC TREATY ORGANIZATION

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E. STAI
Major General, NOAF
Chairman, MAS

RECORD OF NATIONAL RESERVATIONS

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RECORD OF NATIONAL RESERVATIONS (Cont)

NATION	SPECIFIC RESERVATIONS

RECORD OF CHANGES

CHANGE DATE	DATE ENTERED	EFFECTIVE DATE	BY WHOM ENTERED

PREFACE

1. The purpose of this document is to provide management as well as designers of NATO Naval Weapon Systems with a comprehensive approach to handle automation planning, design and implementation in accordance with the requirements, needs and limits of the military user/operator in order to ensure effective system performance.

2. This Allied Naval Engineering Publication, ANEP-22, has been prepared by IEG/6 Sub-Group 8 ON THE INFLUENCE OF HUMAN FACTORS ON SHIP DESIGN.

3. Each nation is encouraged to use this ANEP in the own design in order to provide a basis for evaluation of its designs by other countries, e.g. for the purposes of procurement decisions.

4. This ANEP is part of the ANEP Series On Ergonomics (Human Factors) In Ship Weapon System Life Cycle which includes issues related to WSLC management, personnel, planning, automation, selection and training, material design, shipboard organization and procedures. The covering document of the series, ANEP-20, ERGONOMICS (HUMAN FACTORS) IN SHIP WEAPON SYSTEM LIFE CYCLE (WSLC) INTRODUCTION, describes the intentions of the ANEP series and the interrelationships between the various issues, as well as providing a full list of the ANEP's, together with a summary of each.

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Chapter 1 - General

1.0 Introduction

a. Automation has been established firmly in the human mind as a possibly never-ending process of improvement. As it covers all aspects of life, it has become an inseparable factor of machine and system design.

Two points in any design that has to combine Human Factors and automations must be mentioned before
- automation isn't a panacea, and
- automation must not be a target in itself.

b. This ANEP will, together with ANEP 20, cover the general aspects of Human Engineering/Human Factors consideration in warship design involving automation. Whereas other aspects like design of man-machine-interface and habitability are rather clean-cut, considerations on the determination of automation cannot be of similar precision and will be of a more literate nature.

1.1 Scope

a. Warship design is design of a very special kind. Warships have the task to fight and the truth that "men, not ships, do fight" has been ensured through history. Thus, it is man who is rightly the focus of our design.

b. A warship has principally two tasks,
- accommodate men, i.e. support human in a basically hostile environment, the sea, and
- provide adequate means for combat as the "main military task".

c. The means mentioned above - and the automation employed - must be viewed at least from the viewpoints of
- usage
- maintenance and
- training

d. The second task, combat, is performance-, i.e. time-critical, and therefore a prime area for automation consideration. A renowned naval leader, Admiral Arleigh Burke, said that "time is the one commodity that can't be regained." It is the underlying task of this publication to point out that this is true not only in combat but in the process of warship design as well.

e. Automation may improve both system effectiveness and system efficiency by allocating to machine those tasks which are too complex, too demanding, or inherently unsatisfying for human beings. It may also reduce manpower requirements without detrimental effects on performance. The identification of candidates for automation is the first major task for Human Engineering to contribute to.

f. But, automation cannot eliminate tasks, but only assist man in their fulfillment. The use of automation creates new tasks of usage and maintenance which may be again target of automation considerations. This possibly endless iteration must be terminated in the design process definitely at a certain point or, to be more precise, a certain level. The definition of this level is the second contribution of the Human Factors Expert/Human Engineer in the development of automation. It is one of the main causes for this publication as well.

g. The third major task of Human Engineering in automation is the constant and permanent stewartship of its goals through all stages of the management and design processes. As this publication is written explicitly for those who guide and control these processes, it shall not only state the goals but prepare a cooperation that is characterized by mutual understanding.

h. Human Factors/Human Engineering has at its disposal a multitude of techniques and tools for general and special analysis. The literature concerning this topic both from government agencies and independent publishers is continuously expanding and can hardly be kept track of. Some of these tools have been selected for extended consideration in this text, but no attempt will be made to provide a list.

i. Three major tasks have been identified for consideration in automation design.
They are
1. Identification of automation candidates
2. Definition of automation level
3. Further cooperation during all stages of design.

The first and second task possess an decisive impact on manning and equipment and therefore on ship size, resulting in a similar impact on procurement and life cycle cost. Decisions on that scale must not only be made at the earliest possible moment in system development, they are probably more of political than technological nature. Although they are a part of the design process by nature, they will be attributed to management decisions, and therefore be dealt with in the appropriate chapter.

j. For those responsible in management and design, cost, both procurement and life cycle, is a major factor. It is omnipresent, and overwhelmingly so, in the minds of managers and designers. Thus, it is not necessary to give it any further special mention in this publication: Budgetary arguments will be considered to be outside of the scope of this paper.

k. Two causes exist which emphasize that automation cannot be total in warship design, a practical and a theoretical one.
The practical: Several tasks allocated to naval ships require the "Human Element" in the first place: from demonstration of goodwill in foreign countries and assistance im major accidents in peace to evacuation of refugees in combat conditions. An automated ship won't be able to "repel boarders".
The theoretical: First, as just mentionend above, the human is able to react to the unknown and unpredictable, especially of another hostile human mind, and the machine isn't. Second, a computer can decide, but not accept responsibility. The wilful by-passing of rules and regulations- after sound consideration - is the strength of the human.

1.2 Definitions

Automation is the appointment of a task previously conducted by a human to a machine. Automation can be applied in several different degrees, defined differently in many publications.

There are three major areas, however, that can be identified anywhere in automation:

- Transfer of a complete function from human to machine, possibly including closed loop control = robotization
- Reduction of physical effort of human by transfering that part of the function to a machine = mechanization
- Reduction of mental effort (sensing calculation, control) of human by application of machine processes = computerization

All three together, as well as each one separately, can be called automation.

Chapter 2 - Management

2.0 Introduction

The traditional way of system management and design in phases and milestones towards a larger degree of detail has led to a rather late involvement of Human Factors/Human Engineering (HF/HE) in the course of the process, as that work has been associated with a certain state of progress of design, resulting in "patch work", additional costs and sub-optimal solutions.

Thus, in many cases, Human Engineering has been a sore spot of System Managers. Its demands and requirements have been neglected, rejected, or sacrificed for something else because they "came in too late".

This frequently published statement points merely to the fact that a management task has been executed badly in those cases: Getting the right people into the right spot at the right time. It is one of the targets of this paper that an omission like that shall be avoided in future system management.

Restriction of funding and personnel are two of the major boundaries for the warship system management decisions. In both cases, automation is offered as a advantageous solution. The system manager has to be aware of its obvious and hidden advantages and disadvantages, as well.

Besides the question whether to automate or not, the question how far one may go has to be answered, too. Both of them are closely correlated, of course, and cannot be answered separately.

2.1 Knowledge Management

The consideration of Human Factors during the decision processes on automation in design is based on knowledge.
It is a management task to ensure that an appropriate knowledge is

1. available, and
2. present
3. up-to-date

at all design considerations and decisions.

An approximate view of the scope of knowledge involved is given in pict. 1.
This huge volume of rapid expanding knowledge cannot be covered by a single person. It is necessary to form a HE/HF expert group to assist the Management.

2.1.1 Availability

a. The present knowledge on the topic of Human Factors/Engineering in Automation must be reviewed considering the given system requirements e.g. by literature review and expert colloquium.

b. Gaps in knowledge that have been detected are to be closed. This is a prime task of Naval Research institutions. The funding and capacities must be secured by the system management.

c. The use of simulation to acquire knowledge gaps which cannot be filled by research is advisable as it promises to be time- and cost-saving. It must be kept in mind, however, that simulation cannot replace field experiments. Recent flaws in the development of fighter aircraft cockpits are a point in case.

d. The field of anthropometrics and biomechanics is not only well advanced, but widespread and acknowledged in its importance. This is expressed in numerous very strict national and international standards and regulations concerning occupational safety, working conditions, etc.

e. The field of cognitive and socio-psychological science within Human Engineering has become well advanced too, but its recognition lacks the backing of official regulations as measurement scales simply do not exist.
The idea that boredom and the lack of job satisfaction and system understanding can have similar detrimental effects like heat or wrong illumination is widely accepted, but not practised on the same scale. It must be pointed out that the effect of these factors may be multiplied in the warship's typical environment of confinement, crisis or combat stress and absence from home.
It is the task of the HF/HE expert team to have that knowledge implemented into the design as well, and the management task to support the associated requirements in view of the less favourite conditions mentioned above.

2.1.2 Presence

a. The HF/HE expert team shall be a permanent member of the decision level. Human and physical sciences are to be represented as well as technological and psychological experience. Team members shall be named personally and employed on a permanent basis for the course of the project.

b. For the naval side, team participation must be planned on a long term basis and must neither depend on "availabitity" of personnel nor be a part-time task. The cooperation of appropriate Naval research facilities has to be ensured.

2.1.3 Updating

a. The HF/HE expert team has to initiate and continue a knowledge (i.e. literature and publication-) search on topics with decisive impact on automation design.
Three important managements aspects are
- appropriate funding
- translator service for foreign publications
(a NATO-known delay of 2 years for translation of STANAGs from English to French is unacceptable)
- access to classified publications/data

2.2 Information management

Information management will be one of the central tasks of future management anyway.

The HF/HE team has to exercise its tasks through all stages and levels of the design process. This includes

- Information access,
- Information storage capability (incl. updating)
- Information dissemination

Such an amount of data management tasks, especially in a complex system, requires the use of computers, including professional help for system maintenance, to keep the team free of administrative burden.

It is up to the system management to provide and support funding and manning for those peripheral tasks as the fulfillment of the central ones will not be possible without them.

2.3. Identification of Automation Candidates

2.3.1 Automation Drivers

Automation drivers are developed from knowledge of conditions or performance that are or have become known to be unacceptable by changes of

- safety standards etc.
- performance requirements
- manning/demographic development
- user reports
- prospective future hostile equipment

The warning that automation cannot be a panacea has been spoken of already.

The obvious and the hidden advantages in its trail are listed, although probably incomplete, on the following pages in the context of Automation Drivers.

A. **Automation as technical progress**

a. Advantages

- Latest state of Development ("State of the Art")
- High performance
- Attractive for high-skilled workforce

b. Disadvantages

- High-tech experts needed
  (costs in recruitment etc.)
- Still a lot of bugs in system possible
- System Security untested

c. Considerations

- At that stage, Human Factors Aspects have a low value.
- User profile and Qualfications has to be extablished
- Test validation for qualification may be difficult

d. Management Decision Support

- Caution against enthusiasm

B. Automation due to health hazards/occupational safety

a. Advantages

- Reaches space prior inaccessible to man
- Reduces or nullifies (personal) danger to human/health
- May reduce manpower requirement

b. Disadvantages

- May induce (lull) into false perception of security

c. Considerations

- Does a maintenance requirement exist in the same dangerous environment (leading to further automation)?
- If the hazard is self-originated, can it be avoided or reduced?

d. Management decision

- May be cost-irrelevant (due to political reasons)
- Future environment-related legislative development must be considered

C. **Automation in time-critical task**

a. Advantages
- "Improving Effectiveness"
- Timely response may contribute to survival
- No time lag due to human psychological problems as shock, boredom etc.

b. Disadvantages
- Machine (performance) may be inferior to man in decision- and detection-tasks in irregular conditions (heavy seastate, Electronic Warfare

c. Considerations
- Keep man in the decision process for system safety (Open Fire-Decision/Control by Veto)
- Criticality of function may require manual backup
- Time gains, seconds or fractions of a second, may be offset by a slow parallel process

d. Management decision
- Necessary for a warship with a equivalent, time critical task e.g. Anti-Air Warfare

D. **Reduction of workload (physical/mental)**

a. Advantages

- Reduction of physical/mental strain and fatigue
- Reduction of omission/commission errors due to the factors mentioned above
- Improving physical health of operator
- Reducing crew requirement

b. Disadvantages

- Reducing job satisfaction may result in lack of interest and low morale

c. Considerations

- Critical Design Issues: control and maintenance
- Other workload distribution by watch organization possible?

d. Management decision support

- Thorough workload analysis necessary

E. Crew reduction

a. Advantage
- "Improving efficiency"
- Crew (cost/LCC) reduction
- Reduces administrative workload

b. Disadvantage
- Loss of manpower for damage control and facilities maintenance
- Other manpower reductions like leave, training courses, sickness etc. have higher percentual effect and may increase additional (unregistered) work load on others

c. Consideration
- True gains within total system are marginal only
- Reduction of personnel must "fit" into total system design

d. Management decision support
- Total system analysis must be of highest quality

2.3.2 **Workload**

a. While other automation drivers like health hazards and critical tasks are more obvious, workload shall be considered in more depth as it is one of the major fields of Human Engineering/ Human Factors. The concept of workload and its analysis has become one of the foundations for decision on function allocation and automation in general.

b. In a modern warship, tasks with physical workload that can be reduced by automation are few. They have been constantly and widely reduced in the recent automation developments. The best tools to assess them are reports from similar classes or ship types (i.e. automation drivers), observations during inspections and plans of the technical layout which must be reviewed by the HE/HF expert team with the help of experienced naval personnel. The fact that unregistered workload can reach a high percentage of the total in a warship must be kept in mind.

c. A major part of the unavoidable physical workload consists not of physical labour, but of long watchkeeping hours and irregular sleep. A similar source of fatigue are abnormal conditions in temperature, humidity, etc., which are not covered under the aspect of occupational safety. The effect of both will be hardly distinguishable from those of mental workload.
Such effects and their accumulation and mutual influence cannot be discovered in simulation, but in field experiments only.

d. The main effort of research today is on mental workload. Measurement techniques can be classified into three categories, subjective, physiological, and behavioral.
Subjective measurement uses individual reports including some rating scale. It includes the risk of bias due to the experiment of other unknown factors, but is very useful to interpret changes in performance. Long-term effects of warship conditions and their tendencies will be well recognizable.

Physiological techniques track the human's capacity and expenditure by his corporal responses like heart rate or eye movement.
Its main contribution is the explanation of highs and lows in human performance due to circadian rhythm and unrecognized individual stress factors.

The most direct way is performance measurement, either by primary or by a secondary task.

Both are able to detect performance decrements, but not to explain their origin.
Their characteristic feature is a high load or overload which the user is confronted with in a rather short interval, similar to a combat situation. The at least equally probable situation of long term underload with sudden change to overload is rarely tested due to lack of time and difficulties in interpretation of results. As this occurrence is quite likely in a warship, it should be a target of future naval research.

All three techniques yield results which must not be reviewed exlusively.
Their use should be complementary to understand man as a whole with his abilities, motives and resources and not a performance delivering service.

2.4 Decision on Automation level

a. The task

- Definition of Automation level

has a large socio-political aspect, too.
The ship that is to be built has to fit into a certain defined political environment. It is necessary to decide which level or what area within defined boundaries of system control shall be made independent of the human being, its limitations and decisions.

It is necessary for the system manager to initiate, prepare, and bring about this decision as early as possible to get a firm requirement for the design process.

b. The HF/HE expert team has to identify and provide background data, e.g. test results from military installation accident statistics, supervision logs from power plants, etc. and to formulate its recommendation.

c. The main tools to find the "right" automation level are
- function analysis
- function allocation

Their basic idea has been the comparison between man an machine, formulated first in the Fitt's List of 1951, the tasks being allocated to the "superior" element.

The comparison's prerequisite is measurement of human performance, which can be done either in field experiments with the multiple problem of correction for biases or in simulation models which are incomplete and questionable by nature.

A more understandable and sound concept is complementarity instead of comparison. In reality, functions are not fulfilled by machine or man, but by both of them together. If the idea that man and machine are complementary instead of comparable in function allocation becomes the basis of function allocation we have passed a major obstacle in system design towards an environment which a future user will recognize as friendly instead of impartial or hostile.

d. The tools and methods of function analysis will remain the same as they have been before, but the way in which they - and their results - are used must change to reflect that man, different from machine, has and needs a psychological environment as well as a physical one. If a function is taken from man because he is "inferior", he will feel like it and his job satisfaction and motivation will be gone. The design for cooperation of man and machine must reflect our respect to man, especially in the most trying cirumstances one can imagine - combat for survival.

Chapter 3 - Design

3.0 Introduction

The long-term planning of National Security and budgeting make warship design a top down process.

At the end of this process task allocation leads to the design of man-machine systems. This is probably, and rightly, a center of effort in human factors consideration on automation, and the topic of a special ANEP (ANEP 27).

The automation of one special task will have implications to nearly all other parts of the design, e.g. ship size, engineering, accomodation etc., which will affect each other again, leading possibly to the rise of another question whether a function/a subsystem shall be automated or not.

Such changes will occur due to design-internal inputs, like the finding of a "better solution" or a hitherto unknown technological breakthrough, or external sources like budgets cuts, availability of personnel, change, addition, or reduction of tasks etc.

Several of the important aspects are going to be covered by special ANEPS and will be mentioned only briefly in this publication.

The viewpoints of usage and maintenance for automation design will be covered on the following pages.

Warship design has to put special emphasis on fulfillment of tasks on reduced capabilities. Degradation and concepts of degraded mode operations have to be dealt with exensively.

Finally, the positive and negative influences of automation on training will be taken into account.

3.1 Total system design

The amount of task and its complexity request the permanent consideration of all aspects trough all stages of the design process - the total system design.

The consideration of Human Factors/Human Engineering ship design in general and on automation must be an <u>iterative process</u> across all areas and all levels of design.

The top-down design must be checked repeatedly in complex systems in an iterative bottom-up investigation to locate and correct automation design errors with respect to Human Factors.

Concurrent Engineering will be one mayor part of total system design. The aspects of usage, amintenance training and system integration must be considered according to their respective concepts. Depending on the scope of automation this may well be a case of mutual influence.

System integration deserves special emphasis. Without it a system will be little more than a conglomerate of different elements from the selected contractors. A special problem in this context is the fact that most market oriented firms have developed a hardware-/ and software concept with very definite, typical, unambiguous characteristics and will not yield easily to integration and the necessary assimilation which must be pressed home in the future user's interest.

Nevertheless, the task of reviewing every bit and piece of the design must not be considered lighty, but conducted thoroughly.

The most important aspects are:

- involvement in the early design stages
- participation in integration processes especially with equipment from different contractors
- use of 3D-models and 1:1 scale mock-ups
- ample time for reviews

3.2. Usage

a. One of the main targets of automation has always been to ease the workload on the user. The research of the recent years indicates that although this goal has been reached there are several negative aspects that should have been thought of before.

b. Two general tasks are left for the operator in an automated system. He may be expected to monitor its behaviour and to provide input in an unnormal situation (take-over). It is one of the "Ironies" of automation that its progress ist terminated if is too difficult to automate, the true difficulties being left to the user who is thought to be relieved of workload.

c. The monitoring situation contains the socio-psychological problems
   - boredom
   - inability of long-term vigilance (another candidate for automation!)
   - lack of insight into the system

   all of which will result in negative user satisfaction, leading to loss of motivation and aggravating the problem.

d. Once the operators task has been changed to monitoring, lack of practice will result in the loss of manual and cognitive skills as development and upkeep of both depends on frequency of use and feedback on effectiveness. This "de-training" and a lack of system understanding and situation awareness may result in serious problems once a take-over is necessary. A belated or inept reaction can bring the system into oscillation or another similar uncontrolled status, where the operator is unable to interpret the system reaction whether it is due to a true failure or his own input. The increase of workload he is not used to any more will add to a stressful situation.

e. The widely adopted installation of experts systems does not change the problem from the viewpoint of human engineering, it transfers it to another level: The system's superior knowledge storage and calculation capacity leaves the operator unable to track its decisions or alternatives. He may be forced to yield to a solution that seems to him "most acceptable" in the present circumstances.

f. In the case that the previously described situation poses an unacceptable risk in the designers mind, the decision on the automation level must be referred back to the system management and reviewed. The results may be a step forward or backward: either automate the system even more, possibly without human control, or fall back to a system status that can be controlled by acquired and trained skills. The use of training to overcome these problems will be covered in a later paragraph.

g. The true design solution is that of a good interface between man and machine. But although there is a huge amount of useful literature on that topic, little progress is sometimes found as well as stunningly bad examples. The design of a good user-interface requires not only sound engineering but constant participation of the future user. As far as possible, the future user should be represented by a significant number of the prospective user population, characterized by factors like experience, skill and age. Otherwise, the design may be biased towards a "good Engineering"-solution or - even worse - to the temporal and personal opinion of a few "experts".

h. Another basic concept of good control interface design is that of "cognitive compatibility", i.e. that the situation and system representation, e.g. by graphs, symbols, and words, conveys the correct information to the user in such a familiar way (seen from his previously acquired knowledge) that he has the least difficulties to interpret it.

i. It must be recognized that mutual relations exist between man-machine interface design and user skill profiles. It is the HE/HF Expert team's task to establish such profiles for given technological alternatives and review whether they "fit" to each other after changes - either in equipment or in manning - have been introduced into planning.

j. Altough the military is inherently reluctant to accept the idea, the "adaptive interface" should be prometed as one of the major contributors to job satisfaction in a MMI workstation. Employing the different user's skills, it should be neither too demanding for a novice nor too amateur-like for a well trained operator.

k. All other aspects off MMI-design shall be referred to ANEP 27.

3.3 Maintenance

a. Beside usage, maintenance is the second viewpoint from which the Human Factors Expert has to look upon automation design.
As maintenance does not only cover the equipment carried in a warship, but extends to the ship itself, too, it has become the prime factor to be considered when dealing with the automation driver of crew reduction.

Warships may not only have more irregular usage terms than their business-drives cousins, but carry the additional task of showing the flag in foreign ports and waters and thus have a greater need of ship maintenance. Similar importance must be attributed to the facts that naval equipment is often singular even to a ship type and cannot be bought off-the-shelf to replace something worn out, and that in most cases the supply of spare parts is limited due to lack of funding, optimistical evaluations of MTBF's or reduction of Life Cycle Costs.

b. Maintenance may be divided roughly into the four areas

a. Routine maintenance
b. Preventive "
c. Condition "
d. Corrective "

c. Automated systems have little demand on maintenance of the first two classes, coincidently there is little use for automation in routine maintenance like cleaning or preventive maintenance as it turns out to be nearly impossible or grossly uneconomic.

What may be automated in routine maintenance is the allocation and control of these tasks in order to save administrative workload and personnel.
The automation should, however, be restricted to control support and the control itself be effected by a person, as nobody likes to be supervised by a machine in a simple task. Such a feeling may have a negative influence on job satisfaction in a task that is uncherished and undervalued among the crew anyway.

d. Condition maintenance has become a major field of automation application in recent years. The Human Engineering problems are more or less those that have been listed already under the user's point of view.

Due to the complex character of the system involved, automation in Built in Test Equipment (BITE) and failure search programs is inevitable and has to use advanced expert systems. Another prime candidate for automation is the handling system for exchange parts.

In both cases, quality testing and assurance must be performed with participation of future user's population representatives to ensure a design that is not a "pure engineering solution" but one that conveys clarity and ease of use to an average user.

e. Corrective maintenance will continue to be a sore in automation efforts.

The danger that automation of system control will lead to reduced system transparency and lack of training as a mental problem for the operators and reduction of the workforce as a physical problem has been mentioned already.

The first problem must be countermanded by good software engineering to further system understanding and enhanced simulation programs including degraded mode and total equipment failure operations.

As the full scope of possibilities of damage cannot be covered in industry-produced-software, such damage control simulation programs might be designed free-programmable to avoid the umpteenth replay of a well-known damage control exercise and to give the crew the chance to train its imaginative powers, contributing to overall job satisfaction.

The second problem cannot be "countered" simply. The approval of the reduction of workforce must be the result of thorough workload analysis in damage control and total system design. The manual work of damage control remains the same, and must be performed by physical labour.

What should be automated is the actual account of personnel and material, e.g. by electronically readable tags and weight-sensible contacts, contributing to a reduced workload and faster and less error-prone way of communication in Damage Control.

3.4 Degradation

a. A design aspect special to warship design is the fact that such a ship is meant to go in harm's way. That implies that the possibility to sustain damage and to have to operate in a degraded operation mode is disproportionally larger than in a "normal" system, e.g. a power plant. The possibility of such an operation mode must be considered not an emergency, but probable.

b. The decisive aspect of degradation design is the criticality of a task for the total system. If the task is considered vital, a backup, automated or manual, has to be incorporated into design.
The concept of degradation is understandable for a total or connected system only; a single system element does not know degradation, it works or it's broken down.

c. If a task is considered as a candidate for automation, the degraded mode operation shall be considered to be a candidate, too, as the task itself does not change. An automated system that continues to work in a degraded mode must have an interface that keeps the user informed of the present status and its limitations as well as the predictable development (positive or negative) with implications for peripheral and central systems. On-line help for the user in the case of partical failure is as essential as off-line help in case of a total one.

d. As Automation is based on electric power, a critical task must have a manual back-up, if possible, e.g. optical fire control/manual loading and firing. The manual back-up must have the same or a similar logic like the automated normal mode in order to avoid errors of wrong handling from right intention.

3.5 Workstation/MMI

a. The interface of man and machine demands a major effort of the Human Engineering expert and is one of the central and critical issues in this context that is going to be covered in a special ANEP 27, devoted to that topic, which will reflect the considerations on usage. Its importance is highlighted in the thoughts on command and control systems.

3.6 Habitability

a. The design of the living conditions aboard must be considered on an equal level with that of Weapon systems or engineering. It is covered, therefore in ANEP 24.

b. Automation in habitability shall not surpass the conditions a crew member is used in his normal social and private life.
Good examples are, e.g. access to the ships library, mail distribution, and computer games.
Bad examples are, e.g. food distribution (except vendor machines) and strict presence control, as nobody likes to be treated as a number or closely be supervised in his private sphere.

c. If an automated system is used for monitoring the whereabouts of personnel during Combat Conditions or prolonged crisis situations, its use and advantages must be made clearly recognizable to the crew.

3.7 Training

a. Automation offers both problems and solutions from the viewpoint of training aboard.
The inherent danger that automation will have a "negative training effect", as the user can neither exercise his skill nor get a feedback whether his work might have been successful or not has been mentioned.

b. In an automated system, training has the double task to hone the user's skills with respect to the present system and to keep his "old" skill alive for the case of degradation or failure and the necessity of manual take-over.

c. As the normal operational mode is too little instructive and the degradation scenario cannot be trained sufficiently in reality, the answer to the problem will be simulation. A training concept part of any automation design. The concept must extend over normal, backup, and degradation modes and be usable in- and outside of normal operation times ("embedded training").

d. One of the major targets of training is to keep and enhance the user's interest and job satisfaction. Simulation programs offer a first-class opportunity to achieve this by taking him into active participation in developing and countering possible scenarios. The more progress a user has made the more chance should he be given to hone his own skills, although a clear line must be drawn at (really) vital security.

3.8 Design Command and Control Systems

a. Automation of time-critical tasks in warships leads to the - technologically as well as budgetary - central design problem of command and control. A modern combat direction system (CDS) - like AEGIS in the CG47-TICONDEROGA Class - reacts on the principle of control by doctrine. Specified rules allow the system to digest an incredible amount of data and transform its evaluation into preprogrammed reactions.

b. The technological problems of designing the decision path (e.g. multiple sensor integration) have been considered elsewhere and cannot be covered in the scope of this publication.

c. The first Human Engineering problem lies with the rules. The political environment has changed from bipolar structures to a wide spectrum of complex combinations. Besides the time problem to get an alteration of rules through the control and confirmation process it is doubtful whether a western-oriented designer's mind is able to follow the ways of thought which may be characterized by religious, ethnic, or other political fanatism. While this environment is quite likely for a warship to be in, its rule-based command and control system may not be up to the correct interpretation of the situation.

d. The solution to apply even more artificial intelligence in knowledge-based systems (KBS) keeps some promise as our knowledge base of the factors mentioned above has expanded. Nevertheless, the conceptual flaw of inability to react in uncertain and unpredictable complex situations remains the same.

e. An improvement, although no solution for this dilemma is the application of the following design rules:

- Possible rule-related misinterpretation of data must be displayed as clearly as possible
- In higher degrees of uncertainty, the data source must be easily recognizable
- Except for fully developed conflict situations, e.g. an AAW battle, the decision to open fire must be allocated to man. The responsibility to automate that decision will rest with him anyway.

Literature

1. Bainbrigde, Lisanne (1985) "Ironics of Automation", in: Automatica, Vol. 19, No. 6, 1983

2. Bubb, Heiner, System Ergonomics as an approach to improve Human rehability, in: Nuclear Engineering and Design 110 (1988) 2. Dez., S. 233 - 245, Amsterdam; NL

3. Fitts, P.M. (Ed.) "Human Engineering for an effective air navigation and traffic control system" National Research Council, Washington, D.C. 1991

4. Jordan, Nehemiah, (1962) "Allocation of Functions between man and machines in automated system" in Journal of Applied Psychology Vol. 47, 1963