- Technical Proposal -

HUMAN FACTORS EVALUATION OF CONTROL ROOM DESIGN AND OPERATOR PERFORMANCE AT TMI-2

Prepared For:

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PART I: TECHNICAL PROPOSAL

1.1 Statement of the Problem

Effective system performance is dependent on the extent to which the system's design incorporates the requirements of its constituent elements. For the human factors engineer, this tenet is expressed in terms of the capabilities and limitations of the human operator. By corollary, we may infer that the more critical the role of the operator, the greater the requirement for his capabilities and limitations to be reflected in the system's design. Too often in the development of complex systems, the requirements of the human operator are subordinated to those of other, "more important" elements, with the result that the system, though technologically sophisticated, can neither be operated nor maintained by man.

In the course of preparing this proposal, Essex has reviewed the current literature on HFE problem areas in control room design. While the consensus of the evaluators is consistent (that is, that HFE in general has not received sufficient attention in the design and development of nuclear control rooms), four distinct areas emerge as requiring immediate and intensive ameliorative action. These are:

- The apparent lack of a comprehensive, standardized approach for integrating human factors engineering methods, techniques, principles, and data into the design and development of nuclear reactor control rooms
- The absence of adequate, enforceable HFE standards for control room design and operation
- The inadequacy of current practices for developing operating procedures
- The general failure of the nuclear industry to identify, and design for, the information requirements of the human operator

The consequences of these shortcomings are directly reflected in the quality of the human engineering characteristics of existing control rooms. Two independent evaluators Lockheed and Aerospace, have reviewed many of the HFE characteristics of control rooms and found them to be singularly inadequate in many respects. The following examples underscore this point:

- In some cases, control room designs appear to <u>maximize</u> visual scan and walking requirements
- In many control rooms there is inadequate storage space for operating procedures. This precludes the operator from gaining timely

access to written procedures, particularly under emergency conditions.

- Meters are sometimes placed as high as 12 feet off the floor, making normal visual inspection impossible.
- Control boards are designed with little or no consideration of the actual tasks to be performed by the operator, resulting in a dearth of functional or operational grouping of controls and displays.
- Display types are incorrectly selected (e.g., indicator lights are used when gauges are required), resulting in inadequate information presentation to the operator.
- Labelling of panels and components is inadequate and/or ambiguous, resulting in operator errors and delays.
- In some cases, workstations are designed such that the operator sits with his back to the primary control board.
- Some control boards are designed as "mirror images," resulting in confusions and negative transfer of learning.
- The absence of lighted indicators is often used to present a positive indication of system status. This technique has long been censured by DOD and NASA standards as ambiguous and unreliable.
- Meters are designed such that, when they fail, the indicator rests in the normal or safe zone.
- There is no evidence of the application of such basic HFE coding techniques as color, shape, position or operations-sequence. This situation compounds the information processing requirements of the operator and increases the probability of error.
- Chart recorders are used where gauges or indicators are required, making real-time access to needed information difficult and error-prone.
- Meters are inadequately coded as to normal, marginal and hazardous ranges, resulting in additional information processing and training requirements.
- Measurement and presentation of parameter status in inconsistent, resulting in excessive requirements for operator computation (e.g., converting water level to gallons)
- Operating procedures are often inadequate, reflecting pre-1950 documentation technology. Additionally, there is considerable disparity, in some cases, between written and actual procedures, and between written and actual display values.
- Trouble-shooting strategies and job performance aids are absent or ineffective.

From a system perspective, this apparent disregard for the requirements of a major element (i.e., the human operator) is categorically untenable. For the system to perform optimally, it is imperative that the design of the system be compatible with the capabilities and limitations of the operator for all functions in which the operator plays a role.

For present purposes, the responsibility of the reactor control room operator may be partitioned into five basic functions:

- Starting up the plant
- Maintaining safe and efficient plant operation
- Protecting equipment and plant from damage
- Monitoring the performance of automatic safety systems
- Providing manual backup for automatic systems, when required

The successful execution of these functions is directly dependent on the effectivness of the control room's design for meeting the information and performance requirements of the operator. From an HFE perspective, the crux of effective design is, therefore, the translation of operator functions into specific tasks and, subsequently, into quantifiable information and performance requirements. These requirements may then be incorporated into the design of the control room, and the content and organization of the operating procedures.

Although the problem may be simply stated, its resolution is a complicated undertaking. The functions of the control room operator are complex and stressful under ideal conditions, when an emergency occurs, such as loss-of-coolant accident (LOCA), the complexity and stress increase exponentially. It is under these conditions that an operator is most likely to make a critical error, yet it is under these same conditions that the control room's design appears least responsive to the operator's requirements. The problem may be brought into sharper relief if we consider the complexity of just the general tasks performed by the control room operator. The operator must:

- Constantly check all meters, recorders, displays and readouts pertaining to the status and performance of the reactor and other plant equipment, being continuously watchful for deviations from expected character.
- Diagnose alarms and interpret trends in control room readouts. When an alarm or readout variation occurs, the operator must be able to immediately corroborate its validity, infer its cause or causes, predict the effect on system performance and safety, and ensure that the necessary corrective action is taken.
- Be prepared to assume manual control of the system in the event that automatic systems fail to operate or are ineffective.

- Ensure the efficient and safe operation of the plant under non-emergency conditions by performing the coordinated manipulative tasks required for frequent set point adjustments of automatic controls.
- Serve as the principal channel for information transfer within the plant to assure that all operators are kept apprised of the situation and their responsibilities.
- Supervise and coordinate the work of subordinate operators, ensuring the quality and safety of their performance.
- Perform regular plant inspections to identify incipient problems, such as excessive equipment wear, damaged equipment, leaks or abnormal valve alignment.
- Scrupulously maintain his familiarity with the plant, and its systems and procedures, and be capable of training and instructing new or upgraded operators.
- Have a working knowledge of the principles of nuclear fission; a general understanding of the characteristics, construction and operation of the reactor, steam generators, turbogenerator, pumps, and heat exchange equipment; and an understanding of the theory and practice governing the generation and safe handling of nuclear and electrical energy, the safe handling of nuclear substances, and the transmission of liquids and steam under high pressure and temperature.

It is clear from the above description, that the job of the control room operator is a critical and complex assignment. To perform effectively, the operator must have thorough knowledge of the principles governing the plant's operation, the function and location of major components, and the ability to conceive their relationship to the total system. He must be constantly aware of the status of each operating component, and be able to interpret the implication for overall system performance.

The March 28th accident at TMI-2 has brought the criticality of the control room operator's role into sharp focus. It is the purpose of this proposal to describe a technical approach for identifying and evaluating the role of the operator in the course and outcome of the accident, and to determine to what extent control room design, operator training and selection, operator performance, and other human factors contributed to the severity of the incident. The specific Content and rationale of the technical approach proposed by Essex are described in the following section.

1.2 Technical Approach

This section describes the technical effort to be applied to the four primary tasks:

Task A - Control Room Design at TMI-2

Task B - Control Room Activity

Task C - Operator Performance

Task D - Application of Human Factors Principles to Control Room Design

TASK A - CONTROL ROOM DESIGN AT TMI-2

Problem: Incidents such as the transient of Three-Mile Island Unit 2 are rarely caused by one failure in a system. Redundancy, high reliability components, planning and maintenance virtually assure that significant accidents (e.g., the release of radiation) will result only when several failures occur at or near the same point in time.

Such was the case of TMI-2. Published scenarios indicate that hardware failures compounded with operational errors to produce the release of radiation and the production of the hydrogen bubble. Since operational errors most often result from inadequate human engineering (e.g., design, training, procedures, etc.), the investigation of the TMI-2 accident must consider this as a potential contributing factor.

Assuming that operator error contributed to the TMI-2 incident and that deficient human engineering decisions contributed to the error, the question for investigation is "what principles, criteria and data were used to make critical human engineering decisions?"

To answer this question, the design process, beginning in 1967, that produced the TMI-2 Control Room (CR) design will be reconstructed from documents and interviews. Human engineering criteria, design bases, standards and principles will be identified and compared to the actual TMI-2 design to identify those actually used. Finally, the TMI-2 CR design process will be compared to the processes of other plants.

Throughout these tasks, Essex nuclear and human engineering personnel will work closely with the NRC contract manager to assure that maximum benefit is returned during the rather short duration of this study.

Objectives:

- Identify the criteria and standards which directly influenced the CR design.
- Identify the actual design basis, operating logic and human engineering principles used in design.
- Determine if CR was designed in accordance with design bases and criteria.
- Compare the TMI-2 design process to that of other plants.

TASK 1. Identify Criteria and Standards

This task will be performed by Essex in three steps at the outset of the contract. First, the NRC regulations and guides applicable to the TMI-2 design and operations will be reviewed for human engineering criteria. Next, non-NRC (industry) standards applicable to nuclear power plant control room design in the late 1960's and early 1970's will be obtained from standards-making organizations (ANSI, ANS, ASME, etc.). Finally, critical aspects of the TMI-2 man/system interface will be compared to non-NRC human engineering standards to determine the use, and consistency of use, of each standard.

As noted above, ineffective control room human factors engineering might have caused or contributed to the human errors recorded during the sequence of events surrounding the TMI-2 accident. In order to obtain an accurate picture of the role of human engineering criteria and standards in the final TMI-2 control room design and operations, it is necessary to reconstruct, for the time of TMI-2 design, construction and testing, complete and faithful lists and descriptions of all NRC/AEC regulations and guides, and non-NRC standards and recommended practices relevant to control room human engineering.

The steps proposed below by Essex are designed to identify all regulations, guides, standards and recommended practices relevant to CR human engineering and available during the late 1960's and early 1970's.

a. Review NRC regulations. Design of TMI-2 was undertaken by Burns and Roe during November, 1967. In a quick look at AEC and NRC documentation, Essex found that:

- The organization of the TMI-2 Final Safety Analysis Report is in general agreement with the 1975 Standard Review Plan; therefore, it seems reasonable to assume that the information required by the SRP will be found in the FSAR. Also, it seems reasonable to expect that many of the Regulatory Guides (or Safety Guides* in the early 1970's) would have been in force during the period of the TMI-2 Control Room (CR) development.
- 10CFR contains many new regulations since 1970, but 10CFR Part 50 and Appendix A to Part 50, giving the General Design Criteria, remained mostly intact since the early 1970's.
- If a human engineering criterion is defined broadly to mean any requirement imposed on the operator/system interface, then NRC documentation contains some human engineering criteria.
    - "The indication system should include a capability of assuring its operational status . . ." BTP EICSB 21.
    - "Appropriate controls should be provided to maintain these (monitored) variables and systems within prescribed operating ranges." SRP (1975) p. 7.7-2.

* Safety Guides date back only to 1970; however, some predecessor is likely to have been available during the late 1960's.

- "In judging the adequacy of any manual initiation features, the other tasks that the operator may be required to perform should be determined . . ." SRP (1975) p. 1.3-11.
- ". . . False indication due to malfunction of an indicating device should not lead to an undesirable manual action" SRP (1975) p. 7.5-4.
- "If the reviewer's judgment is that manual initiation is sufficiently reliable . . ." SRP (1975) p. 7.3-7.
- ". . . in the case of operator error, there are sufficient time and sufficient information . . . the consequences of such an error are acceptable." BTP EICSB 20.

Essex approaches the examination of regulatory documentation as a fairly standard documentation review task. The primary objective is a thorough review of these documents and a complete identification of all CR-relevant criteria, guides, etc., that require the application of human engineering principles. All regulatory documents will be reviewed twice: first by nuclear engineers who will uncover criteria applicable to CR design; then by human engineers who will determine whether the criteria requires human engineering. This task will be performed in five steps:

(1) Review the late 1960's and early 1970's versions of 10CFR

(2) Re. ew the Final Safety Analysis Report for TMI-2

(3) Review NRC-provided contracts and agreements (Met. Ed., Jersey Central Power, Burns and Roe, Babcock & Wilcox) to identify regulations imposed on the control room. Then identify human engineering criteria contained in these regulations.

(4) Extract human engineering criteria from current SRP, Regulatory Guides, 10CFR and use these to aid in identifying NRC/AEC regulations applicable during the design, construction and test phases of TMI-2.

(5) All human engineering regulatory criteria applicable to TMI-2 will be compiled into a list quoting the regulation, its source and its earliest (post-1966) imposition date.

Some of the current NRC regulations pertaining to human engineering are listed below.

- NRC Regulatory Guides

1.8	Personnel Selection and Training
1.22	Periodic Testing of Protection System Actuation Functions
1.47	Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems
1.33	Application of the Single-Failure Criterion to Nuclear Power Plant Protection Systems
1.62	Mutual Initiation of Protection Actions

1.78	Assumptions for Evaluating the Habitability of a Nuclear Power Plant Control Room During a Postulated Chemical Release
1.81	Shared Emergency and Shutdown Electric Systems for Multi-Unit Nuclear Power Plants*
1.114	Guidance on Being Operator at the Controls of a Nuclear Power Plant

- 10CFR Chapter 1

  Part 1 - Statement of Organization and General Information

  Part 21 - Reporting of Defects and Non-Compliance

  Part 50 - Domestic Licensing of Production and Utilization Facilities

  Part 55 - Operator's Licenses

- Standard Review Plan

  Chapter 7 Instrumentation and Controls
  9.5.2 Communications System
  9.5.3 Lighting System
  Chapter 13 Conduct of Operations
  Chapter 15 Accident Analyses

Sections of the TMI-2 Final Safety Analysis Report that may identify human engineering criteria include:

3.1	Conformance with AEC General Design Criteria
6.	Engineered Safety Features
7.	Instrumentation and Controls
9.5.2	Communication System
9.5.3	Lighting System
13.	Conduct of Operations
15.	Accident Analyses
17.	Quality Assurance Program (several sections)

b. Review non-NRC standards. As with a., above, Essex approaches the identification of CR-relevant industry standards as a two-phase activity: nuclear engineers and past TMI-2 operators will identify CR standards; then human engineers will determine if they specify or constrain the man/system interface in the CR. The reviewed outlined below will produce a comprehensive list of all non-NRC standards and recommended practices available to TMI-2 CR designers/planners during the design, construction and testing phase of the power plant. Essex will begin this task immediately after contract award.

(1) All standards and recommended practices named in the NRC-provided SRP and contracts and agreements (Met. Ed., B&R, B&W, etc.) will be identified and listed.

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* TMI-2 is not a sister plant to TMI-1.

(2) Using the "Status Reports" of the Nuclear Standards Management Board (NSMB) and catalogs of standards organizations (ANSI, ANS, ASME, EIA, IEEE, ISA, NEMA, NFPA, SAMA and UL) standards and recommended practices for nuclear power plants published during the late 1960's and early 1970's will be identified and listed.

(3) To assure that all control room human engineering standards have been located, Essex will trace current control room human engineering standards back through their preceeding generations to 1967, or to their origin if later than 1967.

(4) As a standard is added to the list, it will be ordered from Global Engineering Documentation Services or the Engineering Societies Library. Both suppliers provide quick turnaround and both have extensive standards libraries dating well before 1967.

(5) Every nuclear-related standard/recommended practice will be reviewed by nuclear engineering and human factors engineering personnel to identify those items relevant to CR design and operations.

(6) As a result of (1) through (5), Essex will compile a complete and faithful listing of CR human engineering standards and recommended practices available to TMI-2 designers. The list will quote the text of the standard and reports its source and first publication date.

Four current standards and recommended practices relevant to human engineering of the CR are listed below:

- ANSI/ANS-3.1-1978. For Selection and Training of Nuclear Power Plant Personnel
- ANS-3.2 (ANSI N18.7-1976). Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants
- ANSI N660 (ANS-51-4-1977). Proposed American National Standard Criteria for Safety-Related Operator Actions
- IEEE Std 566-1977. IEEE Recommended Practice for the Design of Display and Control Facilities for Central Control Rooms of Nuclear Power Generating Stations

A brief review of the 1968 ANSI Nuclear Standards uncovered only one entry that might have CR-relevant items (N2.3-1967 Immediate Evacuation Signal for Use in Industrial Installations Where Radiation Exposure May Occur), and this standard is definitively peripheral to control panel operations of interest at TMI-2. Therefore, Essex believes that the number of human engineering-relevant industry standards available during the late 1960's will be limited.

c. Application of human engineering standards. The final step in Task A.1 will be to identify which of the standards and recommended practices listed in b., above, were actually applied in TMI-2 design.

There are two reasonable approaches to this problem. First, Met. Ed., B&R and B&W contractual and design documentation could be reviewed for references and citations. Second, the standards could be compared to TMI-2 design. Essex believes that the number of relevant standards and recommended practices will be sufficiently small to permit both approaches.

(1) Standards and recommended practices will be drafted into a checklist. Then, with the approval of the NRC contract manager, Essex human engineering personnel will perform an on-site* test and evaluation of the TMI-2 design using the standards/recommended practices identified in b., above. The result will be a listing of conforming/violating design features.**

(2) NRC-provided engineering documentation on the design, development and testing of the TMI-2 control room will be thoroughly surveyed for citations and references to standards. The result will be a listing of human engineering standards and recommended practices used to justify design decisions.

(3) Lists from (1) and (2) will be compiled and the standards list prepared in Task A.1.b will be annotated to show those standards actually used in TMI-2 control room design.

2. Design Basis, Operating Logic and Human Engineering Principles

a. Design Basis and Operating Logic. Design Bases identify the specific functions to be performed by a system (10CFR50.2). Design bases (e.g., protection against natural phenomena, environmental and missile, containment) are included as part of the General Design Criteria (GDC) in Appendix A to 10CFR Part 50 and are applied, by system, throughout the TMI-2 FSAR (e.g., 4.3.1 Design Bases - Nuclear Design; 10.2.1, Design Bases - Turbine Generator, etc.)

While 10CFR does not specify the design bases for power plant CRs, Appendix A, Criterion 19 - Control Room holds that the control room must permit safe plant operation under accident conditions, including LOCAs. Interpreted broadly, this criterion implies that the control room must be designed to permit safe operation under conditions resulting from design bases events applicable to each system interfacing with the CR. Thus, to some degree, the required designed bases for the TMI-2 CR can be characterized by a listing of bases for all systems with instrumentation located on one or more of the CR's control panels.

Although the TMI-2 FSAR includes a general assessment of the conformance of systems, structures, etc., with the GDC, Essex has been unable to locate a consolidated list of design bases used for control room design and operation. Furthermore, the FSAR does not seem to reflect an integrated, systematic approach to assuring acceptable human performance in CR operations: the operating logic for systems interfacing with the CR is given, but general logics

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* If NRC prefers, the evaluations can be performed, to a large extent, on drawings, photographs, etc.

** Note: If the NRC wishes, the criteria/guides from Task A.1.a. and the current standards/recommended practices could be added to this step.

for operating all systems simultaneously and safely have not been uncovered. This may be contrary to GDC 1 which states that systems (e.g., TMI-2 control room) must be "... designed, fabricated, erected and tested to quality standards commensurate with the importance of the safety function to be performed." Since the control room performs an important safety function, the CR design and design bases should have been identified and considered in the Met. Ed. FSAR, such that the quality standards could be assessed.

In the following step, Essex nuclear engineers will review CR and systems documentation to identify design bases and operating logic relevant to CR design. These engineers will compare design bases and logic to determine if they were incorporated in the as-built CR design. Human engineers will determine if the CR could be operated safely under relevant design basis events.

(1) Documentation relevant to the design, development and construction, and testing of the TMI-2 control room will be examined to identify any and all design bases used in development control room man/system interfaces.

(2) To further expand the list of CR design bases and identify operating logics, Essex nuclear and human factor engineers will review documentation on each power plant system using the control room to perform primary or backup operations vital to the purpose of the system, or to the safety of the system, plant or environment. Much of the data needed to expand the design bases will come from the TMI-2 FSAR sections concerning conformance with AEC General Design Criteria; design bases for nuclear, thermal and hydraulic, leakage, identification of safety criteria; turbine generator; main steam supply system; and accident analyses. At the same time, the NRC-provided FSAR: control room layout drawings; control panel drawings; accident analyses; and system functional flow charts and schematics will be analyzed and reviewed to determine the operating logics for systems interfacing with the control room.

(3) In this step, Essex will evaluate control room design against the operating logic, from "b" above, to determine whether the logic, as stated, is actually incorporated in as-built control room design. Also, control room design requirements will be derived from each design basis found in "b" and "a". Actual control room design will be compared to these requirements to determine which design bases were used in designing the as-built control room.

b. Human engineering principles. In addition to design bases and operating logic, Task A.2 requests the identification of human engineering principles that were applied in the as-built design of the control room. For several reasons, Essex expects this identification to require more than a "review of design studies and analyses" as stated in the Scope of Work.

- First, designers no doubt used a variety of principles or rationale for CR design decisions, some decisions were based solely on cost; others on standard practice (Section 7 of the SRP entitled "Instrumentation and

Controls," recognizes standard practice as a valid design rationale in no fewer than three places); still other decisions were based on experience, regulatory criteria or engineering/construction convenience.

- Second, design engineers are not likely to record design rationale unless required to do so; therefore, most human engineering principles used in the TMI-2 control room design will not be documented.

- Third, many of the control panel components were probably purchased "off the shelf," having been developed for prior nuclear, industrial or perhaps military applications. The human engineering applied in the design of these components may not be readily apparent through the CR or component documentation.

- Finally, past human engineering surveys of CRs have frequently reported that designs overlook many human engineering principles or criteria. If TMI-2 follows this pattern, human engineering principles may not appear at all in design studies or analyses.

To determine which human engineering principles were used in the CR design, Essex proposes to review NRC-provided design analyses and identify the principles and to examine a set of critical CR design features (i.e., features which would significantly impact operator performance of safety-critical tasks). This examination, performed by experienced human engineers, will result in the identification of human engineering principles prominent in the actual CR design.

1. Design studies and analyses, FSAR, component specifications, component selection criteria and other NRC-provided documentation will be reviewed to identify the princples governing the design of the interface between the operator and the system (operator/control panel; operator/operator; operator/procedures). Those principles that conform to human engineering principles of the late 1960's and early 1970's will be identified and the concomitant design decisions will be noted. A letter report will be sent to the NRC contract manager.

2. The two Essex-employed past TMI-2 operators will team up with human engineers to identify 50 or so critical design and operational features of the TMI-2 CR. For instance, controls/displays that are critical to emergency operation; vital information that must be communicated between operators; operator procedures that must be performed quickly and without error; environmental features (e.g., noise levels, lighting); color coding, etc. Then the design of these features will be compared to human engineering principles (late 1960's through early 1970's). When the two agree, other similar CR features will be compared to the principle to determine its breadth of application. Human engineering principles discovered through this process will be recorded together with concomitant design decisions and a letter report will be provided to the NRC contract manager.

TASK 3. CR Design Evaluation

Task A.1 is devoted to identifying the criteria, standards, recommended practices and guides imposed on or available to TMI-2 control room designers. The basis for design decisions, and human engineering principles applied to TMI-2 CR design and operations were reconstructed from TMI-2 documentation during Task A.2. In this task, the as-built design of the control room will be compared to criteria, standards, design bases, etc., to determine if the CR was designed in accordance with these requirements.

a. Determine human factors aspects of control panel design. Using established human engineering standards (e.g., MIL-STD-1472B, MIL-J-83302) and state-of-the-art literature, Essex will prepare a comprehensive listing of potential human engineering aspects of CR design and operations. This list will be compared to contractual documentation (drawings, Final Safety Analysis Report, contracts, special study reports, etc.) and the human factors aspects germane to the CR design will be determined. Some categories of human factors design aspects include control/display integration; visual displays; audio displays; controls; labeling; anthropometry; workspace design; environment; troubleshooting strategy; document readability; and information flow and communications.

   As Essex reviews the TMI-2 documentation, an accounting will be kept of the number of times each aspect occurs in the design. A list and definition of all CR human engineering aspects will be prepared and given to the NRC contract manager. At the end of this step, Essex will prepare a checklist on the dynamic aspects of CR design (e.g., display update rates) to be assesed in Task 3.b.

b. Visit to TMI-2. Essex personnel representing nuclear and human engineering specialties, as well as a past TMI-2 operator, will visit TMI-2 accompanied by the NRC contract manager. During this visit Essex personnel will be briefed on the pre-accident configuration of the TMI-2 control room.

   Essex will provide the NRC contract monitor with a list of questions which should be covered during the briefing. For instance: What procedures were being performed (all operators)? What systems were active/inactive? What annunciators were on? What actions or tests were planned, etc.?

   Essex will film and/or video tape the control room, if permitted. Accurate visual records of the entire room and all panels, with narration, would be helpful in all tasks.

   Some human factors aspects will not show up in drawings (e.g., rate-of-change of display pointer position, color contrast, actual blinking frequencies, etc.); these aspects will be assessed while at the TMI-2 facility or by using video tapes. At the end of this task, Essex will prepare a complete list of human factors aspects of TMI-2 design for review by the NRC contract manager.

c. Compare criteria and design basis to human factors requirements. Each human factors aspect of the CR design and operation (Task A.3.a) is a human factors requirement; that is, it requires human engineering principles, data, criteria, etc., to assure effective integration of the operator into the CR systems.

In conjunction with the NRC contract manager, the human engineering effectiveness of TMI-2 design will be examined by comparing principles, criteria, standards, etc., available to the TMI-2 designer to human engineering requirements (aspects). Theoretically, there should be at least one standard item or principle or criteria, etc., answering each requirement. Past research provides insights into human factors aspects frequently overlooked in CR design.

- Visual envelope and anthropometrics
- Display location and selection
- Control/display functional and operational grouping
- Labeling
- Control coding, etc.

These make one conclusion very clear—human factors requirements in past CR designs are quite likely to outnumber criteria, standards, guides, princples, etc. TMI-2 is likely to be no exception.

Once every criteria, standard, etc., has been matched to one or more human factors requirements, Essex will prepare a report for the NRC contract manager listing the requirements and criteria that match, and the requirements for which there were no criteria or standard.

d. Identify implicit philosophical or broad-based design concepts. Unlike human engineering principles, uncovering broad-based CR design concepts or philosophies should be relatively straightforward. Concepts such as "single failure," which holds " . . . that the system can perform all protective functions concurrent with failure of any sensor, logic circuitry and components," are usually spelled out in the general design criteria, the SRP, contract documentation, etc. Other concepts, such as automatic initiation with manual backup, undoubtedly will play an important role in CR design and will be apparent from CR design.

There are general design management approaches to CR design which, if adopted, would significantly impact design. These include: design by precedent; minimum cost; and minimum schedule impact. While these are not design concepts, their impact on the CR human engineering would be significant.

(1) Using general design criteria and the SRP, Essex will develop a list and description of probable design philosophies and broad-based design concepts applicable to CR design. This list will be provided to the NRC contract managers.

(2) The TMI-2 FSAR and CR design documentation will be examined against the list of probable concepts and relevant CR design philosophies will be noted.

(3) Each concept will account for certain features of the system (e.g., redundant monitors). If most of the human engineering features of critical systems can be accounted for by one or more concepts, this analysis will be terminated and the predominant design concepts/philosophies will be reported to the NRC contract manager.

(4) If a significant number of human engineering aspects of critical CR systems remain after (3), Essex human engineers will examine the control room (films, video tapes, etc.) to identify possible philosophies. Some of the characteristics to be examined include: control location and type; display location and type; system grouping on and across panels; functional/operational sequencing; anthropometric considerations; design of job performance aids, troubleshooting procedures and labeling; job shift cycle; annunciator types and groupings; and role of training.

(5) At the end of this step, Essex will prepare a report describing all broad-based design concepts and general design management approaches embodied in the TMI-2 CR design. Each concept will be described in terms of the human engineering features it accounts for.

e. Quantity and prominence of CR information. Control room operators are presented information by several sources: voice communications with other operators; log books; instructions and operator procedures; controls (position and labeling); displays; job aids; and so on. All of this information together with data from memory are used by the operator to assess situations and select responses. The SRP specifies ". . . that the operator will be provided with sufficient information to perform required manual safety functions should such action become necessary." SRP p. 7.5-2.

The Scope of Work asks the contractor to "Determine if the quantity and prominence of information presented in the control room are consistent with design bases and criteria." The number of sources of information in the control room are far too numerous to evaluate each against the bases and criteria. Therefore, the two past TMI-2 operators employed by Essex will be asked to identify important sources of information in the CR. No restrictions will be placed on the type of source,* it may be documentation, display, verbal communications, etc.

Once the past-operators have prepared a list of important sources, Essex will present the list to the NRC contract manager for approval. Given approval, Essex will compare the quantity and prominence of information on the list to criteria, standards, design bases and human engineering principles. The result of this step will be a report listing: the CR information commensurate with criteria, bases, etc.; a list of information sources for which no criteria, etc., exist; and a list of criteria for which no sources exist.

* Except that all safety-related displays will be included

TASK 4. Compare the Design Process for TMI-2 CR With That Used in Other Nuclear Plant Control Rooms of the Same Design

The basic objective of this task is to determine whether the control room design process for TMI-2 is typical or atypical of plants designed during the same time period. Given that the general design criteria, 10CFR Part 50, Safety (regulatory) Guides, and FSAR requirements formed a common backdrop for the development of same-vintage nuclear power plants, it seems reasonable to expect that design processes would be quite similar across plants.

On the other hand, these same documents leave a great deal of latitude when it comes to implementing the man/system interface; therefore, different engineering approaches to CR design might result in more or less conformance to accepted human factors principles.

a. Select sites. Essex and the NRC contract manager will select at least two plants of the same generation as TMI-2. Some selection factors include:

- Basically the same GDC applied as TMI-2
- Basically the same technology available
- SAR format and factors similar
- Basically the same functional complexity
- Basically the same operator training requirements

Three LWRs (two plants) that might be suitable include:

- Calvert Cliffs 2 (BG&E)
- Peach Bottom 2, 3 (Phil-Elect.)

b. Human factors criteria and design bases. Using documentation such as FSARs, 10CFR Part 50, Safety (regulatory) Guides, etc., Essex nuclear engineers will identify the control room design bases and criteria derived from the various systems. Human engineering personnel will use the same documentation, together with any CR study or analysis reports to identify the human factors criteria applied to CR designs.

Bases derived from the systems and human factors criteria will be compiled into an evaluation checklist for each site to be visited.

At this point NRC-arranged discussions with designers, design managers, CR engineers for each plant would be most helpful to determine if the bases and criteria are comprehensive and accurate.

Before visiting the control rooms, Essex will submit the human factors bases and criteria checklist for NRC review and approval.

c. Site visits. Essex nuclear and human engineering personnel will make visits to the NRC selected nuclear power plant control rooms. The nuclear engineer will be responsible for determining if the instrumentation in the CR is adequate for design basis events, and the human factors engineer will assess the compliance of control room design with design criteria employed during the design process.

d. Comparison of TMI-2 design process to other plants on approval from the NRC contract manager. Essex human factors personnel will develop a model for human engineering design process followed at TMI-2 and at the other plants. This model will show

- The management of CR design
- The criteria and design bases used
- Human engineering during early planning
- The primary human factors design decisions and the application of design bases and criteria to each
- The role of human factors in personnel training
- System testing—the application of human factors to quantify the man/system interface.

Other aspects of human factors in CR design can be added on request from NRC.

Annex 1 Documentation and Information Requirements

The list below identifies, by topic or title and source, the documentation and information needed to complete Task A.

Topic/Title	Source
• 10 Code of Federal Regulations	On hand at Essex
• NRC Regulatory Guides	List on hand at Essex: actual guides supplied by NRC
• Final Safety Analysis Report on TMI-2	Available in NRC Public Reading Room on Microfiche—Hard copy from NRC would be preferable
• Lists of Industry Standards for Nuclear Power Plants (ASMG, ANS, etc.) 1967-1974	NSMB "Status Reports" and Society catalogs
• Industry Standards (Text)	Globe Engineering Doc. Ser. & Eng. Soc. Library
• Control room layouts; control panel drawings	NRC (from B&W, Met Ed, B&R)
• Design Studies and Analyses	NRC
• TMI-2 Procedures	NRC
• Films/Video Tape of TM2-2 CR (if permitted)	Taken by Essex during visit
• All engineering, design, development and testing information on control room	NRC
• Interviews with engineers (B&K and B&W) involved in CR design (if possible)	Arranged by NRC
• Preliminary Safety Analysis Report on TMI-2	NRC
• TM2-2 CP and OL Safety Evaluation Reports and Documents	NRC
• Preliminary and final SAR's for same-vintage power plants	NRC
• Control room layouts and control panel drawings for same-vintage power plants	NRC

Topic/Title	Source
• CP and OL safety evaluation reports and documents for same-vintage power plants	NRC
• Standard review plan for the review of safety analysis reports for nuclear power plants	On-hand at Essex

TASK B

CONTROL ROOM ACTIVITY

Problem — The design and layout of operator workspaces and the relative locations of these stations can significantly impact operator performance. This is particularly true during emergency conditions when timely and error-free operator performance is critical. The location of single stations, station design relative to the required tasks, interactions with other operators, and the amount of transiting between stations can either inhibit or facilitate operator performance. As it relates to the incident at TMI-2, the layout of the control room may or may not have contributed to the magnitude of the accident. The purpose of this task is to identify and analyze the extent and efficiency of operator activity during the initial time period of the accident.

Objectives — The objectives of this effort are to:

- Construct a full-scale mockup of the TMI-2 CR for use in studying operator activity
- Prepare a comprehensive timeline of control room activities during the first 150 minutes of the accident
- Video tape the activity sequence to provide data for activity analysis
- Identify an ideal activity sequence for comparison with actual activity
- Identify operator actions/inactions which constitute deviations of actual performance from ideal performance and determine the degree to which these resulted from design features of the CR

Approach — The initial steps will be to review available data which bear on the sequence of events in the CR during the 150-minute period. This will be supplemented by CR walk-throughs to permit Essex personnel to familiarize themselves with the CR.

Based on these data and additional operator interviews as required, a timeline diagram will be prepared by Essex employed ex-TMI-2 operators and human engineers showing all data available. An activity classification will be developed including at least:

- Identification of stations
- Activities per each station
- Interactions between operators
- Transit between pairs of stations

Station does not necessarily refer to control panels or delineated workspaces. The stations will be operator locations made necessary by the tasks involved. Activities within stations will include:

- Display monitoring and interpretation
- Control operation
- Data look-up
- Data recording
- Decision processes
- Other categories as required by the available data

The resulting timeline will show classified activity blocks per operator by time unit. The timeline will be made as accurate as possible by:

- Construction from basic event chronologies
- Identification of gaps/inconsistencies, if any
- Review by operators involved
- Review by the NRC contract manager and appropriate NRC personnel
- Iteration of the above

The resulting timeline will be reviewed by NRC to determine operator actions/inactions which influenced the outcome of the accident. These will include:

- Failure to respond to events
- Incorrect response to events
- Excessive response time
- Response out of sequence

Next, CR engineering data, photographs, drawings, and data from CR walk-throughs will be used to produce a full scale CR mockup. The mockup will be constructed in separate transportable sections. Panel components such as controls and displays will be represented by photographs. The panels to be represented in the mockup will include those listed in the subject RFP. The mockup will be reviewed for accuracy by the NRC project manager and appropriate NRC personnel.

When the mockup is completed, the activity timeline discussed previously will be used to conduct walk-throughs of the activity sequence. Discrepancies between the existing timeline and features of the mockup will be identified and resolved by means of further operator interviews.

When the timeline has been finalized, the operators or mock operators will be video taped as they enact the sequence of events in the timeline. Two general types of taping will be used. Vertical view and/or horizontal view cameras will be used to record between station transits and dwell time at stations.

Over-the-shoulder cameras will be used as required to record activity sequences at stations. The resulting films will constitute the raw data for further analysis. Analysis will include:

- Continuous plots of single opertor transits between and dwells at stations
- Descriptive statistics of time spent in transits, dwells and activities by operators
- Graphic and numerical descriptions of operator position at stations in relation to station features such as controls and displays
- Analysis of operator field-of-view and field-of-reach per station

These results will constitute the description of activity during the 150-minute period.

A nominal or ideal timeline will be developed by Essex nuclear engineering/operational personnel and human engineers, based on:

- Procedures documents
- Training materials
- Inputs from NRC personnel

The ideal timeline will detail ideal operator performance during the 150-minute period. This will be used in comparison with the actual timeline to evaluate actual performance. Performance measures will be defined to quantify:

- Time in operation at stations in ratio to transit time
- Time required for selected activity sequences
- Effective activity time per operator
- Delay time in starting activities
- Distribution of time in activity categories

Performance measures will be calculated for the ideal timeline and from the obtained actual activity data. The two sets of measures will be compared as overall efficiency indicators.

Discrete deviations from the ideal timeline will also be noted, described and categorized—particularly where these are related to the critical actions/inactions previously discussed. Numerical data will thus consist of frequency counts of types of deviations from ideal (in all activity categories) and statistical measures based primarily on time. From past experience on similar efforts, Essex considers that these data will measure speed and accuracy, the two primary characteristics of operator behavior.

The comparative data obtained in the manner described will be reviewed systematically by Essex and NRC. Consideration of both single departures from ideal performance on a case-by-case basis and statistical measures of total performance will serve to establish:

- Activity patterns which precipitated or contributed to major operator inactions (such as excessive transit time, problems in obtaining necessary information)
- Activity patterns which preceded major incorrect actions and which are indicative of the course (such as improper control activation)
- Excessive time to carry out activity sequences relative to nominal performance
- Excessive transit time relative to nominal performance
- Unnecessary or non-productive activity sequences

These cases will be evaluated against the CR design features including station design and total CR configuration design. Cases will be attributed to:

- Station design problem
- CR configuration problem
- Information flow/availability problem
- Other categories as required by the data

or combinations of the above as warranted by:

- The actual and comparative data
- Review of procedures, manuals, etc.
- Accepted human engineering standards and practice with regard to
  - individual workspace design
  - multi-man workspace design
- Failure of operators to follow established procedure
- Information flow based on task requirements
- Visibility and vision envelope
- Anthropometrics and reach/access envelope
- Interactions between operators
- Display/control labeling, marking
- Availability of feedback to operator
- Control discrimination
- Display discrimination
- Task input-output compatibility

- CR environmental factors

These findings together with all raw data and summary data, known data gaps, and recommendations in the areas of human engineering and operator performance will be submitted to the NRC Project Manager. The mockup sections will also be deliverable as directed by the Project Manager.

TASK C
OPERATOR PERFORMANCE

Problem — The accident at TMI-2 evolved from a complex interaction of equipment failures and operator actions/inactions. Although at this point it is impossible to establish the precise contribution operator performance made to the severity of the incident, it is reasonable to assume that the manner in which the operators responded significantly influenced the course and outcome of the accident. Additionally, it can be postulated that at least three major factors influenced the decision-action sequences taken by the operators during the accident:

- Training
- Information transfer
- Policy (e.g., operator selection methods and criteria, definition/assignment of authority and tasks, decision-making responsibilities, etc.)

It is the purpose of this task to identify and analyze the relative contributions of each of the above factors to operator performance during the TMI-2 accident. The specific objectives of this task are presented below.

Objectives

1. Determine the adequacy of the training program to ensure the operators' capability to diagnose problems and take appropriate actions during normal and emergency conditions, emphasizing the requirements which surfaced during the TMI-2 accident
2. Identify the basis for each significant action/inaction resulting from operator performance that cannot be attributed to inadequate training
3. Evaluate the adequacy of information transfer between shifts, and between operators and maintenance personnel at TMI-2.

Approach — The technical approach proposed by Essex to achieve the above objectives involves the conduct of six tasks. The content and rationale of each of these tasks are described below.

Task 1: Identify and Analyze Control Room Operator Training Program — Task 1 will focus on the identification and analysis of the principal elements of the training program(s) received by TMI-2 control room operators prior to the accident. As presently conceived, the effort will focus on three critical facets of the program(s): philosophy, content and structure. Philosophy represents the rationale, whether tacit or stated, which dictates the selection of skills and knowledge to be addressed by the program. Additionally, philosophy determines the allocation of training resources (i.e., time, money and materials) to the various issues selected for inclusion in the program. Content involves the specific information chosen to impart the selected skills and knowledge to the operators. Structure represents the methods and media selected to convey the necessary content.

Each of these areas will be analyzed to determine which of its features are salient to the present investigation. Available documentation will then be reviewed to obtain information regarding the content and rationale of selected features.

Task 2: Identify Critical Operator Decision-Action Sequences During the Accident — Operator performance is best described in terms of decisions and actions. Decisions represent the information and cognitive aspects of operator performance, while actions involve the patterns of responses selected to implement decisions. The majority of critical decision-action sequences performed by the nuclear reactor control room operator are diagnostic in nature, requiring that the operator: collect and organize information from a variety of sources, make a decision regarding plant status, and select an appropriate course of action.

The purpose of this task is to identify specific operator decision-action sequences which had a demonstrable impact on the course and outcome of the accident at TMI-2. This will be accomplished by a thorough review of documentation describing the chronology of events during the accident and, if necessary, interviews with control room operators. The focus of this effort will be directed at organizing the accident scenario into a series of discrete, but meaningful, decision-action sequences. The term "meaningful" is used here to imply logic of structure for the sequences; that is, each sequence will commence at a precise point in time dictated by the onset of a stimulus, and proceed, through the decision process, to the culmination of the operator's response (action). Each of these sequences will be described in sufficient detail to permit the human factors specialist to determine precisely what transpired during the accident. At a minimum, the descriptions will include:

- Actual status of the plant at the time of the sequence (to the extent known)
- Displayed status (e.g., readouts from gauges, dials, other operators, etc.)
- Perceived status (i.e., operators' interpretation of displayed information)

- Decision rationale (i.e., algorithms, table look-ups, anything which influenced the operators' decision regarding plant status)
- Response logic (i.e., rationale for selecting a particular course of action)
- Response method (i.e., procedures selected to implement decision)
- Response verification (i.e., methods used to validate accuracy and adequacy of response)

A listing will be made of all critical decision-action sequences, describing salient characteristics. This list will serve as the basis of subsequent evaluations regarding the adequacy of training and information transfer.

Task 3: Identify and Analyze Training Requirements for Critical Decision-Action Sequences — Each of the critical decision-action sequences identified in Task 2 will be analyzed to determine the information and performance requirements of the operator. Each of these requirements will in turn be analyzed to determine what skills and knowledge were required in order for the operator to have performed in an accurate and expeditious manner. In analyzing skill requirements, the following taxonomy will be employed:

- Motor Skill — Ability to perform mechanical manipulation of tools or controls
- Perceptual Skill — Ability to assimilate information from displays or other indications of system/component status
- Perceptual-Motor Skill — Ability to assimilate information from displays or indiction while simultaneously manipulating controls
- Memory Skill — Capacity to recall procedures, set-points ranges, display readings, etc
- Perceptual-Memory Skill — Capacity to evaluate system status in terms of established ranges of tolerance not presently available
- Diagnostic Skill — Ability to infer location, cause and implication of malfunction from available data sources
- Tactual/Kinesthetic Skill — Ability to perform a function without visual guidance
- Information Retrieval Skill — Ability to locate and utilize available information sources (e.g., emergency procedures, system diagrams and functional descriptions, etc.)
- Organization/Management Skills — Ability to organize and manage information, personnel and equipment to achieve a specified goal
- Verbal Skill — Ability to communicate information and to receive and understand information communicated verbally, or by means of printed text

Knowledge requirements will be analyzed using the following taxonomy:

- System Knowledge — Information pertaining to the functions and interrelationships of the various systems within the plant
- Component Knowledge — Information pertaining to the location, function and operation of the various system components (i.e., controls and displays)
- Operational Knowledge — Information requried to operate controls and interpret display information to ensure safe, efficient plant operation
- Diagnostic Knowledge — Information required to diagnose alarms and interpret trends in control room readouts, including inference of cause(s) and prediction of impact on system performance
- Corrective Knowledge — Information required to conceive, organize and implement a plan of ameliorative action
- Special Knowledge — Specialized information involving: principles of nuclear fission; theory and practice governing the generation and safe handling of nuclear and electrical energy; safe handling of radioactive substances; transmission of steam and liquids at high pressure and temperature, etc.

Each task within each decision-action sequence will be described in terms of its inherent skill and knowledge requirements. These descriptions will then serve as a basis for evaluating the adequacy of the training program.

Task 4: Evaluate Adequacy of Control Room Operators Training Program — The purpose of this task is to compare the skill/knowledge requirements identified in Task 3 to the content and structure of the operator training program (as described in Task 1), in order to evaluate the adequacy of the program for preparing operators to diagnose problems and take appropriate actions during normal and emergency conditions. The effort will focus on the adequacy of the training program in terms of the following:

- Philosophy
  - method of selecting content (e.g., use of task analyses, operational sequence analyses, operator inputs/feedback, etc.)
  - rationale for allocating resources (e.g., task criticality, cost, availability, etc.)
  - frequency with which program is updated
  - methods for incorporating changes in system design, procedures, etc. into program
  - instructor selection methods and criteria
  - trainee performance monitoring, measurement and criteria
  - methods for selecting content presentation techniques
- Content
  - relevance (i.e., applicability to skill and knowledge requirements)

- fidelity (i.e., correlation to actual conditions during normal, degraded and emergency modes of operation)
- comprehensiveness (i.e., degree to which program content encompasses the range and extent of conceivable operating conditions)

- Structure
  - suitability of content presentation techniques (e.g., text, audio-visual, lecture, simulation, etc.)
  - organization of techniques
  - time spent on specific skills and knowledge
  - provisions for feedback to trainees
  - instructors' capabilities
  - adequacy of measures and performance assessment procedures
  - adequacy of course administration

Each of these areas will be evaluated in terms of adequacy for the general requirements of the control rooom operator, and in terms of the specific decision-action sequences of the TMI-2 accident.

Task 5: Identify and Analyze Non-Training Related Actions/Inactions — The purpose of this task is to identify the basis for significant actions/inactions resulting from operator performance that cannot be attributed to inadequate training. With the exception of design problems resulting from failure to comply with human engineering principles and standards (to be addressed in Task D), the majority of non-training related erroneous operator actions/inactions result from inaccurate or ineffective system policy. In general terms, policy may be defined as those characteristics of the system responsible for identifying, organizing and implementing strategies for achieving optimal system performance.

As it relates to the TMI-2 accident, the following issues of policy are relevant:

- Methods and criteria for selecting operators
- Methods for defining and assigning authority and decision-making responsibilities
- Methods for defining and assigning tasks
- Procedures for ensuring safe, efficient plant performance
- Methods for ensuring the quality of operating procedures (both normal and emergency)

Each of the decision-action sequences identified in Task 2 will be analyzed to determine which of their components can be attributed to non-training related factors. Each of these factors will be analyzed and described in terms of its relative contribution to significant operator actions/inactions during the accident.

Task 6: Evaluate the Adequacy of Information Transfer at TMI-2 — The purpose of this task is to evaluate the adequacy of information transfer between shifts, and between operators and maintenance personnel at TMI-2. Information tranfer may be evaluated in terms of four basic properties:

- Dissemination — The effectiveness with which information is distributed between the various personnel active within the system
- Compilation — Provisions within the system for acquiring and storing information
- Computation — Methods available within the system for organizing and reducing information
- Access — Provisions within the system to ensure the timely availability of needed information

Individual messages may be evaluated in terms of the following:

- Relevancy — The precision with which message content is selected to ensure that the data provided are necessary and sufficient for the user's requirements
- Accuracy — The degree to which message content reflects the actual conditions which it describes
- Comprehensiveness — The degree to which message content provides the total of available information (within the constraints of relevancy)
- Organization — The effectiveness of the message's structure for ensuring accurate interpretation of meaning and necessary action to be taken (if any)
- Timeliness — The extent to which the message is provided within the time-frame required for user response

A review will be made of NRC and Met Ed requirements to identify criteria for each of the above information transfer and message characteristics. The criteria will then be applied to the information transfer system at TMI-2 to determine its adequacy. Additionally, information transfer procedures for TMI-2 will be compared to those of comparable plants (i.e., plants identified in Task A). Significant variations in procedures will be noted and described.

TASK D

APPLICATION OF HUMAN FACTORS PRINCIPLES TO CONTROL ROOM DESIGN

Problem — Human factors engineering test and evaluation (HFE T&E) encompasses the techniques, methods, principles and data used to assess the adequacy of a system's design. In general, effective system performance is dependent on the extent to which the system's design incorporates the requirements of its constituent elements. For the human factors engineer, this tenet is expressed in terms of the capabilities and limitations of the human operator as they relate to the operator's functions within the system. By corollary, the crux of effective design, from an HFE perspective, is the translation of operator functions into specific tasks and, subsequently, into quantifiable information and performance requirements. These requirements are then used as standards against which the adequacy of the design of the man-system interface is measured. For the nuclear power plant, the keystone of this interface is the control room. As it relates to the incident at TMI-2, HFE T&E provides the tools for estimating the degree to which the control room's design and established operating procedures precipitated and/or compounded the sequence of events and associated operator actions which led to the accident.

Objectives:

1. Identify systems, components and procedures in the control room which played a critical role during the first 150 minutes of the accident
2. Identify relevant human factors considerations for each system, component and procedure which had a critical relationship to the accident
3. Evaluate degree of compliance of critical systems, components and procedures to applicable human factors principles and standards
4. Assess the impact on operator performance of specific system, component and procedural features which fail to comply with human factors principles and standards
5. Evaluate the integration of the control room design with the reactor system design within the context of the human factors program development
6. Identify and analyze the approaches taken by other organizations to incorporate human factors principles and standards into the design and operation of man-machine systems of comparable complexity, including at least one example of an advanced control room design concept being offered by a U.S. nuclear plant supplier, and compare these approaches to that used in the development of TMI-2.

Approach — The technical approach proposed by Essex is to address each of the above objectives as an individual task. The specific content and rationale of each of these tasks are described below:

Task 1: Identify Critical Systems, Components and Procedures — The focus of this task will be to identify the systems components and procedures which played a critical role in the first 150 minutes of the accident at TMI-2. This will be accomplished by a thorough review and analysis of the critical timeline actions/inactions (critical points) within the control room which had a significant impact on the course and outcome of the accident. Based on this review, a comprehensive enumeration will be made of operator decisions and actions having a discernable relationship to the accident. Each decision-action sequence will be analyzed to determine which control room systems, components and procedures were involved. These elements will be selected as candidates for further evaluation.

Task 2: Identify HFE Considerations — Each system, component and procedure identified as critical to the TMI-2 accident will be evaluated to identify HFE considerations relevant to its design. The types of considerations to be expected for systems and components include, but are not necessarily limited to, the following:

- Location and Arrangement — The positioning of a component as it affects the ability of the operator to reach, operate or manipulate it, including location of openings (accesses), cover or door operation, location of components (knobs, levers, etc.) as well as its relationship to other components.
- Size and Shape — The maximum and/or minimum dimensions of components that are required for adequate man use, including the effects of anthropometric and special clothing considerations, and the shape and contour of handles, knobs and other controls to enhance both the identification and use of the component.
- Direction and Force — The movement and/or force required to operate or generally manipulate a component (handle, control, fastener, etc.) with emphasis on the direction of motion corresponding to the display, component, total item reaction or standard practice as well as the minimum strength required.
- Clearance — The unobstructed space surrounding a component which allows the operator to perform required actions, the adequacy of which varies as a function of the amount of body involved (hand, fingers, arm, torso, etc.) and, where appropriate, will also include considerations such as gloves, boots, protective clothing, etc.
- Visibility — Those aspects of a component that contribute to the operator's ability to see it clearly, including location, size, shape, color, contrast, field of view, viewing distance, reflectance and illumination.
- Use Conditions — Those aspects of a component that pertain to its operational status before, during and after use, as well as the maintenance of an acceptable environment in the workspace areas.

- Safety — Those aspects of a component that could cause injury to the operator or other personnel, including preventative aspects for reduced visibility, accidental contact with electrical, temperature, chemical, radiation and pressurization hazards, and danger to sight and hearing, particularly under the conditions of emergency-induced stress.
- Operating Procedures — Those operational and informational aspects affecting or improving human performance as found in equipment design handbooks as well as job aids, checklists, training tests, troubleshooting guides and repair manuals with specific attention to the safety aspects when using the components.

For each selected system and component, a comprehensive listing will be made of all HFE considerations relevant to its design and operation.

Human factors considerations relevant to procedures include:

- Content Fidelity — The degree to which established procedures reflect the actual operating conditions for which they were intended
- Content Comprehensiveness — The degree to which established procedures encompass the range and extent of conceivable operating conditions.
- Readability — Those aspects of written procedures which influence the operator's ability to interpret their content (e.g., language, structure, logic, etc.)
- Legibility — Those characteristics of written procedures which affect the operator's ability to discern figures and text within the expected environment (e.g., character size, figure-ground contrast, font, etc.).
- Usability — Those characteristics of written procedures which influence the operator's ability to respond in an effective, expeditious manner (e.g., clarity and succintness of content, efficient use of diagrams, etc.).
- Maintainability — Those qualities of a document's design which contribute to the ease by which it may be updated.

Each human factors consideration identified as relevant to the present effort will be reviewed to determine the source(s) of applicable criteria. At present, it is assumed that the majority of the necessary criteria will be contained in MIL-STD-1472B, MIL-H-46855 (DOD) and MSFC-512 (NASA).

Task 3: Evaluate Control Room Compliance — Each selected system, component and procedure will be evaluated to determine the degree to which it complies with accepted human engineering standards. For systems and components, criteria contained in MIL-STD-1472B, MIL-H-46855 , and MSFC-512 will be employed, focusing on the following system/component characteristics:

- Control/display integration
  - position relationships
  - movement relationships
  - control/display ratio
- Visual displays
  - illumination
  - information
  - location and arrangement
  - coding
- Audio displays/warnings
  - signal characteristics in relation to operational conditions and objectives
  - clarity of meaning
- Controls
  - selection (appropriateness)
  - direction of movement
  - arrangement and grouping
  - coding
  - prevention of accidental activation
- Labeling
  - orientation and location
  - content
  - design of characters
- Workspace
  - visual envelope
  - reach envelope
- Environment
  - temperature and ventilation
  - illumination
  - noise
  - vibration

Written procedures will be evaluated using guidelines contained in similar documents (e.g., MIL-M-29355, Technical Manual for the Preparation of Operation and Maintenance Instructions for Operators of Various Types of Equipment). For each system, component and procedure, significant deviations from the stated criteria will be noted and described.

Task 4: Assess the Impact of System/Component/Procedure Noncompliance — In conjunction with the NRC Project Manager, each incident of non-compliance will be analyzed to determine its impact on operator performance as it relates to the decision-action scenario developed in task 1. Each criterion discrepancy will be categorized according to the following rationale:

1. Highly Probable - all available evidence indicates that the subject discrepancy had a significant impact on operator performance during the incident.

2. Probable - all available evidence indicates that the subject discrepancy had a moderate impact on operator performance during the incident.

3. Uncertain - available evidence is inconclusive

4. Improbable - all available evidence indicates that the subject discrepancy had minor, if any, impact on operator performance at the time of the incident.

5. Highly Improbable - all available evidence indicates that the subject discrepancy was unrelated to operator performance.

Task 5: Evaluate Integration of CR Design with Reactor System Design — In conjunction with the NRC Project Director, information obtained in Tasks A, B and C1-4 will be reviewed to determine the methods and rationales employed in ensuring the effective integration of the control room design with the reactor system design. This task will focus on the design/development process within the context of human factors program development. In addition, the process will be evaluated to determine: to what degree operator/maintainer task analyses are used in generating staff selection and training requirements; the adequacy of methods used to develop, test and evaluate operational procedures, particularly emergency procedures; and the effectiveness of License Event Reports feedback. Where existing records are inadequate or ambiguous, attempts will be made to identify and interview personnel responsible for making design decisions. Data collected during this task will be organized into a flow chart depicting the procedural and decision-making process employed in the design and development of the TMI-2 control room. Demonstrable inadequacies in the process will be noted and evaluated.

Task 6: Identify Approaches of Other Organizations — Task 6 will focus on the identification and analysis of approaches taken by other organizations to incorporate HFE principles and standards into the design and operation of man-machine systems similar in complexity to TMI-2. The effort will concentrate on such factors as:

- Development of alternate concepts
- Tradeoff studies
- Selection of optimal concept
- Use of mockups and simulation
- Developmental test and evaluation
- Operational test and evaluation
- Design modification
- Design verification

As presently conceived, the effort will focus on such organizations as DOD (Army, Navy, Air Force), NASA and regulated industries (chemical, steel). In addition, the process employed by at least one U.S. nuclear plant supplier in developing advanced control room design concepts will be analyzed.

Data collected during this task will be organized into a flow chart depicting the procedural and decision-making process employed by each selected organization. These charts will then be compared to the process employed in the design and development of TMI-2. In conjunction with NRC managers, significant variations will be identified and an estimate of their impact on the performance of the operator will be made.

1.3 Major Anticipated Difficulties and Problem Areas

The major problem area to be overcome in the conduct of the proposed effort is the effective utilization of the limited time available. This difficulty will be most evident in the initial data acquisition, where the availability of necessary data is not strictly within Essex control. In order to attentuate the impact of this problem, Essex has organized the technical and management structure of the proposed program to facilitate data acquisition and information transfer within and between the various task teams. This is accomplished primarily through regular interaction between Dr. Malone and the various task team leaders, each of whom will be responsible for organizing and administering the requirements of their respective tasks, and keeping Dr. Malone constantly apprised of progress and potential problem areas. In this manner, Dr. Malone will be in a position to perceive the larger scope of the effort and to ensure the efficient utilization of material and personnel resources, thereby avoiding unnecessary duplication of effort and assuring effective dissemination of information.

Additionally, Essex has, at its own expense, undertaken to acquire several of the principal documents necessary for the conduct of the effort. These documents will expedite the initial phase of the program and provide an additional buffer against the abbreviated time frame.

1.4 Essex Assumptions and Requirements

The technical proposal as described herein is based on the following assumptions and requirements.

- Essex recognizes the requirement for extraordinarily rapid response during this project, and has acquired a number of relevant information sources to expedite initial data collection. Essex assumes, however, that the following information will be made available by NRC at the outset of the contract:
  - NRC Regulatory Guides
  - Preliminary and Final Safety Analysis Reports on TMI-2
  - Lists of Industry Standards for Nuclear Power Plants (ASMG, ANS, etc.) 1967-1979
  - Industry Standards (Text)
  - Control Room Layouts and Panel Drawings
  - Design Studies and Analyses
  - TMI-2 Procedures (Normal and Emergency)
  - Engineering, Design, Development and Testing Information on Control Room
  - TMI-2 CP and OL Safety Evaluation Reports and Documents
  - Preliminary and Final SARs for Same-Vintage Power Plants

- Control Room Layouts and Panel Drawings for Same-Vintage Power Plants
- CP and OL Safety Evaluation Reports and Documents for Same-Vintage Power Plants
- Descriptions of Event Chronologies
- Tapes of Operator Interviews
- Documentation on Operator Training Programs

- Essex anticipates that in some instances existing documentation may be inadequate or ambiguous, in such cases, Essex assumes that NRC will assist in setting up interviews with cognizant personnel.
- Essex assumes that access to TMI-2 will be granted for the purposes of initial familiarization and subsequent data collection (e.g., video-taping, photography, etc.)
- Essex assumes that NRC will assist in setting up interviews with engineers and designers at Burns and Roe, Babcock and Wilcox, and other comparable organizations, as required.

1.5 Adequacy of Proposed Approach

Essex is confident that the approach as proposed herein will provide the technical and managerial efforts necessary to meet or exceed the requirements as set forth in the subject scope of work. Essex also asserts that the caliber of personnel to be assigned to the program are unparalleled in the field, both in terms of experience and expertise, and are willing to make the personal investments of time and energy necessary to achieve the program objectives. Essex sees no need to elaborate on these points, but instead, to let the content of the approach speak for itself.

1.6 Proposal Authors

The following Essex personnel were responsible for the content and organization of this proposal:

Dr. Thomas Malone
Dr. Mark Kirkpatrick
Mr. Jimmie Johnson
Mr. Kenneth Mallory
Mr. David Eike

PART II: QUALIFICATIONS, EXPERTISE AND AVAILABILITY

2.1 Personnel

The Essex Corporation is uniquely qualified to conduct this effort as described in the technical proposal by virtue of the experience and expertise of its staff. Essex was originally founded as a human factors engineering research and development company. In its ten year history Essex has succeeded in becoming one of the largest human factors engineering organizations in the world, employing 52 people in the human factors division of whom 45 are professionals, more than half of whom have advanced degrees. In 1976 Essex added a Systems Engineering Division to the already well established Human Factors Division. The majority of the 50 personnel in the Systems Engineering Division have extensive experience with Naval nuclear submarine systems. Most of the contractual effort conducted by this Division concerns the engineering design of the TRIDENT nuclear submarine. Several current employees of Essex, located at the System Engineering Division's branch office at Harrisburg, Pennsylvania, have served as nuclear power plant operators. **Two of these people have over seven years experience** as **operators (auxiliary and control room) at Three Mile Island. Both were operators during final construction and testing at TMI-2.**

Essex Corporation therefore comprises an organization which contains personnel with the range of skills required to successfully complete the proposed effort. The corporation will make available, on a priority basis, the best personnel on its staff to form an interdisciplinary team of nuclear engineers, former control room operators, and human engineering and training specialists. The Corporation can assure NRC that, with this team, it can complete the proposed effort within the established time and funding constraints. Resumes of personnel who are proposed for assignment to this project are included in Appendix A. Brief overviews of the relevant experience and capability of these personnel, along with indications of the percentage of their time to be devoted to each task, are presented below.

Program Manager — Dr. Thomas B. Malone (100 Percent Available). Dr. Malone has over 16 years of experience as a human factors professional encompassing a wide range of content areas. These include human factors engineering design, test and evaluation, operator performance evaluation, development of human factors requirements standards and specifications, conduct of simulation studies, applications of human factors technology to new systems, and development and assessment of training programs. He is presently Vice President and Technical Director at Essex and is responsible for direction of the Human Factors Division. Dr. Malone has extensive experience in program management serving in a managerial capacity on numerous government-sponsored projects. Dr. Malone will serve as Responsible Officer and Program Manager on this effort. He will not charge NRC for the portion of his time expended in managing the program, about 25 percent, but he will be involved in the conduct of Tasks C and D, which will require 75 percent of his time.

Task A Team Leader — Mr. Kenneth M. Mallory, Jr. (100 Percent Available). Mr. Mallory has extensive experience in the areas of human factors design, safety, development and evaluation of user manuals and procedures, workstation design and human performance evaluation. His 17 years of experience in applied design and analysis will significantly add to the Essex capability. He has directed a number of efforts to apply human factors engineering principles and practices to spacecraft design, weapons systems, hospital systems, information systems, surveillance systems, and transportation systems. Mr. Mallory will spend half of his time directing and participating in this task. The other half will be spent in Task D.

Task B Team Leader — Dr. Mark Kirkpatrick (100 Percent Available). Dr. Kirkpatrick has 12 years of experience in the design and evaluation of control and display systems, information processing systems, computer and mathematical simulation studies, and operator performance reliability measurement in complex weapons systems. As chief scientist for Essex, Dr. Kirkpatrick has been involved in the design and analysis of numerous studies of human performance in complex systems. He will be assigned to Task B for 50 percent of his time with the other half assigned to participation in Task D.

Task C Team Leader — Mr. Jimmie H. Johnson (100 Percent Available). Mr. Johnson has 24 years experience in the application of human factors and training technology to complex weapons systems. Prior to joining Essex in 1978 he served as Head of the Human Factors Engineering Branch at the Naval Air Systems Command. His primary areas of expertise include personnel selection and training. He will be assigned to this task on a full-time basis.

Task D Team Leader — Mr. David R. Eike (100 Percent Available). Mr. Eike is Program Manager for the Essex Human Performance Program. He has considerable experience in the evaluation of complex man-machine systems such as Army missile systems, electronic and communications systems. He has demonstrated on numerous occasions his ability to identify human factors engineering design problems in complex systems in a quick response effort. He will be assigned to this task for 100 percent of his time.

Team Members

Mr. Kenneth A. Moore, Jr., has 14 years experience in the engineering design and development of Naval nuclear systems. He currently directs the Essex TRIDENT program concerned with development of logistics systems and maintenance programs for the TRIDENT submarine. He will be assigned to this proposed effort for 25 percent of his time.

Mr. Douglas Metcalf is presently a senior program manager for the TRIDENT Submarine Acquisition Project Integrated Logistic Support Program, a life cycle performance testing program for all phases of the nuclear submarine. He has served as a qualified nuclear engineering officer in the Navy and is familiar with all aspects of the Navy Nuclear Propulsion Plant. He will be available to this effort for 50 percent of his time.

Mr. Jeffrey S. Kohl has over five years of experience in the design and evaluation of the man-computer interaction in both military and commercial complex systems. He has designed and conducted a number of tests of the human factors aspects of hardware, software, procedures and training material utilizing both live and simulated environments. He will be assigned to this effort full time.

Mr. William T. Brann was employed by Metropolitan Edison for six years and was a qualified control room operator at the Three Mile Island Nuclear Power Plant (TMI-2) as well as an auxiliary operator "A" on TMI-1. He has developed operating procedures and provided training to other employees. Mr. Brann is presently participating in an Essex program to provide maintenance monitoring for TRIDENT at the Essex Harrisburg facility. He will be assigned to this effort 50 percent of his time.

Mr. Robert W. McGough, Jr., received operator training at the Three Mile Island Nuclear Power Plant and is familiar with control room layout and design at this plant. He is presently developing maintenance plans for the TRIDENT program at the Essex Harrisburg facility. He will expend half time on this program.

Mr. Kem Robertson is presently involved with the development of conceptual designs into mockups of space hardware. Mr. Robertson has a wide range of design and fabrication skills which enable him to contribute to all phases of mock-up design. He will expend a quarter of his time on this program.

Mr. Clifford Baker has been involved in establishing the role of human factors engineering in the acquisition of ships and major weapon systems. He will be available to this proposed effort on a full time basis.

2.2 Corporate Experience

During its ten years as a corporate entity, the Essex Corporation has been almost exclusively involved in human factors engineering research, analysis, design, and test and evaluation. This involvement has included both development and validation of new methodologies as well as the application of available technology. The experience developed over these years, as relevant to this proposal, can be described in three general areas: identification and analysis of human factors requirements; human engineering design and evaluation; and conduct of task order contracts.

Human Factors Engineering Technology for Ships. Naval Sea Systems Command Contract N00024-76-C-6129, 1975-78. The Human Factors Engineering Technology for Ships study presently being performed by Essex Corporation, is a project directed at the technological assessment and integration of human factors techniques, methods and data into the Ship Planning and Acquisition Process (SP&AP). The first approach to HFEI was completed in 1975. It resulted in a definition of the SP&AP and in the definition of human factors techniques germane to that process.

The second phase of the program was designed to specify the timing and type of impact that human factors engineering has on the SP&AP. The second phase resulted in the accumulation of HFE source materials and the development of an assessment technique to evaluate the data base required for the successful implementation of HFE technologies.

A standard HFE design process has been developed and an assessment has been completed of available HFE techniques, methods, principles and data which apply to the process. The kinds of analysis techniques incorporated into the design process include the following:

1. Functional Flow Block Diagrams (including information flow and processing analysis)
2. Operational Sequence Diagrams
3. Systems Analysis and Integration Models
4. Function Allocation Methods
5. Successive Validation Techniques
6. Trade-off Studies
7. Design Requirements Determination
8. Detailed Task Descriptions
9. Task Analysis and Loading Analysis
10. Time Line Sheet Development
11. Models for Computer Simulation
12. Multiple Process Charts
13. Training Analysis Techniques
14. Breadboard, Brassboard and Mock-up Construction and Use
15. Human Factor Checklists
16. Operator Error Analysis (e.g., critical incident techniques)
17. Human Reliability Analysis

The present (third) phase of the HFEI project is directed toward the determination and evaluation of selected HFE techniques applied in operational environments. Requirements analysis, operational sequence diagrams, and task/operator loading analyses, among others, have been applied to aircraft carrier subsystems such as the arresting gear subsystems and Pri-Fly under operational conditions. The objective of the third phase is the development of HFE techniques which can be used to efficiently specify optimal design for task and operator requirements in future systems.

HFE Technology Applied to Major Navy Weapon Systems. Naval Air Development Center, Contract N00024-76-C-6129, 1977-78. This effort, which is a task under the HFE Technology for Ships program, has as its objective the survey and assessment of HFE technologies as they apply to major weapon systems acquisition. Products of this task, currently nearing completion, include: (1) a description of the weapon system acquisition process, including major activities and milestones; (2) descriptions of the applicability of HFE technologies to specific requirements within the acquisition process; and (3) identification of technology shortfalls.

HFE Technology Applied to the Beartrap Recovery Assist, Secure and Traverse System. Naval Sea Systems Command and Naval Air Engineering Center, Contract N00024-76-C-6129, 1977-78. This effort, which is also a task under the HFE Technology for Ships program, is concerned with applying HFE technologies to the redesign of the Beartrap Landing Safety Officer (LSO) console. The initial segment of this effort entailed the identification and analyses of LSO function and tasks, the description of operational conditions, the allocation of functions, and the development of operational sequence diagrams.

HFE Technology Applied to Carrier Arresting Gear Systems: Naval Sea Systems Command and Naval Ocean Systems Center, Contract N00024-76-C-6129, 1977-78. This task of the HFE Technology for Ships program is concerned with applying HFE methods, techniques, priniciples and data to the design of the seven operator stations of the Mark-14 arresting gear system, and to the redesign of two stations for the current Mark-7 system. The early portion of these efforts involved a complete application of the HFE analysis process described in the technical approach section (2.0) of this proposal.

HFE Inputs to F-18 Avionics. SCI Systems Inc., Huntsville, Alabama, Purchase Order A 38821. A crew task analysis for F-18 pilot operations was prepared for the Navy for flight activities associated with the Intercommunications Set (ICS). The ICS panel includes controls and displays for IFF equipment, the Instrument Landing System (ILS), Mode 4 equipment, audio controls for detecting presence of surface-to-air missiles and electronic countermeasures, as well as secure and plain voice communications. Pilot operations were defined combat and return. Information identified for each crew subtask includes criticality, automated or manual operations, time required, skills and knowledge required, and special human engineering considerations.

Plan for HFE Input to the CV-TSC Software Specification. Naval Air Development Center, December 1977 under the Essex HFE Technology for Ships program. Identified CV-TSC system functions and system software requirements. Analyzed HFE requirements for software specification, including: I/O; controls and displays; information requirements; decision requirements; diagnostics: information processing, retrieval, update and entry requirements; and man-computer interface requirements.

Shuttle Crew Requirements for Spacecraft Retrieval and Servicing. Marshall Space Flight Center, Contract NAS8-31946, 1975-77. This program entailed determining requirements for astronaut extravehicular activity in support of satellite retrieval and servicing operations. Complete mission, system, functional and requirements analyses were performed to identify tasks, operational constraints, environments, and support systems.

HFE Design of F-18 Avionics Panel. SCI Systems Inc. Purchase Order A 38821, 1976-77. Essex has performed various human engineering analyses and design efforts related to avionics C/D panels under contract to SCI of Huntsville, Alabama. Essex personnel were employed as consultants by SCI during preparation of the SCI IACS proposal. In the course of this effort, Essex contributed to or was responsible for the following:

- Development of the HFE plan
- Identification of the required HFE development tests
- Panel layouts for a semi-dedicated C/D concept and a multi-function concept
- Software requirements including CRT page content, page layout, page transition control, character type and size, C/D compatibility
- CRT tube selection
- Control selection
- Compliance of design with applicable HF standards such as MIL-STD-1472B

During the SCI effort to develop the F-18 Intercommunications Set (ICS) Essex was under subcontract to SCI for the HFE portion of the design effort. Essex contribution included:

- Preparation of Human Engineering Program Plan
- Task analysis and preparation of Task Analysis Report in compliance with UDI-H-21358 and MIL-H-46855A
- Analysis of maintenance functions and preparation of the Human Engineering Maintenance/Accessibility Report in compliance with DI-H-2108
- Participation in design reviews

HFE Design of RPV Control Console. Rockwell International, Contract H221-ST-705104, 1973-74. In the design of a conceptual RPV C/D panel for the U.S. Air Force, Essex personnel were employed as consultants with the responsibility for HFE efforts including:

- Function allocation
- Analysis of workload and manning requirements

- Analysis of information flow between crew members
- Console design layout

<u>Teleoperator Man-Machine Interface Design</u>. NASA Headquaters (Contract NASW-2418, 1971; Contract NASW-2220, 1972); NASA George C. Marshall Space Flight Center (Contract NAS8-28298, 1971-1973; NAS8-30545, 1973; NAS8-31848, 1974-1978). NASA is currently analyzing and designing teleoperator systems for remotely controlled rendezvous, docking, repair, and retrieval of low earth orbit satellites. Since 1971, Essex has been involved in development of requirements, conceptual design, and laboratory testing of the teleoperator man-machine interface. This effort has included human factors engineering work on the following teleoperator vehicle subsystems:

- Remote video
- Mobility
- Manipulator
- Control

In the area of the remote video system, Essex has performed laboratory studies using the Teleoperator Visual System Laboratory at the George C. Marshall Space Flight Center to develop an empirical data base on human performance in using video feedback to perform judgment, estimation, and decision tasks necessary for teleoperator missions. Specific test efforts applied to conceptual designs in this area include:

- Determination of target detection, recognition, and localization performance as a function of video parameters such as:
  - displayed image size
  - target/background contrast
  - signal-to-noise ratio
  - horizontal resolution
  - frame rate
  - video format - analog or digital
- Determination of range and range rate estimation accuracy using both monoptic and stereoptic television
- Determination of manipulator tip placement accuracy using both monoptic and stereoptic television and variable placement monoptic television
- Development of a computer program to predict resolution of X, Y, and Z location via stereoptic television (The program uses the parameters of the stereoptic television and stereo system, such as camera baseline and convergence angle, and extrapolates laboratory data to predict the resolution capability of the observer when using the system; it is currently being used to evaluate stereo field coverage and resolution capabilities and requirements for teleoperator flight experiments to be flown on the Space Shuttle.)

- Determination of recommended monitor size for the Space Shuttle aft cabin control stations (This study was performed to assess viewing requirements of expected Shuttle missions and to trade image characteristics against monitor size/volume.)

In the area of mobility systems, Essex has performed tests of trajectory control and docking accuracy in remotely controlled rendezvous using spacecraft simulators at the Marshall Space Flight Center. In these studies, Essex personnel have planned tests, derived dependent measures, installed and checked out laboratory equipment, collected data, and analyzed data. At present, Essex is conducting tests of effects of alternate thruster firing modes on propellant consumption during remote rendezvous and docking under control of a human operator.

In the area of manipulator system technology, Essex has conducted tests of manipulator placement accuracy and small object removal/replacement in the Manipulator Laboratory at Marshall Space Flight Center. Specific efforts in this area have included:

- Tests of performance of different manipulator configurations varying in joint design and number of degrees of freedom
- Evaluation of effects of different controller configurations and modifications to existing controllers on operator performance in remote control of manipulators
- Evaluation of effects of camera placement on performance in remote control of manipulators
- Design, fabrication and installation of manipulator test hardware

In the area of control systems, Essex has developed manipulator control computer programs which accept digitized controller inputs, transform these according to selected control laws, and output appropriate joint angle commands.

Extravehicular Activity Requirements Analysis and Crew Systems Design. NASA Johnson Space Center, Contract NAS9-13710, 1973; NASA George C. Marshall Space Flight Center, Contract NAS8-31454, 1975-1977. Extravehicular activity (EVA) is currently envisioned by NASA as both a primary and back-up mode for accomplishing a range of Shuttle missions requiring experiment deployment, operation and stowage. Essex has been under contract to the Marshall Space Flight Center to perform requirements analysis, task analysis and evaluation of EVA hardware concepts from the crew systems standpoint. Specific efforts performed in this area include:

- Examination of planned Shuttle flights to identify potential EVA tasks
- Task analysis of potential EVA procedures to identify subtask allocation to crew members, subtask sequences, support equipment and timeliness
- Identification of key EVA tasks which serve as examples of all tasks identified
- Design and fabrication of submersible payload mock-ups to permit evaluation of task performance using the Marshall Space Flight Center Neutral Buoyancy Facility
- Preparation of a Shuttle user's document designed to aid in selection from among the available modes for operations, maintenance and repair including:
  - Shuttle attached remote manipulator
  - Free-flying teleoperator
  - Automated servicer
  - Baseline EVA
  - EVA plus manned maneuvering unit
- Preparation of Shuttle user's document giving guidelines for pay-load design to permit servicing by an EVA crewman

Control Station Design for Space Tug. NASA George C. Marshall Space Flight Center, Contract NAS8-31836, 1976-1977. The Tug is a remotely controlled launch vehicle designed by NASA to perform transfer of payloads from the low earth orbits attainable by the Shuttle Orbiter to high earth orbits including geosynchronous. The Tug will be launched from the Shuttle and will transfer to high earth orbit under remote control from the ground.

Essex has performed analyses of the up- and down-link commands and responses necessary to control the Tug, has developed C/D panel layouts to accommodate this information, and has prepared test plans and control law concepts for Tug simulation studies.

HFE Technology for Beartrap Helicopter Hauldown. HFE Technology for Ships, Naval Sea Systems Command. This task entailed the application of HFE technology to the redesign of the LSO console of the Beartrap RAST. The design efforts were applied to the following:

- Station location on deck
- Console arrangement on deck
- Console placement with respect to LSO's visual field
- Station manning

- Station environment
- Station workspace
- Lighting
- Panel maintenance
- Communications
- Panel design
  - evaluation of existing panel
  - development of panel design requirements and guidelines
  - development of alternate design concepts
  - trade-offs between alternate designs and current design
  - selection of improved panel design

HFE Technology Applied to Carrier Arresting Gear Systems. HFE design and evaluation methods were applied to the Deck Edge and Pri-Fly stations of the Mark-7 arresting gear system currently on Naval aircraft carriers. The Essex HFE Design Process was also applied to the design of the seven stations of the Mark-14 arresting gear system being designed for the CVV. These stations include: Deck Edge, Pri-Fly, Central Monitor, Arresting Gear Officer and three Engine Room stations.

HFE Technology for Test and Evaluation (T&E). Foremost among the HFE T&E efforts conducted by Essex are the HEDGE (Human Engineering Data Guide for Evaluation) developed by Essex for the U.S. Army TECOM in 1974 (and updated in 1977) and the HFTEMAN (Human Factors Engineering Test and Evaluation Manual) prepared for the Navy Pacific Missile Test Center in 1976. The 1977 version of HEDGE is an official Army T&E document representing a consolidation of twelve Test Operating Procedures (TOPs) and MIL-STD-1472B. Both HEDGE and HFTEMAN are unique in their innovative approach to the organization of the T&E effort, emphasizing the development of a T&E strategy that is specific to the equipment undergoing evaluation. The techniques provide guidance to the test planner concerning: what to test; what criteria or standards to apply; and how to conduct HFE tests and evaluations. Both techniques approach test requirements in terms of equipment user requirements, such as what he must do with the item, under what conditions, to what accuracy, for what duration and frequency, etc.

Summary of Recent Essex HFE Programs

Personnel Affordability: State-of-the-Art

- Customer - Army Research Institute
- Contract - MDA903-79-M-3975

- Term - June-July 1979
- Cost - $10,000
- Scope - Report on the state-of-the-art in personnel affordability. Identify gaps and research needs
- Product - Report as per scope
- Program Manager - C. Alan Boneau
- Staff
  - 1 Senior Scientist

Human Engineering Design Criteria for Modern Control/Display Components and Standard Parts

- Customer - U.S. Army Missile R&D Command
- Contract - DAAK40-79-C-0144
- Term - May 1979-May 1980
- Cost - $88,600
- Scope - Update and revise MIL-STD-1472B
- Product - Updated and modified sections of MIL-STD-1472
- Program Manager - Mr. David Eike
- Staff
  - 3 research scientist
  - 1 research associate

Human Factors Engineering Studies for Missile Programs

- Customer - U.S. Army, White Sands Missile Range (William Fry)
- Contract - DAAD07-79-C-0063
- Term - April 1979-April 1980 (with 2 1-year options)
- Cost - $230,000
- Scope - Perform Human Factors Test and Evaluation for Army Missile System
- Product - Test plans and test reports
- Program Manager - Mr. David Eike
- Staff
  - 3 research scientists
  - 1 research associate

Human Factors Engineering Studies for Tactical Systems at Fort Huachuca

- Customer - U.S. Army Electronic Proving Grounds
- Contract - DAEA18-79-C-0029
- Terms - February 1979-February 1980
- Cost - $77,385
- Scope - Perform Human Factors Test and Evaluation on electronic and communications system
- Product - Test plans and test reports
- Program Manager - Mr. David Eike
- Staff
  - 1 research scientist
  - 1 research associate

HFE Support: Crew Requirements/Crew Station Design

- Customer - Naval Air Development Center
- Contract - N62269-79-C-0233
- Terms - February 1979-February 1980 (2 1-year options)
- Cost - $400,000
- Scope - A task order contract to enhance system performance in present and future air systems
- Product - Dependent upon particular task order
- Program Manager - Mr. J. Johnson
- Staff
  - 3 senior engineers

HFE Technology Applied to Beartrap

- Customer - U.S. Naval Sea Systems Command; Naval Air Engineering Center; Air 537 (Ships Configuration Branch); PMA 266 (LAMPS)
- Contract - N00024-76-C-6129
- Term - July 1977-June 1978
- Cost - $100,000
- Scope - Apply HFE techniques, methods, principles and data to the design of the LSO station of the Beartrap Recovery Assist, Secure and Traverse system
- Product - A report describing the design of the LSO console
- Program Manager - Dr. Thomas B. Malone
- Staff

- 1 senior scientist (Dr. Mark Kirkpatrick)
- 1 research scientist (Mr. David Eike)

HFE Technology Applied to Carrier Arresting Gear Systems

- Customer - Naval Sea Systems Command; Naval Air Engineering Center; Naval Ocean Systems Center
- Contract - N00024-76-C-6129
- Term - January 1977-September 1978
- Cost - $140,000
- Scope - Apply HFE technology to the redesign of the Mark-7 and to the design of the CVV Mark-14 arresting gear systems
- Product - Station designs and mock-ups delivered to NAEC
- Program Manager - Mr. Clifford Baker
- Staff
  - 1 senior scientist (Dr. James McGuinness)
  - 1 research scientist (Mr. Jeffrey Kohl)

HFE Technology Applied to Major Weapon Systems Acquisition

- Customer - Naval Air Development Center
- Contract - N00024-76-C-6129
- Term - January-October 1978
- Cost - $35,000
- Scope - Identify HFE requirements within the acquisition process; assess HFE technology for these requirements; identify technology shortfalls
- Product - A report describing the acquisition process, HFE technologies as they apply to the process, and requirements for advanced technology
- Program Manager - Dr. Thomas B. Malone
- Staff - 1 research associate

Human Factors Test and Evaluation of the Improved Hawk

- Customer - U.S. Army White Sands Missile Range, Mr. William Frye, Head of RAM T&E
- Contract - DAAD07-77-R-0059
- Term - May-August 1977
- Cost - $18,000
- Scope - Plan and conduct an HFE test and evaluation of the Improved Hawk command and control, communications, information processing, human performance reliability, and environmental effects

- Product - Results of a human factors test and evaluation of the Improved Hawk Air Defense Missile System
- Program Manager - Dr. Thomas B. Malone
- Staff
  - 2 research scientists (Mr. Jeffrey Kohl and Mr. Nicholas Shields)
  - 1 research assistant (Mr. David Eike)

Update of HEDGE and Production of Test Operating Procedure

- Customer - U.S. Army Test and Evaluation Command, Mr. James Perkins
- Contract - DAAD05-76-C-0787
- Term - September 1976-December 1977
- Cost - $60,000
- Scope - Update the Army HEDGE and produce a standard Test Operating Procedure (TOP) to apply to all HFE T&E conducted within TECOM (TOP 1-2-610)
- Product - HEDGE and TOP
- Program Manager - Dr. Thomas B. Malone
- Staff
  - 2 research scientists
  - 1 graphic artist
  - 1 electronic typewriter operator
  - 1 technical editor

Preparation of a HEDGE and TOP for Cold Regions T&E

- Customer - U.S. Army Test and Evaluation Command, Mr. James Perkins
- Contract - DAAD05-77-C-0724
- Term - January 1977-January 1978
- Cost - $40,000
- Scope - Develop a HEDGE and TOP specifically for Cold Regions testing at Ft. Greely, Alaska
- Product - Cold Regions HEDGE and TOP
- Program Manager - Dr. Thomas B. Malone
- Staff
  - 1 research scientist
  - 1 graphic artist
  - 1 electronic typewriter operator
  - 1 technical editor

Development of the Army HEDGE

- Customer - U.S. Army Test and Evaluation Command
- Contract - DAAD05-73-C-0388
- Term - September 1973-August 1974
- Cost - $45,000
- Scope - Develop guidance documents on what to test and how to plan and conduct HFE tests, for Army test planners who are not familiar with human factors
- Product - HEDGE and Guidebook Supplement
- Program Manager - Dr. Thomas B. Malone
- Staff
  - 1 research scientist
  - 1 graphic artist

Human Factors Test and Evaluation of the M60A-2 Tank

- Customer - U.S. Army Institute for the Behavioral Sciences, Ft. Hood Field Unit
- Contract - DAAG08-73-C-0207
- Term - July 1974-June 1975
- Cost - $80,000
- Scope - Plan and conduct an HFE test and evaluation of the M60A2 tank system, including design for operability, design for maintainability, design for habitability and training
- Product - Results of HFE T&E
- Program Manager - Dr. Thomas B. Malone
- Staff - 2 research scientists

Development of HFTEMAN

- Customer - PMTC, LCDR Moroney
- Contract - N00123-75-C-1364
- Term - November 1975-September 1976
- Cost - $68,000
- Scope - Development of a set of guidelines on what to test and how to test for Navy HFE DT and OT applications
- Products - Specifically formatted three-volume set of documents —course of instruction for Navy and Marine Corps DT and OT personnel
- Program Manager - Dr. Thomas B. Malone
- Staff - Mr. Sheldon Shenk, Ms. Kathleen Sperry, Dr. Mark Kirkpatrick

Development of Methods to Evaluate Man-Machine Interfaces

- Customer - NASA Headquarters, Dr. Stanley Deutsch
- Contract - NASW-2747
- Term - June 1974-March 1975
- Cost - $25,000
- Scope - Develop and validate methods to evaluate the man-machine interface of space shuttle control consoles - based on the Army HEDGE approach
- Product - Report on evaluation methods
- Program Manager - Dr. Thomas B. Malone
- Staff - 1 research scientist

Test and Evaluation of Remotely Controlled Spacecraft Man-Machine Interfaces

- Customer - NASA Marshall Space Flight Center, Mr. W. Thornton, Mr. E. Guerin
- Contracts - NASW-2220, NAS8-28298, NAS8-30545, NAS8-31848
- Term - March 1971-Present
- Cost - $800,000
- Scope - Plan and conduct experiments and evaluations to assess the human factors considerations of design concepts proposed for the control of the space shuttle free flying teleoperator system
- Product - Annual research reports
- Program Manager - Dr. Thomas B. Malone/Dr. Mark Kirkpatrick
- Staff
  - 4 research scientists
  - 4 research associates
  - 1 research support person

Development of Orientation Film for HFTEMAN

- Customer - PMTC, LCDR Moroney
- Contract - N00123-77-C-1044
- Term - April-June 1977
- Cost - $8,000
- Scope - Develop an orientation/instruction film on HFTEMAN, for users of the volumes who are not familiar with HFE
- Product - A film, produced in close coordination with the Navy Photographic Center, Anacostia, Maryland
- Program Manager - Mr. Sheldon Shenk

- Staff - Ms. Kathleen Sperry, Dr. Thomas Malone

Task Orders - Human Factors and Training Research for DARPA

- Customer - DARPA Cybernetics Technology Office. Dr. Robert Young
- Contracts - 1975-1977/MDA 903-75-C-0227; 1978/MDA 903-77-C-0355
- Term - 1975-Present
- Cost - 1975-77/$396,882; 1978/$385,000; 1979/$305,000
- Scope - Conduct special studies for CTO on a task order basis (To date, a total of 70 task orders have been processed, including evaluation of map display concepts, assessment of job performance aid technology, and development of measures of combat effectiveness/readiness.)
- Product - Task reports
- Program Manager - Ms. Barbara McKeithan, Dr. Thomas B. Malone
- Staff
  - 1 research scientist
  - 1 research associate
  - Consultants as required

Task Orders - Trident Submarine Integrated Logistics

- Customer - Navy Ship Parts Control Center, Mechanicsburg, PA
- Contract - N00104-76-A-0403
- Term - September 1976-Present
- Cost - $850,000
- Scope - Conduct studies and analyses to develop software systems concepts and criteria for integrated logistics and maintenance of the Trident submarine (To date, 50 task orders have been processed.)
- Product - Task reports
- Program Manager - Mr. Irving Birnbaum
- Staff - 30 technical and support personnel located at Camp Hill, PA, and Alexandria, VA

Task Order - Motor Vehicle Testing

- Customer - Department of Transportation, National Highway Traffic Safety Administration, Dr. P. R. Knaff
- Contract - DOT-HS-120-3-544
- Term - 1972-1975
- Cost - Up to $20,000 per task for 16 tasks

- Scope - Conduct of 16 task orders for inspection, testing and evaluation of motor vehicle equipment
- Product - Task reports
- Program Manager - Mr. B. Livingston
- Staff
  - 1 research scientist
  - 2 technicians

Application of Instructional Technology to Maintenance Training

- Customer - Navy Training Equipment Center, Dr. Knox Miller
- Contracts - N61339-74-C-0151, N61339-75-C-0097, N61339-76-C-0015, N61339-76-C-0128
- Term - July 1974-Present
- Cost - $1.2 Million
- Scope - Survey instructional technologies and develop a training system concept for non-electronic maintenance training; apply the concept to two training courses (Automatic Boiler Control and Woodward Governor Maintenance); and develop course hardware and software
- Product - Maintenance training systems, including media, materials, software, and courseware, for two maintenance training courses
- Program Managers - July 1974-December 1976, Dr. Thomas B. Malone; January 1977-Present, Dr. Robert G. Kinkade
- Staff
  - 7 courseware developers
  - 2 support persons

Human Factors Criteria for Vehicle Controls and Displays

- Customer - Department of Transportation, National Highway Traffic Safety Administration
- Contract - DOT-HS-120-1-174
- Term - September 1971-September 1972
- Cost - $80,000
- Scope - Development and evaluation of criteria for the standardization of control and display location, coding and operation in passenger cars, trucks and buses
- Product - Reports on analytic and experimental studies of control/display design, development, test and evaluation
- Program Manager - Dr. Thomas B. Malone
- Staff - 3 research scientists

PART III. PROGRAM MANAGEMENT

3.1 Program Management Office Structure

The proposed structure of the Essex program management office is depicted in Figure 1. As indicated in this figure, Essex proposes to establish a structure directed toward the simultaneous completion of all four tasks (A, B, C and D). The rationale for this approach is based on these facts:

1. Essex, with its cadre of human engineering professionals and nuclear engineering specialists, is fully capable of performing all activities described in the statement of work prepared by NRC within the required two-month period.
2. Essex management is committed to this effort to the extent of relieving key Essex personnel from other duties to ensure their availability to the NRC program.
3. Given the magnitude of the scope of the effort, and the tight timeframe, it will definitely be more cost-effective for NRC to consolidate the tasks into a single contract rather than to deal with different contractors on individual tasks.

The first two of these facts are evident from an assessment of the capabilities, experience and expertise of Essex and of Essex personnel, and in the assurances made to NRC in this proposal that Essex will in fact provide the proposed personnel for the stated portion of their time. The cost effectiveness of a single contract needs elaboration. That the dollar cost would be less with a single contractor as opposed to multiple contractors follows from the fact that the different tasks would be treated in an integrated manner with a single contractor.

The effectiveness of the single contractor approach results from a number of factors, including:

- Integration of activities across tasks, thereby avoiding repetitious effort in a tight time span
- Integration of information across tasks such that relationships between problems identified in different tasks can be more readily understood.
- Integration of people across tasks to enhance the generation of insights into problems in one task based on inputs developed in other tasks.
- Flexibility of resource allocation in situations where the task plans must be modified in real time.

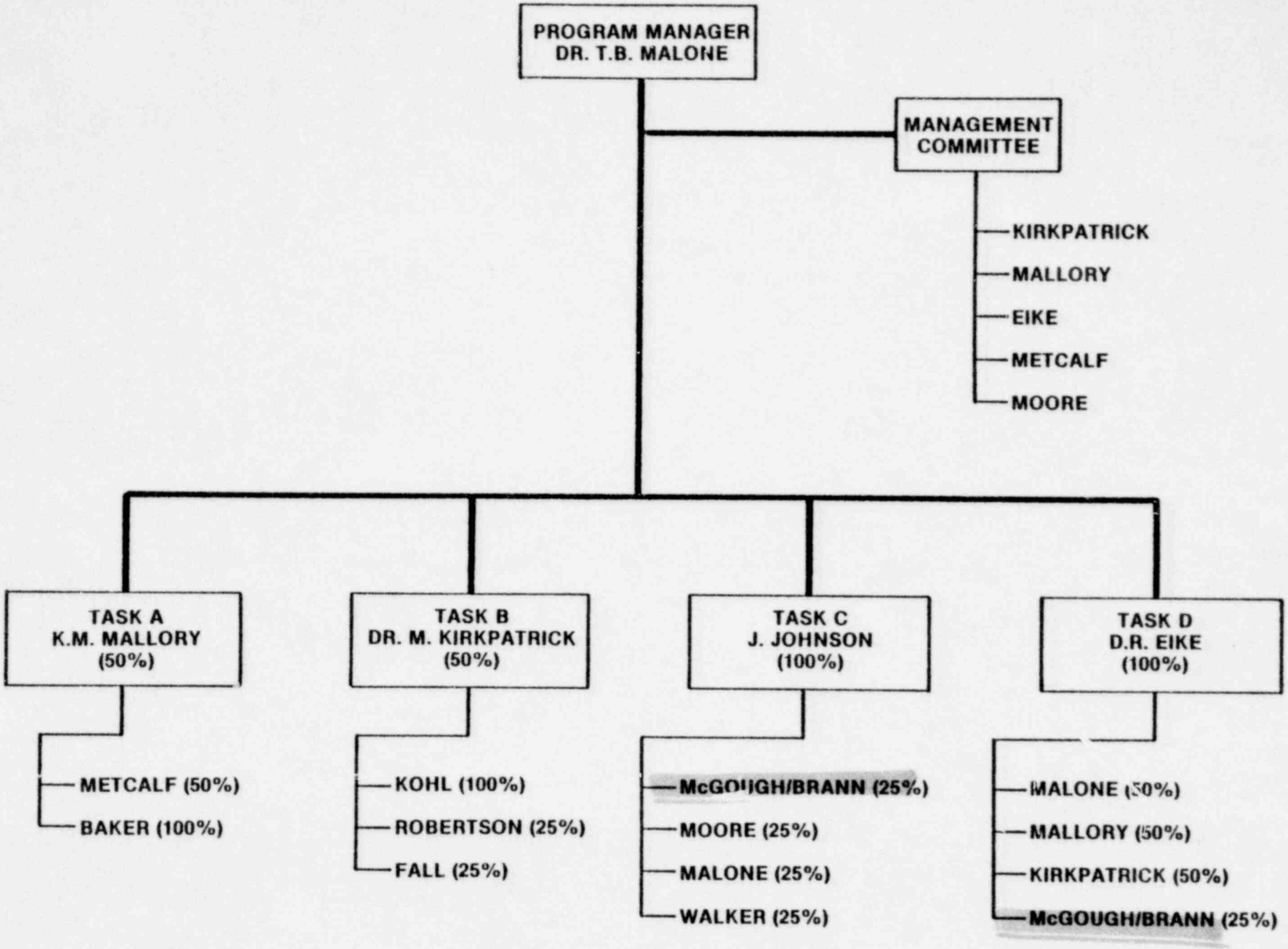

FIGURE 1 MANAGEMENT STRUCTURE

- Responsiveness to unforeseen problems and difficulties by increasing or enhancing the personnel allocation to individual tasks.
- Reduced number of interfaces and newly established working relationships.
- Integration of the effort to develop task products.

3.2 Program Management Responsibilities

As indicated in Figure 1, the responsibility for the management of the total effort within Essex will be vested in a single individual, Dr. Thomas B. Malone. Each of the tasks will be managed by a task leader. The program manager will be supported by a management committee made up of the three task leaders and three Essex nuclear engineering specialists, two of whom have experience as operators in industrial nuclear plants, specifically at Three Mile Island. The function of the committee is to assist the program manager in the integration of efforts across tasks, identification of problems within tasks, assess reallocation of resources to correct task problems and integration of insights and outputs.

3.3 Management Controls

In the course of its ten-year history, Essex has processed over 120 separate contracts without a cost overrun. This is due, to a significant extent, to Essex' philosophy of "active management." Briefly, this philosophy involves the active participation of management-level personnel in all phases of the technical effort. From concept initiation, through development and implementation, Essex managers are involved in all major policy-making decisions. This ensures that the direction and extent of the subject technical effort will be maintained within the scope of available funds and personnel resources.

As it applies to the present effort, Essex' active management philosophy has been instrumental in the content and organization of the technical approach as proposed herein. Essex managers, working in close association with technical personnel, have carefully designed the proposed program to be completed within the cost and time restrictions described in other sections of this proposal. Essex forsees no difficulty in completing the technical effort as proposed, and guarantees the preclusion of a contract cost growth.

3.4 Schedule and Milestones

The schedule, in terms of milestones, is presented below: *

Event	Applicable Task(s)	Due Date
Complete regulations review	A	August 10
Complete mockup design	B	August 10
Complete analysis of training program	C	August 10
Identify decision-action sequences	C	August 10
Identify control panel systems and components	D	August 10
Standards review complete	A	August 17
Review of design bases and operating logic complete	A	August 17
Timeline design review complete	B	August 17
Mockup review	B	August 17
Training requirements identified	C	August 17
Human Factors design considerations identified	D	August 17
Review HF aspects of TMI-2 CR	A	August 24
Complete evaluation of standards applications to CR design	A	August 31
Complete review of H.E. principles applied to as-built CR	A	August 31
Visit to TMI-2	A/B/C/D	August 31
Filming of CR activity completed	B	August 31
Select same-vintage sites	A	Sept. 4

* This schedule assumes a contract start-date of 1 August 1979.

Event	Applicable Task(s)	Due Date
Complete evaluation of component compliance	D	Sept. 5
CR Design Evaluation	A	Sept. 6
Evaluate same-vintage plant design processes	A	Sept. 14
Complete evaluation of training requirements	C	Sept. 14
Analyze non-training actions/inactions	C	Sept. 14
Assess impact of component non-compliance	D	Sept. 14
Evaluate integration of CR	D	Sept. 14
Other approaches identified	D	Sept. 14
Complete review of philosophies	A	Sept. 17
Visit control rooms of same-vintage plants	A	Sept. 17
CR information evaluation complete	A	Sept. 28
Comparison of TMI/Vintage plant design processes complete	A	Sept. 28
Preliminary Report	A/B/C/D	Sept. 28
Final Report	A/B/C/D	Oct. 10

The schedules and milestones for each of the four tasks are presented in tables 2, 3, 4 and 5.

TASK A - CONTROL ROOM DESIGN AT TMI-2

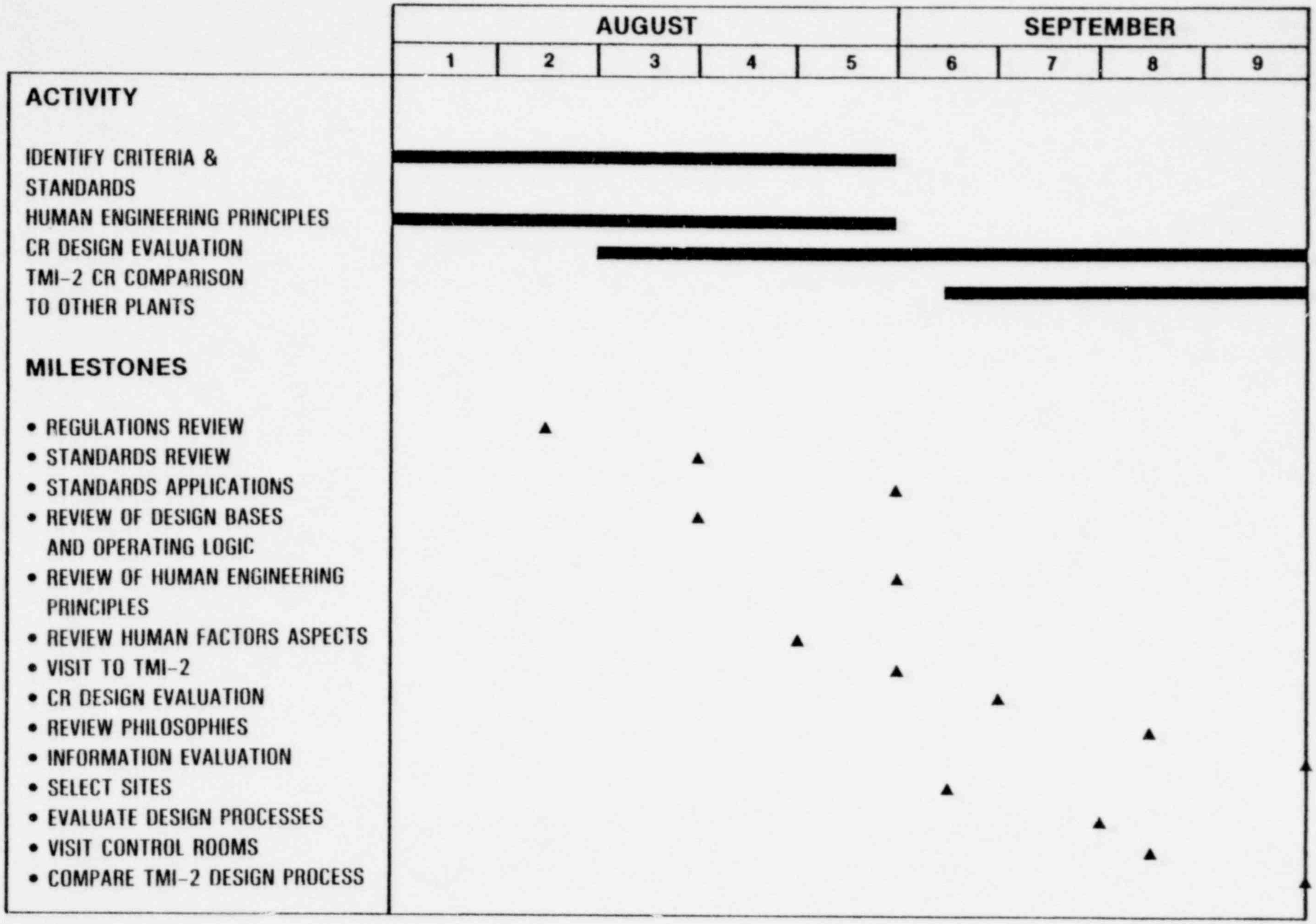

FIGURE 2

TASK B - CONTROL ROOM ACTIVITY

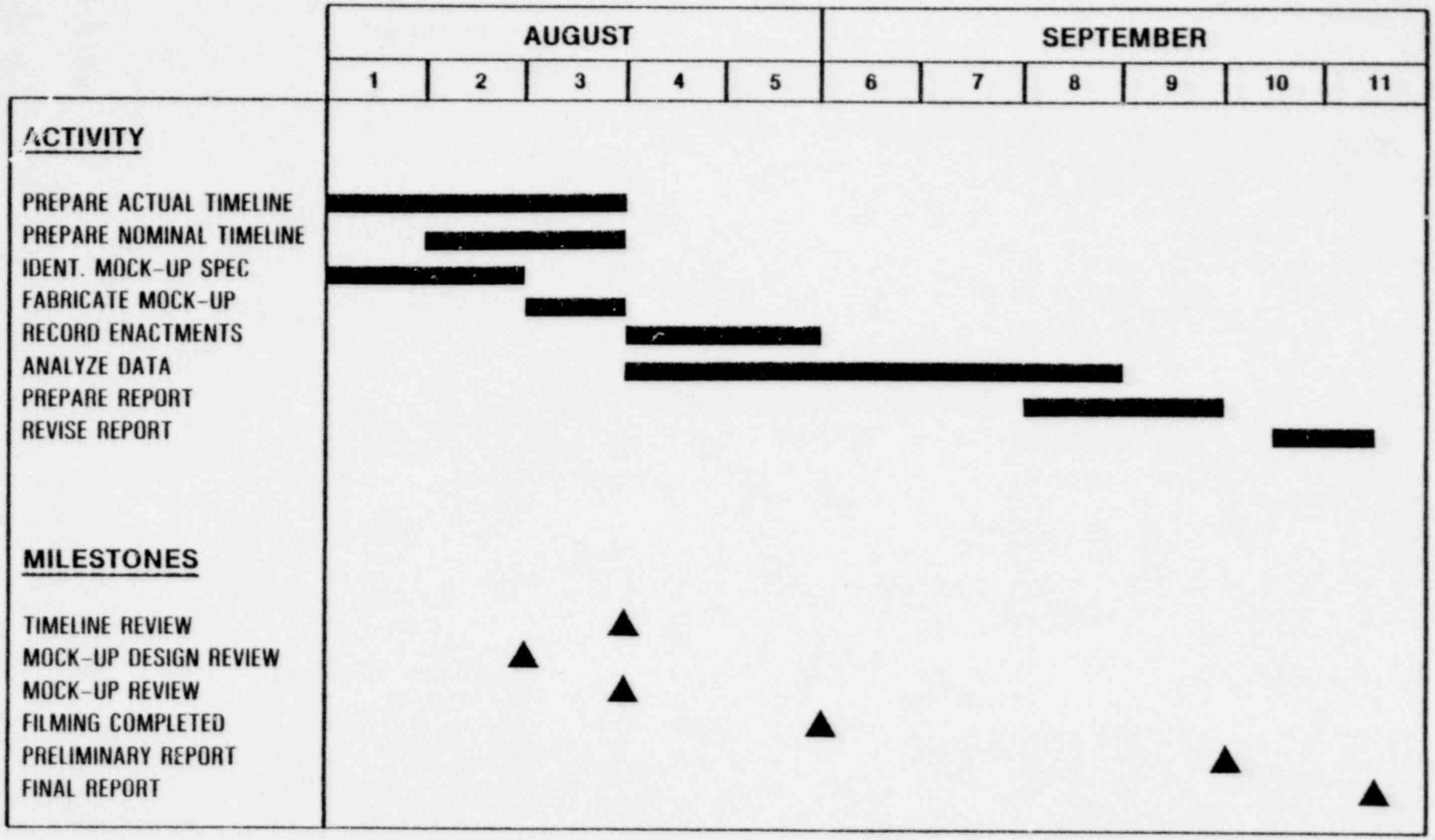

FIGURE 3

TASK C - OPERATOR PERFORMANCE

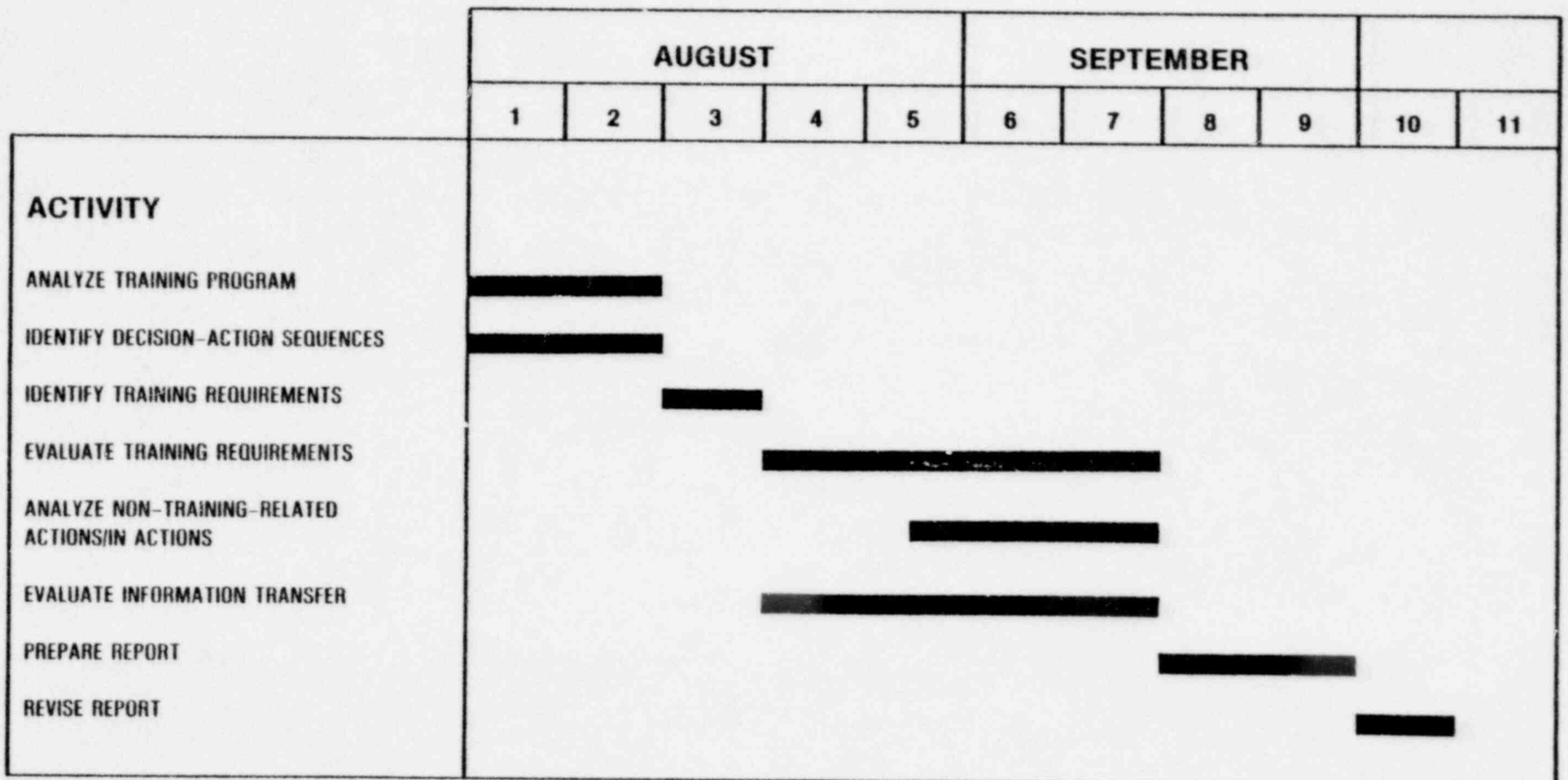

FIGURE 4

TASK D - APPLICATION OF HF PRINCIPLES TO CR DESIGN

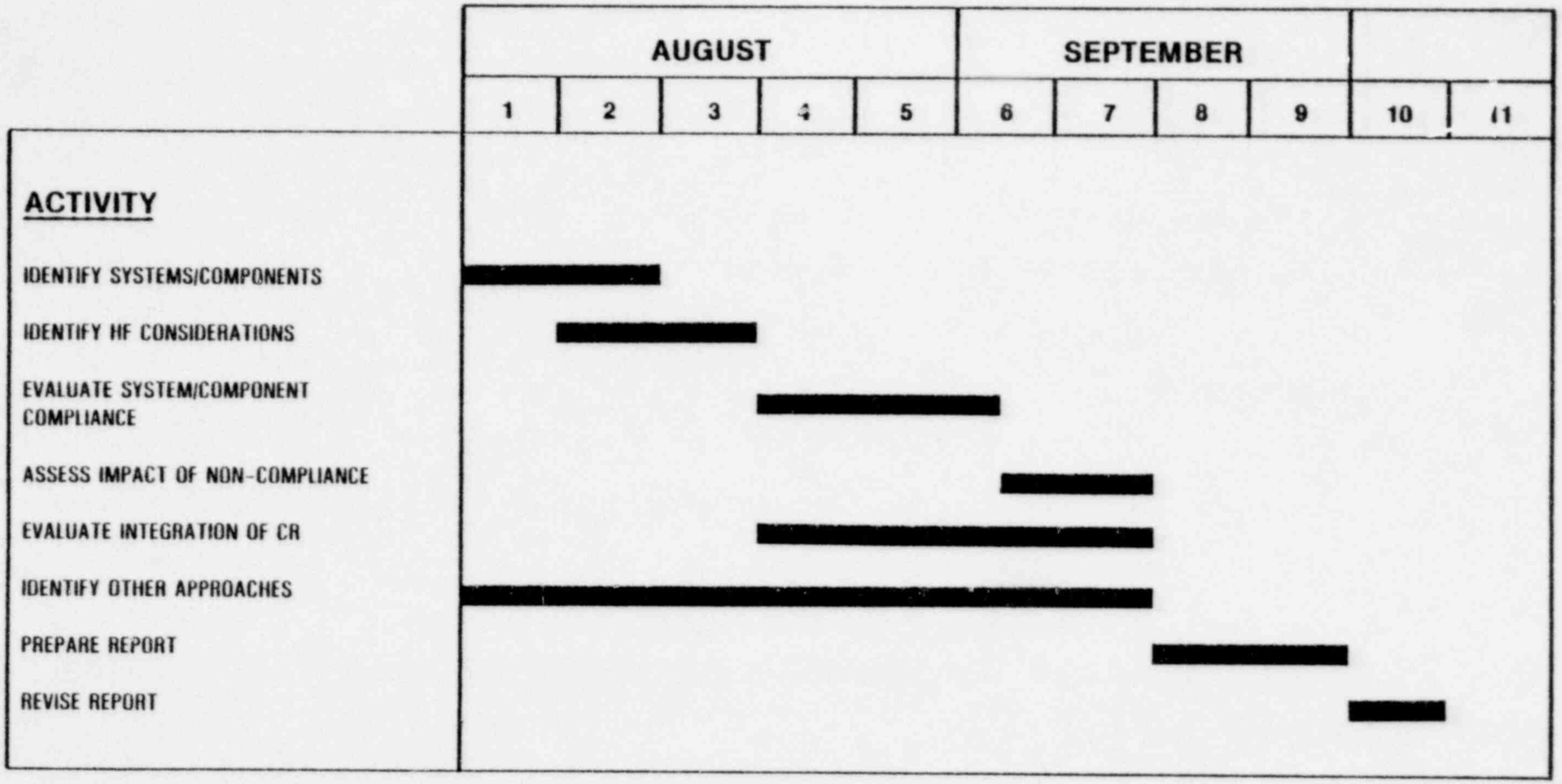

FIGURE 5

APPENDIX A

RESUMES OF KEY PERSONNEL

THOMAS B. MALONE

EDUCATION:

1964	Ph.D. -	Experimental Psychology, Fordham University
1962	M.A. -	Experimental Psychology, Fordham University
1958	B.S. -	Experimental Psychology, St. Joseph's College

EXPERIENCE:

February 1971 Present

ESSEX CORPORATION
Alexandria, Virginia

Vice President and Technical Director - Behavioral Sciences Division - Responsible for the direction of programs in the Behavioral Sciences Division, including the areas of Human Factors Engineering; Human Resources Development; Human Performance Research, Test and Evaluation; Crew Systems Development; Space Systems; and Training R&D.

Program Manager for a continuing program to assess and apply human factors engineering technology to the design of surface ships and ship systems for the Naval Sea Systems Command, Contract N00024-76-C-6129, April 1976-present.

Principle Investigator for an effort to assess and apply Human Factors Engineering Technology to Major Weapon Systems, for the Naval Air Development Center and Naval Sea Systems Command, Contract N00024-76-C-6129, July 1979.

Program Manager for Development of Human Engineering Criteria for Modern Control/Display Components and Standard Parts, Human Engineering Laboratory, U.S. Army Missile R&D Command Detachment, Contract DAAK40-79-C-0144, May 1979.

Principal Investigator for a program to provide human factors Test and Evaluation support to Missile Systems, at the Army White Sands Missile Range, Contract DAAD07-79-C-0063, April 1979.

Principal Investigator for a Human Factors Test and Evaluation Program for Army Command, Control and Communications Systems, U.S. Army Electronic Proving Ground, Ft. Huachuca, Arizona, Contract DAEA18-79-C-0029, February 1979.

Principal Investigator for an effort to apply human engineering concepts and criteria to the design of Naval air systems, Naval Air Development Center, N62269-79-C-0029, February 1979.

Program Manager for Development of Methods for Measuring and assessing human performance reliability of Army Systems during DT&E. U.S. Army, TECOM DAAKN-78-C-0079, October 1978.

Program Manager of a study to apply HFE technology to the Mark-14 Arresting Gear System for Naval Sea Systems Command, Contract N00024-76-C-6129, October 1978.

Program Manager for the Application of HFE Technology to the Mark-13 Catapult System, Navy Air Systems Command, Contract N00024-C-6129, October 1978.

Principal Investigator for an effort for NASA Life Sciences to establish procedures and criteria for selecting shuttle payloads and experiments, March 1978.

Program Manager of a study to apply Human Factors Engineering Technology to the Beartrap Helicopter Recovery Assist, Secure and Traverse System for Naval Sea Systems Command, Contract N00024-76-C-6129, January 1978.

Principal Investigator for a study of innovative methods for improving passenger car driver performance for DOT NHTSA, November 1977.

Principal Investigator for a Research and Development Program for the Defense Advanced Research Projects Agency (DARPA) Cybernetics Technology Office, Contract MDA903-77-C-0355, October 1977.

Program Manager for Planning and Conduct of a Human Factors Evaluation of the Improved Hawk Missile System, Contract DAAD07-77-0059 for White Sands Missile Range, May 1977.

Principal Investigator, Development of a Training Film for the Navy Human Factors Test and Evaluation Manual (HFTEMAN), Contract N00123-77-C-1044, April 1977.

Program Manager for Development of Test and Evaluation Procedures for Materiel Operated in Cold Regions, U.S. Army Test and Evaluation Command, Contract DAAD05-77-C-0724, January 1977.

Program Manager for Development of a Course Curriculum for a Selected Maintenance Training Course, N61339-76-C-0128, Naval Training Equipment Center, 1976.

Program Manager for Conduct of a Survey of Power Mower Warning Labels, Consumer Product Safety Commission, CPSC76214900, 1976.

Program Manager for an Effort to Develop Consolidated Human Factors Test and Evaluation Procedures for the Army Test and Evaluation Command, DAAD05-76-C-0787, October 1976.

Program Manager for the Analysis of Human Factors Requirements and Development of Design Criteria for Remotely Controlled Vehicles, NASA Marshall Space Flight Center, NAS8-31848, 1976.

Principal Investigator for a Program to Support the Cybernetics Technology Office, Defense Advanced Research Projects Agency, Contract MDA903-75-C-0227, 1976-77.

Program Manager, Advance Concepts of Naval Marine Engineering Maintenance, Contract N61339-76-C-0015, for the Naval Training Equipment Center, 1976-1977.

Principal Investigator, Field Test Evaluations of Rear Lighting and Signaling Systems, Contract DOT-HS-5-01228, conducted for Department of Transportation, 1975-1977.

Principal Investigator, Identify, Evaluate and Improve On The Job Training Program for Navy Food Programs, Contract N00123-76-C-0186, for the Navy Personnel Research and Development Center, 1976.

Program Manager, Development of the Navy Human Factors Test and Evaluation Manual (HFTEMAN), Contract N00123-75-C-1364, 1976.

Program Manager, Assessment of the Degree of Generalizability in Selected Advanced Maintenance Training Concepts, Contract N61339-75-C-0097, for the Naval Training Equipment Center, 1975.

Program Manager, Development of Shuttle Payload EVA Requirements, Contract NAS8-31454, conducted for NASA MSFC, 1975.

Program Manager, Research and Development of an Engineering Training Management System, Contract N00244-75-M-AK25, for the Navy Personnel Research and Development Center, 1975.

Program Manager, Tug/SEPS/Free Flying Payloads Simulation Demonstration, Contract NAS8-31451, conducted for NASA MSFC, 1975.

Program Manager of a study to develop advanced techniques of shuttle and spacelab man-machine interface evaluation, for NASA HQ, Contract NASW-2747, 1975.

Principal Investigator for a research study of the role of alcohol in non-fatal motor vehicle accidents involving injury, for DOT NHTSA, Contract No. DOT-HS-4-00954, 1975.

Principal Investigator for an effort to develop and evaluate advanced instructional technology concepts for marine engineering maintenance training, for the Navy Training Equipment Center, Contract No. N61339-74-C-0151, 1975.

Program Manager of a study to develop techniques for defining experimenter requirements for Spacelab payloads using network modeling approaches, for NASA MSFC, 1975.

Program Manager for a study to identify roles of EVA and remote manipulator systems for space shuttle and shuttle payload support missions, for NASA JSC, 1974.

Program Manager for development of a human engineering data guide for evaluation (HEDGE), for the U.S. Army Test and Evaluation Command, 1974.

Program Manager for a man-machine evaluation of the M60A2 tank system, Modern Army Special Systems Test Evaluation and Review (MASSTER) and Army Research Institute (ARI), 1974.

Program Manager for an effort at NASA MSFC concerned with planning and conducting man-systems simulation studies to support earth orbital teleoperator systems technology development; supervision of a team of scientists performing man-system simulation evaluations programs, 1972-74.

Program Manager for a contract with DOT NHTSA to develop standardized control/display location, operation, and coding criteria for cars, buses and trucks, 1973.

Responsible for specifying system requirements and development planning for the National Information System to Psychology, for the American Psychological Association, 1971.

Developed shuttle and sortie lab mission support requirements to support the definition of a Free Flying Teleoperator Flight Experiment Definition, for Bell Aerospace, 1973.

Developed guidelines and decision criteria for determining the role of man in shuttle and sortie lab missions, for NASA HQ, 1972-1973.

Identified specific applications of space teleoperator technology to problems in the medical areas of prosthetics, orthotics, and sensory aids, for NASA HQ, 1973.

Served on a special NASA task team to investigate technology requirements for shuttle teleoperator retrieval of payloads - responsible for the man-machine interface requirements, 1972.

Served as a special consultant to the NASA Sortie Lab Life Sciences Payload Planning Panel, for human performance evaluation, teleoperators and EVA, 1973.

Presentation of technical papers on teleoperator and EVA systems to the First National Teleoperator Conference (1972), the AAAS Symposium on Shuttle Payloads (1972), the IEEE Conference on Cybernetics and Manual Control (1973), Robot and Manipulator Symposium, Udine, Italy (1973), Naval Maintenance Conference (1975), Maintenance Training Conference (1975) Annual Meetings of the Human Factors Society (1973-1975), Congress of the IEA (1976), and to various technical meetings at NASA HQ NASA MSFC, DOT NHTSA, NTEC, and Army TECOM.

Served as the Technical Program Chairman for the 1973 Human Factors Annual Meeting, and Chairman of the Technical Sessions Subcommittee for the 1976 International Ergonomics Association Congress.

November 1965
February 1971

URS SYSTEMS CORPORATION, Matrix Research Division
(Formerly MATRIX CORPORATION)
Falls Church, Virginia

Vice President and Director, Human Factors Branch - Developed the NASA Human Facors Research and Advanced Development Program for teleoperator systems.

Development of requirements for head-up displays for Civil Aircraft Applications.

Developed an Integrated Pedestrian System in Denville, New Jersey.

Managed an operating division engaged in man/systems analysis and integration and Human Performance Research.

Leader of a team of scientists for defining requirements for the Manned Orbiting Laboratory Mission Control Center.

Supervised the design and testing of control consoles for high performance aircraft radar homing and warning systems.

Participated in the analysis and design of advanced shipboard electronic warfare systems (SHORTSTOP).

Evaluated human factors design techniques for Naval weapons system design.

Managed the Matrix effort concerned with developing design requirements for the Apollo Telescope Mount.

Determined human performance problems for oil operations on the North Slope of Alaska.

Analysis of astronaut capability on the lunar surface.

Developed design requirements for lunar shelter habitability.

Determined effects of noise and vibration on helicopter pilots.

Determined pedestrian safety requirements and design criteria.

Developed design requirements for remote manipulator systems for aerospace applications.

Analyzed astronaut capability to perform extravehicular activity.

Managed a team of human factors specialists concerned with analysis and design of a command/control center for a classified remotely controlled intelligence surveillance system.

July 1963 – November 1965: GRUMMAN AEROSPACE, Long Island, New York

Head, Crew Systems Simulation Group - Managed and conducted computer based simulation studies of lunar module rendezvous, docking, landing, powered descent and abort.

PUBLICATIONS:

Books:

Malone, T.B. (Editor). Proceedings of the 6th Congress of the International Ergonomics Association, University of Maryland, College Park, MD. 1976.

Malone, T.B. and Ranc, M. (Editors). Proceedings of the 17th Annual Meeting of the Human Factors Society, Washington, D.C. 1973.

Perkins, J.C., Maxey, G.C., (TECOM); Malone, T.B., Shenk, S.W., and Kirkpatrick, M. (Essex Corporation). Human Factors Engineering: Part I - Test Procedures; Part II - HEDGE. TECOM TOP 1-2-610, 20 December 1977.

Malone, T.B., and Shenk, S.W. Cold Regions Human Factors Engineering: Part I - Test Procedures; Part II - HEDGE. TECOM TOP 1-2-611. Prepared under contract DAAD07-77-C-0724, 20 January 1978.

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Published Articles:

Baker, C.C., Johnson, J.H., Malone, M.T., and Malone, T.B. "Identification of HFE Technology Gaps in Addressing HFE Requirements of the Navy Systems Acquisition Process," Proceedings of the 23rd Annual Meeting of the Human Factors Society, Boston, Massachusetts, 1979.

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Malone, T.B., Delong, J., and Farris, R. "Survey, Evaluation and Design of On-the-Job Training for the Mess Management Specialist Afloat." Naval Personnel Research and Development Center NPRDC SR 77-3, January 1977.

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Shields, N.L., Malone, T.B., and Kirkpatrick, M. "Manipulator System Performance Evaluation: Some Problems and Approaches." Paper presented to the National Bureau of Standards workshop on performance evaluation of programmable robots and manipulators, Annapolis, MD, October 1975.

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Kirkpatrick, M., Shields, N.L., Malone, T.B., Fredrick, P.N., and Brye, R.G. " Manipulator System Performance Measurement." Paper presented to the Second Conference on Remotely Manned Systems, July 1975.

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Malone, T.B. and Deutsch, S. "The Applications of the Remote Control of the Manipulator in Manned Space Exploration." Paper presented at the Robot and Manipulator Symposium (ROMANSY, '73), Udine, Italy, September 1973.

Malone T.B. "Teleoperators and EVA for Shuttle Missions." Paper presented to the AAAS and ASA Conference on Shuttle Payloads, Washington, D.C., December 1972.

Malone, T.B. "Man-machine Interface for Controllers and End Effectors. Paper presented at the First National Conference on Teleoperators, Pasadena, CA, September 1972.

Malone, T.B. "Evaluation of Human Operator Visual Performance Capability for Teleoperator Missions." Paper presented at the First National Conference on Teleoperators, Pasadena, CA, September 1972.

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Bayol, M.E. and Malone, T.B. Naval Electronic Systems Command Department Control Point Joint Electronics Type Designation System Nomenclature Action Request Processing Course. Final Report under Contract N00600-76-D-1687, April 1978.

Malone, T.B. and Baker, C.C. Human Factors Engineering Technology for the Mark-14 Arresting Gear. Final Report under Contract N00024-76-C-6129, March 1978.

Malone, T.B., Kirkpatrick, M., Kohl, J.S., and Baker, C.C. Field Test Evaluation of Rear Lighting Systems. Final Report under Contract DOT-HS-5-01228, February 1978.

Malone, T.B., Kohl, J.S., Eike, D.R., and Shields, N.L. Human Factors Engineering Evaluation of the Improved HAWK with Product Improvements. Final Report under Contract DAAD07-C-0092, August 1977.

Farris, R., Malone, T.B., and Kirkpatrick, M. Comparison of Alcohol Involvement in Exposed and Injured Drivers. Final report under Contract DOT-HS-4-00954, May 1977.

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Malone, T.B., Kirkpatrick, M., McGuinness, J., and Kohl, J.S. Human Factors Engineering Technology for Ship Acquisition. Final report under Contract N00024-76-C-6129, Naval Sea Systems Command, October 1976.

McGuinness, J., and Malone, T.B. Consumer Survey for Power Mower Hazard Warning Labels and Power Mower Noise. Under Contract CPSC 76214900 for the Consumer Product Safety Commission, October 1976.

Malone, T.B. Navy Sea Systems Command Program Management Course Curriculum. Under Contract N00004-76-M-6243, October 1976.

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Kirkpatrick, M., Brye, R., and Malone, T.B. Man-systems Evaluation of Moving Base Vehicle Simulation Motion Cues. Final report prepared for NASA MSFC on Contract NAS8-29914, April 1974.

Malone, T.B., Shenk, S.W., Weiss, E.C. Human Factors Engineering Data Guide for Evaluation (HEDGE) and Guidebook Supplement. Prepared under Contract DAAD05-73-C-0388 for the U.S. Army Test and Evaluation Command, March 1974.

Kirkpatrick, M. Shields, N.L., and Malone, T.B. Earth Orbital Teleoperator System Man-Machine Interface Evaluation. Final report prepared for NASA MSFC on Contract NAS8-28298, January 1974.

Malone, T.B., and Kirkpatrick, M. The Role of Man in Flight Experiment Payload Missions. Final report prepared for NASA MSFC on Contract NASW-2389, August 1973.

Malone, T.B., Shields, N.L., and Kirkpatrick, M. Report on Earth Orbital Teleoperator Visual System Evaluation Program. NASA MSFC, December 1972.

Malone, T.B. Free Flying Teleoperator Mission Analysis. Report for NASA MSFC, December 1972.

Malone, T.B., Krumm, R., Kao, H., and Shenk, S. Human Factors Criteria for Vehicle Controls and Displays. Final report for the Department of Transportation under Contract DOT-HS-120-1-174, August 1972.

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Malone, T.B., Schowalter, D. and Schweikert, G. Development of an Integrated Pedestrian System for New Jersey Route 46. Prepared for Madigan-Hyland, Long Island City, NY, April 1970.

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Schowalter, D., Malone, T.B., and Shenk S.W. Lunar Habitability System Design. Report prepared for NASA, Contract NASW-1941, March 1970.

Malone, T.B., Bender, H., and Kahn, M. Analysis of Astronaut Performance in the Lunar Environment. Report prepared for NASA, Contract NASW-1751, May 1969.

Malone, T.B., Eberhardt, P., and Gloss, D. Human Factors Techniques Employed in Deriving Personnel Requirements in Weapon System Development. Bureau of Naval Personnel, report PRR-68-3, October 1967.

Malone, T.B., and Tostan, D. Effects of Noise and Vibration on Commercial Helicopter Pilots. Report prepared for NASA, contract NASW-1829, April 1970.

Malone, T.B. Apollo 1 Telescope Mount Program Simulation Plan. Submitted to Brown Engineering Company, Huntsville, AL, May 1967.

Malone, T.B., Tostan, D., and Witas, C. Report on Radar Homing and Warning Equipment Design Criteria. Prepared for ATI, Inc., Palo Alto, CA, May 1966.

Malone, T.B. Manned Orbiting Laboratory Mission Control Center Design Guidelines. Prepared for Douglas Aircraft Company, May 1966.

Malone, T.B. Lunar Module Simulation Requirements - A series of Simulation Program Plans. Prepared for Grumman Aerospace Company, 1963-65.

Malone, T.B. Stimulus and Observer Variables in the Perception of the Ames Trapezoid Illusion. Ph.D. dissertation conducted for United States Navy Training Device Center, 1964.

Malone, T.B. Effect of Stimulus Wavelength on the Area-Intensity Visual Absolute Threshold Function. Unpublished Masters Thesis, Fordham University, 1962.

MARK KIRKPATRICK III

EDUCATION:

1971	Ph.D. -	Experimental Psychology, The Ohio State University
1967	M.A. -	Engineering Psychology, The Ohio State University
1965	B.A. -	Psychology, The Ohio State University

EXPERIENCE:

January 1977
Present

ESSEX CORPORATION
Alexandria, Virginia

Technical Director - Responsible for project management of efforts performed under contract to NASA and DOT.

July 1972
January 1977

ESSEX CORPORATION
Huntsville, Alabama, Facility

Director of Huntsville Operations - Responsible for directing and coordinating research and development performed by the Huntsville staff.

Conducted laboratory and simulation studies of operator performance in earth orbital teleoperator mission tasks. These studies have encompassed all elements of the teleoperator system including visual, mobility, and manipulator subsystems. Study approaches have included analysis, laboratory test, and complete man-in-the-loop simulation. Responsiblities included experimental design, test conduct, data analysis, and report writing.

Conducted a study of monitor sizing requirements for the Shuttle aft-cabin CRT displays based on operator perceptual capabilities, video system parameters, and viewing requirements.

Conducted a study to develop methodology for trade-offs and analysis in the area of crew time, loading, and skills in Spacelab experiments. This effort included development of a data form for Spacelab experiment functional requirements and use of a monte-carlo simulation program to exercise experiment task networks.

Performed an empirical study of human acceleration thresholds during complex vehicle simulation. These data were collected to provide parametric information on acceleration sensitivity so that motion washout techniques could be used to enhance simulator validity.

Participated in a study of Shuttle EVA requirements and hazards. Developed EVA approaches based on past EVA operations during manned space missions.

Participated in a study of man-machine integration requirements for TUG/SEPS/IUS. Responsibilities included development of control/display requirements and development of test plans and procedures for TUG/IUS simulations.

Participated as statistician in a variety of studies conducted by Essex Corporation. Responsible for statistical analysis of variance and multiple regression. Has generally advised Essex personnel in matters of data recording, analysis approach, and analysis procedures as applied to a wide range of projects.

Responsible for general direction of research performed by the Huntsville office including project planning, technical approach, data collection, data analysis, report writing, marketing, and proposal writing.

September 1972 THE UNIVERSITY OF ALABAMA IN HUNTSVILLE
December 1967 Huntsville, Alabama

Instructor - Teaching responsibilities have included courses in sensation and perception, statistical analysis and organizational behavior at both the undergraduate and graduate levels.

December 1967 ROCKWELL INTERNATIONAL
July 1972 Columbus, Ohio

Member of the Technical Staff - Participated in simulation programs involving air-to-ground E/O guided missile systems. Also involved in studies of driver behavior and effects of innovative route guidance systems using an automobile simulation technique. Responsibilities on these projects included planning, experimental design, development of mathematical models of human performance, statistical analysis of data, and report writing. Other activities included development of a stochastic model of visual search behavior and acting as a consultant in statistics and experimental design for various engineering groups at the Missiles Division of Rockwell International.

September 1966 HUMAN PERFORMANCE CENTER, OHIO STATE UNIVERSITY
December 1967 Columbus, Ohio

Research Assistant - Conducted research on human factors in reconnaissance imagery interpretation.

PROFESSIONAL SOCIETIES & ACTIVITIES

Human Factors Society

Technical Program Chairman for the 1974 Annual Meeting

President of Huntsville Chapter, 1975

Certified SCUBA Diver

NAVI basic certification

NASDS advanced open water certification

PUBLICATIONS:

Malone, T.B., Kirkpatrick M., McQuinness, J. and Kohl, J.S. HFE Technology for Ship Acquisition, Essex Corporation, Alexandria, Virginia, under Contract N00024-76-C-6129, October, 1976.

Pruett, E.C., Dodson, D.W., and Kirkpatrick, M. Extravehicular Activity Design Guidelines and Criteria. Report Number 4-76-6, Essex Corporation, Alexandria, Virginia, under Contract NAS8-31454.

Malone, T.B., Pruett, E.C., Dodson, D.W., and Kirkpatrick, M. External Operations, Maintenance, and Repair (OMR) Mode Selection Criteria. Report Number 4-76-5, Essex Corporation, Alexandria, Virginia, under Contract NAS8-31454, May 1976.

Pruett, E.C., Kirkpatrick, M., Malone, T.B., and Shields, N.L., Jr. Development and Verification of Shuttle Payload Extravehicular Activity (EVA) Requirements. Report Number 4-76-4, Essex Corporation, Alexandria, Virginia, under Contract NAS8-31454, March 1976.

Pruett, E.C., and Kirkpatrick, M. Tug/SEPS/Free-Flying Payloads Simulation Demonstrations. Phase I Report, Essex Corporation, Alexandria, Virginia, under Contract NAS8-31451, January 1976.

Kirkpatrick, M., Shields, N.L., Jr., Malone, T.B., and Guerin, E.G. "A Method and Data for Video Monitor Sizing." Proceedings of the Sixth Congress of the International Ergonomics Association, July, 1976.

Shields, N.L., Kirkpatrick, M., Malone, T.B., and Huggins, C. "Design Parameters for a Stereoptic Television System Based on Direct Vision Depth Perception Cues." Proceedings of the Nineteenth Annual Meeting of the Human Factors Society. Human Factors Society, October, 1975.

Kirkpatrick, M., Shields, N.L., Brye, R.G., and Vinz, F. "A Study of Moving Base Simulation Motion Cues Utilizing Washout Technique." Proceedings of the Nineteenth Annual Meeting of the Human Factors Society. Human Factors Society, October, 1975.

Kirkpatrick, M., Malone, T.B., and Shields, N.L. Earth Orbital Teleoperator Visual System Evaluation Program. Report I. Essex Corporation, Alexandria, Virginia, under Contract NAS8-28298, March, 1973.

Breda, W.M., Kirkpatrick, M., and Shaffer, C.L. A Study of Route Guidance Techniques. NR72H-229, Rockwell International Corporation, September, 1972.

Kirkpatrick, M. "Measures of Automobile Simulator Validity." Paper presented at the Workshop on Human Factors in the Design and Operation of the Highway Transportation. Washington D.C., January, 1972.

Kirkpatrick, M. Some Multi-State Models for Visual Search Performance. Doctoral Dissertation. The Ohio State University, June 1971.

Kirkpatrick, M., Kopala, E.W., and Smith, R.H. Aided Target Acquisition Performance Measurement Program. NR71H-19, Rockwell International Corporation, March, 1971. (Confidential report, title unclassified).

Levy, G.W., Kirkpatrick, M., Shaffer, C.L., and Breda, W.M. "Simulation Determination of Driver Information Lead Distance Requirements." Paper presented at the American Psychological Association Annual Convention, Miami, Florida, September, 1970.

Kopala, E.W., Shaffer, C.L., and Kirkpatrick, M. A Study of Operator/ System Performance Using a Helmet Imaging and Pointing System to Direct a Television Seeker. NR70H-279, Rockwell International Corporation, August, 1970.

Shaffer, C.L., Kirkpatrick, M., and Breda, W.M. A Driving Simulation to Determine Information Lead Distance Requirements for an Electronic Route Guidance System. NR70H-167, Rockwell International Corporation, June, 1970.

Levine, J.M., Kirkpatrick, M., and Shaffer, C.L. Information Seeking with Conflicting and Irrelevant Inputs. NR69H-525, Rockwell International Corporation, October, 1969.

Kirkpatrick, M. Development and Evaluation of a Random Walk Model of Visual Search Behavior. NR69H-760, Rockwell International Corporation, December, 1968.

Breda, W.M., Shaffer, C.L., and Kirkpatrick, M. Target Acquisition Study for an Indirect Fire Point Optical Contrast Guidance System. NR68H-706, Rockwell International Corporation September, 1968 (Confidential report, title unclassified).

Kirkpatrick, M. Quantification of Subjective Quality and Complex of Reconnaissance Imagery. M.A. Thesis, The Ohio State University, December, 1967.

Malone, T.B., Kirkpatrick, M., and Frederick, P.N. Role of Man in Flight Experiment Payloads - Phase II. Essex Corporation, Alexandria, Virginia, under Contract NAS8-30953, July, 1975.

Kirkpatrick, M., Shields, N.L., Malone, T.B., Frederick, P.N., and Brye, R.G. "Manipulator System Performance Measurement." Paper presented to the Second Conference on Remotely Manned Systems, July, 1975.

Kirkpatrick, M., Shields, N.L., Malone, T.B. A Study of Payload Specialist Station Monitor Size Constraints. Report No. H 75-10. Essex Corporation, Alexandria, Virginia, under Contract NAS8-30545, February, 1975.

Shields, N.L., Kirkpatrick, M., Frederick, P.N., and Malone, T.B. Earth Orbital Teleoperator Visual System Evaluation Program. Report No. 3. Essex Corporation, Alexandria, Virginia, under Contract NAS8-30545, February, 1975.

Shields, N.L., Kirkpatrick, M., Malone, T.B. and Huggins, C.T. "Optical Range and Range Rate Estimation for Teleoperator Systems." Proceedings of the Eighteenth Annual Meeting of the Human Factors Society. Human Factors Society, October, 1974.

Malone, T.B. and Kirkpatrick, M. Role of Man in Flight Experiment Payloads - Phase I. Essex Corporation, Alexandria, Virginia, under Contract NAS8-29917, July, 1974.

Kirkpatrick, M., and Brye, R.G. Man-Systems Evaluation of Moving Base Vehicle Simulation Motion Cue. Essex Corporation, Alexandria, Virginia, under Contract NAS8-29914, April, 1974.

Malone, T.B., Kirkpatrick, M., Shields, N.L., and Brye, R.G. Earth Orbital Teleoperator System Man-Machine Interface Evaluation. Report No. H-4-1. Essex Corporation, Alexandria, Virginia, under Contract NAS8-28298, January, 1974.

Malone, T.B., Kirkpatrick, M., and Shields, N.L. Manipulator System Man-Machine Interface Evaluation Program. Report No. H-4-3. Essex Corporation, Alexandria, Virginia, under Contract NAS8-28298, January, 1974.

Kirkpatrick, M., Shields, N.L., and Malone, T.B. Earth Orbital Teleoperator Visual System Evaluation Program. Report No. H-4-2. Essex Corporation, Alexandria, Virginia, under Contract NAS8-28298, January, 1974.

Kirkpatrick, M., and Brye, R.G. Teleoperator Docking Simulation. Report No. H-4-4. Essex Corporation, Alexandria, Virginia, under Contract NAS8-28298, January, 1974.

Kirkpatrick, M., Shields, N.L., and Huggins, C. "Some Effects of Transmission Parameters on Detection and Recognition of Television Images," Proceedings of the Seventeenth Annual Meeting of the Human Factors Society. Human Factors Society, October, 1973.

KENNETH M. MALLORY, JR.

EDUCATION:

M.S. - Experimental Psychology, Tufts University

B.S. - Experimental Psychology and Mathematics, Lynchburg College

Intensive course in computer programming and analysis (Assembly language and FORTRAN)

EXPERIENCE:

September 1978- Present

ESSEX CORPORATION
Alexandria, Virginia

Staff Scientist - Human Factors Engineering planning and management. Responsible for the design and development of procedures and documentation; for evaluation and specification of spacecraft habitability; and for operator integration into complex man/computer systems.

July 1974- September 1978

KENNETH MALLORY AND ASSOCIATES, INC.

President - Worked on documentation and program planning/ implementation activities.

Procedures and Documentation

Prepared user documentation to support NASA's Life Sciences program. Included were TECHNICAL AND PLANNING GUIDES used by several thousand life scientists; experiment procurement documents; JOB PERFORMANCE AIDS (JPAs) used to operate Life Sciences data retrieval systems; QUESTIONNAIRES sent to scientists and used by NASA to plan its Life Sciences Program; QUESTIONNAIRES used to collect data on Flight Experiment hardware and vehicle requirements, NEWSLETTER reports published periodically to inform the Life Sciences community on the status of NASA's Life Sciences Program.

Also developed a two volume, fully human engineered QUESTIONNAIRE for General Dynamics/Convair. This questionnaire collected information on engineering requirements for the Space Shuttle and Spacelab.

Developed a set of HUMAN ENGINEERING GUIDELINES for documentation design, based on a thorough search of relevant literature.

Developed and automated a 2000-citation Life Sciences BIBLIOGRAPHY cross-referenced and printed in 88 discipline categories. Report format was human engineered.

Program Planning	Designed, specified, tested and used procedures and SOFTWARE to evaluate the suggestions made by several thousand scientists concerning the objectives and implementation of NASA's Life Science Program.
	Developed a Monte Carlo MODEL for optimizing the assignment of experiments to several Shuttle/Spacelab missions.
	Designed, specified, tested and used SOFTWARE to synthesize free-form text descriptions of 2500 suggested experiment objectives into 27 scientific objectives.
	Developed MANAGEMENT PLANS for the Life Sciences Flight Experiment Program. Plans covered all phases (planning to post-flight) and all three Life Sciences centers and headquarters; responsibilities were allocated to activities; preliminary schedules were outlined; documentation requirements were identified.
Hardware	Assisted NASA/Headquarters personnel in a critical evaluation of HUMAN ENGINEERING STANDARDS to be applied to manned spacecraft and ground equipment design.
	Designed, developed and fabricated a voice recorder CONTROL PANEL for use by a QUADRAPLEGIC. Project involved a complete static/dynamic anthropometric work-up, selection of control surfaces and selection of off-the-shelf hardware that could be operated by chin or shoulder.
May 1967- July 1974	URS/MATRIX CO.
	<u>President</u> (1971-1974)
	<u>Director, Huntsville Division</u> (1967-1968, 1969-1971)
	<u>Staff Scientist</u> (1968-1969)
Procedures and Documentation	Directed the development of CREW PROCEDURES and JOB PERFORMANCE AIDS for operation of Skylab's solar observatory.
	Directed the development of PROCEDURES and JOB PERFORMANCE AIDS for Skylab EVA operations.
	Participated in the development of NASA HUMAN ENGINEERING STANDARDS.
	Developed a USER-ORIENTED PROCEDURE for selecting optimum extravehicular systems for spacecraft.

Systems Development

Applied modified DELPHI TECHNIQUE in the selection of the final configuration of Skylab's Apollo telescope Mount Control Console.

Participated in design of SIMULATOR for training of MOTOR-CYCLE OPERATIONS.

Managed design of CREW STATION for manned remote manipulator system.

Participated in the design and managed the development of a 6 d.f. HANDCONTROLLER suitable for a variety of manual control applications.

Participated in design of general purpose EVA WORKSTATION for the Shuttle space vehicle.

Managed the man/systems design and CREW FAMILIARIZATION of Skylab's Apollo Telescope Mount Control Panel.

Designed and managed design activities on several Skylab EVA WORKSITES.

Developed MODELS for semi-automatic reduction of video tape data on human performance and reliability.

System Testing and Evaluation

Developed and managed implementation of technique for IDENTIFYING CONTROL PANEL DESIGN DEFICIENCIES through analysis of operational telemetry data.

Participated in and directed development of DIAGNOSTIC PROCEDURE to locate man/equipment interface deficiencies.

Planned and directed FUNCTIONAL AND TASK ANALYSES on spacecraft man-in-the-loop control system. Verification of design through computer-based visual/kinematic and zero-gravity simulation.

Performed data reduction and STATISTICAL ANALYSES on man-in-the-loop simulation results.

Developed flight experiments, using noninterference testing techniques, to QUANTIFY CREW WORK PERFORMANCE in zero and partial gravity environments.

Developed TAXONOMY for relating human performance to tasks and task environments.

Participated as EXPERIMENTER and TEST MONITOR in human performance tests in the hardware development phase of the Skylab Program.

Designed and managed development of an automatic in-vehicle system to COLLECT VIDEO DATA ON DRIVER PERFORMANCE and the causes of traffic accidents.

Participated in design and managed developmental testing of a complete video system for the collection of IN-SITU HUMAN PERFORMANCE data (SPACELAB).

Managed the design of a full-scale simulation of Skylab extra-vehicular solar environment. Later used simulator to EVALUATE EQUIPMENT DESIGN and verify procedures.

Designed neutral buoyancy simulation of intravehicular cargo transfer on Skylab. Results closely approximated transit times and rates on board the spacecraft.

Safety

Developed and implemented program to provide OCCUPATIONAL SAFETY AND HEALTH SURVEYS to small business enterprises.

Provided Occupational Safety and Health CONSULTING SERVICES to architectural and engineering activities.

Developed a comprehensive SAFETY AND HEALTH LIBRARY with associated information retrieval system.

Managed program TO MINIMIZE HAZARDS in Skylab extra-vehicular activities.

Implemented program for TRAINING ENGINEERS in occupational safety and health.

Performed an analysis of the EFFECTIVENESS of the Occupational Safety and Health Administration through April 1974.

Program Planning

Participated in the application of a LATTICE TECHNIQUE to the development of research objectives for NASA's Office of Life Sciences.

Participated with A&E firms in the application of human and system engineering techniques to HEALTH CARE facility master planning.

Participated in the development of a MODEL to assess the costs of including EVA on Space Shuttle missions.

Managed effort to DEFINE THE SKILLS which must be provided by crews of future space vehicles.

Participated with A&E firms to INTEGRATE HUMAN ENGINEERING into planning and design.

June 1965-
May 1967

GENERAL DYNAMICS/ELECTRIC BOAT DIVISION

Human Engineer - Developed analytical man-computer MODELS and DISPLAY INTEGRATION TECHNIQUES to be used in submarine control systems having ten years' lead time.

Proposed and developed prototype of a REAL-TIME MAN/COMPUTER INDUCTIVE REASONING SYSTEM for use in submarine attack control systems.

Designed and monitored development of 3-D TV SYSTEM for use with underwater remote manipulators.

Provided MATHEMATICS SUPPORT to submarine training simulator development (analog computer).

Participated in series of experiments on DECISION MAKING STRATEGIES in anti-submarine warfare.

March 1963-
June 1965

AVCO/RAD

Human Engineer - Designed and verified an automated (fault tree) method for ASSIGNING RELIABILITY REQUIREMENTS TO HUMAN OPERATORS in re-entry vehicle systems.

Participated in the implementation of a HUMAN ERROR REDUCTION PROGRAM for re-entry vehicle assembly, maintenance and test operations.

Designed a series of experiments aimed at QUANTIFYING HUMAN RELIABILITY, including: readying the connector pins; mating of connectors in close quarters; digital to binary translation; localization of a low-light-level beacon.

Participated in evaluation and re-design of GROUND TEST EQUIPMENT (large scale and multi-man)

Evaluated use of switch setting checks as a means to IMPROVE HUMAN RELIABILITY.

August 1962-
March 1963

PHILCO CO.

Computer Programmer/Analyst - Developed computer programs (Assembly language) for the STATISTICAL REDUCTION of SAGE radar data.

Designed and programmed a DIGITAL SIMULATION of a biological organism responding to the hunger drive.

PUBLICATIONS & PRESENTATIONS

"Life Sciences Status Report - No. 8." To NASA/Headquarters, Washington, D.C., July 1979.

"Program Requirements Document - Organization and Management of the (NASA) Life Sciences Flight Experiments Program." (Draft). To NASA/ Headquarters, Washington, D.C., October 1978.

"Specialized Life Sciences Bibliographies." Fifteen reports prepared for NASA/ Headquarters, Washington, D.C., July 1978.

"Life Sciences in the Shuttle Era." 78-ENAs-34 Co-authored with Dr. Stanley Deutsch/NASA, 1978.

"Space Shuttle Payload Requirements Questionnaire." (Draft) Vol. 1 & 2. To General Dynamics/Convair, San Diego, CA, February 1978.

"Life Sciences Guide to Space Shuttle and Spacelab." (Draft). To NASA/ Headquarters, Washington, D.C., March 1977.

"Fact Sheet for Proposed Life Sciences Flight Experiments." (Draft). To NASA/Headquarters, Washington, D.C., March 1978.

"Guide to the Preparation of Life Sciences Flight Experiment Proposals." (Draft). To NASA/Headquarters, Washington, D.C., March 1978.

"Planning for Life Sciences Research in Space." 76-ENAs-52 Co-authorized with Dr. Stanley Deutsch/NASA

"An Operations Research Approach to Assigning Flight Experiments to Life Sciences Missions." To NASA/Headquarters, Washington, D.C., July 1976.

"Achievements and Forecasts for Human Factors in Manned Spaceflight." 1975 Human Factors Annual Meeting. Co-authored with Dr. Stanley Deutsch/ NASA.

"OSHA - Will it Work?", presentation to New York Academy of Sciences, New York, April 10, 1974.

"The Role of the Human Factors Company in Consumer Product Safety" workshop at the 17th annual meeting of the Human Factors Society, October 16-18, 1973.

"An Artificial Gravity Performance Assessment Experiment," presentation to AIAA Weightlessness and Artificial Gravity Meeting, Williamsburg, VA, August 9-11, 1971.

Selection of Systems to Perform Extravehicular Activity, Final Report on Contract NAS8-24834, April 27, 1970.

Application of Teleoperators to EVA Tasks, Honorarium at the University of Michigan, October 1970.

"Man vs Manipulator," presentation given to NASA Committee on EVA, Washington, D.C., April 1970.

Serpentine Actuator Man/System Feasibility Analysis Report, Technical Report to Brown Engineering Co., November 1967.

Man/Systems Feasibility of Using the Serpentine Actuator in AAP-4, Final Report, task under NAS8-20073, December 1967.

"Concept Identification - A Critical Comparison of Rote Learning and Inductive Reasoning," presented at the Eastern Psychological Association, March 1967.

Apollo Telescope Mount Dynamic Crew Procedures Demonstration, NASA MSFC Report 10M33202, September 1968.

Controller Comparison for the ATM Experiment Pointing Control System, NASA MSFC Report 10M33209, July 1968.

Automated Link Analysis Model, Technical Report to Brown Engineering (under NAS8-20073), January 1968.

A Submarine Tactics Evaluation System, Technical Report, General Dynamics Corporation, March 1967.

Description of a Real-Time Statistical Technique to Determine Level of Training, Technical Report to Brown Engineering (under NAS8-20073), October 1967.

The Integration of Two Non-Metric Scaling Techniques, Technical Report, Tufts University, February 1967.

A Fault Tree Technique for Assigning Reliability Requirements to Operator Tasks, Technical Report, AVCO Corporation, August 1965.

An Experimental Assessment of Illumination Requirements for Human Operator Detection of a Blinking Light in a Low Light Level Environment, Technical Report, AVCO Corporation, February 1965.

"Experimental Comparison of Connector Coding Techniques", paper presented to Air Force Conference on Electrical Connectors, Los Angeles, California, May 1964.

"Human Operator Connector Torqueing Capabilities", paper presented to Air Force Conference on Electrical Connectors, Los Angeles, California, May 1964.

DAVID R. EIKE

EDUCATION:

1978	M.A. - Experimental Psychology, George Mason University Fairfax, Virginia (Expected June 1979)
1976	B.I.S. - Experimental Psychology, George Mason University, Fairfax, Virginia

EXPERIENCE:

May 1977 Present — ESSEX CORPORATION
Alexandria, V ginia

Program Manager, Human Performance Evaluation - Responsible for the organization, management and quality control of efforts to evaluate the human factors engineering characteristics of guided missile systems at White Sands Missile Range, and advanced electronics/communication systems at U.S. Army Electronic Proving Grounds (Ft. Huachuca). Currently assisting in a program to develop human engineering criteria for modern control/display components to be used in upgrading MIL-STD-1472.

Research Scientist - Principal investigator for human factors evaluation of the Communications Nodal Control Element (CNCE) of the Tactical Communications Control Facilities (TCCF). Responsibilities included: development of the test plan; monitoring and evaluation of the T&E effort of Martin-Marietta (prime contractor for TCCF); on-site data acquisition; data analysis, including error likelihood and conformance to MIL-STD-1472B; and preparation of test report containing design evaluation and recommendations.

Assisted in the Test and Evaluation of human factors design problems in the Improved Hawk Missile System. Responsibilities included: assisting in preparation of the test plan; review and analysis of technical literature; functional and requirements analysis; development of operational sequence diagrams and task analyses; on-site data acquisition, including: human performance data, T&E of specific equipment items and interviews with operational and maintenance personnel; reduction and interpretation of data; drafting conclusions of subtests for final report.

Assisted in the Test and Evaluation of human factors design problems in the Beartrap Recovery Assist, Secure and Traverse (RAST) system. Responsibilities included: development and preparation of the test plan; review and analysis of technical literature; functional and requirements analysis; development of operational sequence diagrams and task analyses; on-site data acquisition, including: error likelihood analysis, T&E of specific equipment items and interviews with operational and maintenance personnel; reduction and interpretation of data; development of trade-off and evaluation criteria; development of alternative console configurations; assisted in design and construction of console mock-ups; preparation of final report.

Assisted in reduction, analysis and interpretation of data collected for a study designed to evaluate the effects of alternative taillight configuration on the frequency and severity of rear-end collisions.

Assisted in the collection, reduction and analysis of data for development of a human factors design guide for Naval ship systems.

1975-1976 GEORGE MASON UNIVERSITY
Fairfax, Virginia

Research Assistant - Assisted faculty members in academic and applied research. Responsibilities included: experimental design, mechanics and evaluation; collection and interpretation of data; descriptive and inferential statistics; handling and training lab animals; and working with adults and children in various experimental settings.

Teaching Assistant - Assisted and lectured in Statistics and Comparative Psychology Labs.

PUBLICATIONS AND TECHNICAL REPORTS

Eike, D.R. and Malone, T.B. Human Factors Engineering Evaluation of the Communications Nodal Control Element of the Tactical Communications Control Facility. Technical Report under Contract DAAK11-78-C-0099, December 1978.

Malone, T.B., Eike, D.R., Baker, C.A. and Andrews, P.J. Human Factors Engineering Technology Into the Naval Ship Acquisition Process: Designing for Operability. Presented at the Human Factors Society Meeting, Detroit, 1978.

Eike, D.R., Malone, M.T. and Malone, T.B. Survey of Task Analysis Methods and Data Formats. Prepared for: Naval Ocean Systems Center, San Diego, CA, 1978.

Malone, T.B., Eike, D.R. HFE Technology for the Beartrap LSO Console. Final Report under Contract N00024-76-C-6129, June 1978.

Malone, T.B., Kohl, J.S., Eike, D.R. and Shields, N.L. Human Factors Engineering Evaluation of the Improved HAWK with Product Improvements. Final Report under Contract DAAD07-C-0092, August 1977.

Eike, D.R., Allen, J.A. Pre-exposure of Dull Versus Complex Stimuli: Implications for the Adult-Child Anomaly in the Latent Inhibition Studies. Presented at the Eastern Psychological Association Meeting, Boston, 1977.

Talley, Walter and Eike, D.R. Human Factors Evaluation of the Communication Satellite Ground Control Terminal (AN/TSC-85), Final Technical Report under Contract DAEA18-79-C-0029, March 1979.

Eike, D.R. Human Factors Evaluation of the Radiation Detector and Computer Indicator. Final Technical Report under Contract DAEA18-79-C-0029, May 1979.

DOUGLAS C. METCALF

TECHNICAL DISCIPLINES

Chemical Engineering, Nuclear Engineering, Mechanical Engineering, Shipsystems Engineering, Shipboard Test and Inspection Program Design, Shipsystem Performance Monitoring, Nuclear Propulsion Plant Operation and Maintenance, Porject Management, Submarine Operations, Deep Submersible Technology, Test Equipment Evaluation, Concept Formulation, Feasibility Analyses, Cost-Effectiveness Trade-off Analyses and Operations Research.

EDUCATION

Yale University, B.E. Chemical Engineering
Navy Nuclear Power School, Nuclear Engineering
Army Logistics Management, Test and Evaluation Management

PROFESSIONAL EXPERIENCE

1. Site Coordinator for the lead site of the SSBN Shipsystem Maintenance Monitoring and Support Office (SMMSO). Coordinated all aspects of a 20-man remote site team engaged in performance monitoring and tracking system for over 60 critical shipsystems. Responsible for review, implementation and operational interface aspects of all test and inspection procedures. Handled all features of site team operations including: communincations, personnel, administration, procurement and support of test equipment, scheduling of all testing and associated maintenance recommendations. Provided an analytical capability to upgrade the system in terms of ship design constraints, ship specification changes, emergent operational requirements and top level requirements.

2. Performed shipsystem liaison on over a dozen major systems with six SMMSO systems engineers; reviewed Performance Criteria (PC) and Conditions To Be Monitored (CTBM) and participated on the Technical Review Boards for all systems. All test procedures developed were evaluated for safety, procedural optimization and compliance with the Navy's Planned Maintenance Subsystem (PMS). Coordinated the SMMSO failure analysis program with the various laboratories for oil analysis, failed bearings and chemical and physical examination. Responsible for the coordination of the LID/URO programs for ensuring continued safe operation to design/limited test depth.

3. Program manager for the SMMSO Ferrographic Oil Analysis program. Evaluated, developed and implemented this technique of wear particle examination which offers substantial failure prediction for oil lubricated machinery. This is the Navy's first field operator application and is fully operational at three sites. In addition, involved in the investigation, contractor selection and/or utilization of a number of state-of-the-art, non-intrusive test techniques including: discrete frequency vibration analysis of rotating machinery, ultrasonic digital thickness measurement of castings and pipe, ultrasonic flow measurement for fluid systems, ultrasonic leak detection, eddy current dealloying detection, dew point measurement and thermometry.

4. As the Supervisor of Shipbuilding's representative, participated in and witnessed the Board of Inspection and Survey (INSURV) trials for three new

construction SSNs and Two Deep Submergence Vehicles (DSV). Witnessed and directed numerous shipbuilder's trials for new construction SSNs. Maintained status and reported progress of the shipyard test program from criticality through dock trials and fast cruise for the new construction submarine USS FLYING FISH, SSN673. Disciplines essential for the successful conduct of this duty included a comprehensive understanding of platform design, systems analyses and test and evaluation master plans.

5. Developed and enforced an on-site inspection program for the major upkeep and trials of the DSVs SEA CLIFF and TURTLE at a location remote from the contractor's facility. Performed as the Government's senior on-site representative during this three-month period.

6. As assistant to the SUPSHIP Quality Assurance Officer, coordinated the rewriting of all the constractor's standard shipyard procedures for testing and inspection to ensure readiness for launch of new construction submarines.

7. While attached to the Squadron staff, revised the Squadron's procedures for implementing the Type Commander's Alteration and Improvement (A&I) program to improve completion status accountability, logistic support and timely accomplishment.

8. As a nuclear submariner, made three POLARIS deterrent patrols, four upkeep periods including two drydockings; qualified in submarines, qualified Engineering Officer of the Watch, Damage Control Assistant, Ship's Diving Officer, Auxiliary Division Officer and 3M Officer.

KENNETH A. MOORE, JR.

TECHNICAL DISCIPLINES

Systems Analysis, Systems Engi..ering, Engineering Design, Nuclear Engineering, Maintenance Management and Planning, Shipboard Test and Inspection Program Design, Shipsystem Performance Monitoring, Nuclear Propulsion Plant Operation and Maintenance, Project Management, Submarine Operations, Test Equipment Evaluation, Concept Formulation, Feasibility Analyses, Cost Effectiveness Trade-off Analyses and Operations Research, Administrative Planning and Program Development, Budget Development, Master Plan Project Development, Management Information Systems Development, DOD PPBS, Logistics Support Analysis, Configuration Management, Supply Support Analysis

EDUCATION

United States Naval Academy, Annapolis, MD. - Graduated June 1965 (B.S.)
Navy Nuclear Power School - Graduated March 1966
Navy Land-Based Reactor Prototype Training (SIC) - Graduated August 1966
Naval Submarine School - Graduated March 1967
Advanced Reactor Propulsion (EBDiv In-Plant Course 101-1F) - Graduated December 1976

PROFESSIONAL EXPERIENCE — 13 YEARS

1. Provides technical guidance and staff support to all major participants in the TRIDENT Program at SPCC and in PMS-396. In this context, develops fiscal, technical and administrative plans for principal logistic and maintenance effort including, but not limited to: Maintenance Plans and Procedures; the LSA process activity; the Maintenance Management System and its accompanying data system, the Performance Monitoring Program and its accompanying data base; and interface controls between SPCC, PMS-396, Electric Boat, TRIDENT Refit Facility and PERA (SS). Coordinates closely the budget requirements for SPCC, PMS-396 and Electric Boat in the general area of logistics and maintenance support. Assists principal personnel at SPCC and PMS-396 with the development and preparation of plans, programs and technical material required by PM2, NAVSEASYSCOM and other top-level organizations directly responsible for effectuating the TRIDENT Submarine acquisition in a prudent and cost-effective manner. Participating in the design, development and ultimate implementation of management information systems germane to the disposition and conduct of the TRIDENT logistics and maintenance support program. In this context, participates in the development of the Maintenance Management Data System, the Performance Monitoring Analysis System and the Logistics Data System--all management information systems essential for the satisfactory conduct of business in the areas of TRIDENT logistics, supply and support, and maintenance. Provides, when required, assistance to logistics management personnel in the SHAPM with the preparation of fiscal programming data in a format consistant with DOD requirements for the Programming - Planning - Budget Cycle. Participates in analyzing the interface between Configuration Management requirements, the proposed Alteration Management System of the MMDS, the appropriateness of a Configuration Status Accounting (CSA) System

and the Logistics Support Monitoring System (LSMS). Currently reviewing LDS requirements primarily from the perspective of effecting a strong interface between maintenance and supply support. Currently analyzing the adequacy of the LSA File to discern the utility of this file for provisioning purposes.

2. Provided technical support to the TRIDENT Program for Maintenance Plans and Procedures development and Performance Monitoring Program Special Engineering Studies. Developed the HM&E Supplement to the Logistic Support Analysis Procedures Manual as a specification for the entire LSA/Maintenance Planning process including the collection of configuration data, provisioning technical data, S&TE requirements, personnel and training requirements and technical documentation requirements as well as detailed requirements for Maintenance Plan and Intermediate and Depot Level Maintenance Requirement Procedure preparation.

3. As Assistant Chief Nuclear Test Engineer for the first TRIDENT Class Submarine Steam and Electric Plant, exercised overall responsibility for the conduct of shipboard acceptance testing of propulsion systems and components. This included the preparation and approval of test procedures, the review and analysis of test procedure results, test program scheduling and coordination, and personnel assignment, training and qualification.

4. As Task Leader for the TRIDENT Class Submarine Logistic Support Analysis/Maintenance Planning Program at Electric Boat Division, was responsible for coordination of the efforts of over 60 engineers and technicians in the production of a wide variety of data products requiring close liaison with the customer government agencies to reconcile problems associated with technical, procedural, fiscal and production aspects of the task. Products developed included System Boundary Descriptions, LSA Candidate Lists, RIC Requests, LSA Data Sheets 2, 3, 5, 7 and 8, Maintenance Plans, Maintenance Procedures (O, I and D Level) and Corrective Maintenance LSAs. This position required extensive knowledge of equipment design and operation coupled with close familiarity with established and developmental maintenance practices and data systems.

5. Participated with senior staff members of NAVSEA PMS-396, TSAM and various SPCC codes in the conceptualization of the Corrective Maintenance LSA process for the input of Provisioning Technical Documentation for the TRIDENT Class Submarine. This effort included a detailed analysis of current SPCC provisioning practices leading to recommendations for overall savings in program time and operations for WSF load. Directed the implementation of the CM LSA Program at Electric Boat Division including overall direction of provisioning conferences.

6. While with the U.S. Navy following nuclear power and submarine training, served as Supply Officer, Main Propulsion Assistant (Machinery Division Officer), Engineer Officer, Navigator, and Operations Officer aboard nuclear powered Fast Attack and Fleet Ballistic Missile submarines. Exercised wide range of responsibilities for operation and maintenance of shipboard systems and equipment including reactor plant, steam plant, navigation, radio, radar, and electronic surveillance measures. Also responsible for training and qualification of officer and enlisted watchstanders. Supervised shipboard radiological controls and propulsion plant water chemistry control. Conducted extensive pre-overhaul testing and planning for propulsion plant systems and served as member of Nuclear Joint Test Group. Also served as Director of Engineering Division,

Officer Training Department, Naval Submarine School with overall responsibility for entry-level through advanced instruction and practical training in the areas of submarine electrical and auxiliary systems, the 3M System, quality control, damage control, supply, and submerged ship control.

WILLIAM T. BRANN

TECHNICAL DISCIPLINES

Nuclear Power Control Room Operation, Nuclear Power Engineering, Maintenance Engineering, Development of Operating Procedures

EDUCATION

Completed the following U.S. Navy courses:

Basic Submarine Engineering, Ships Hydraulic Systems, Nuclear Power School, Nuclear Power Prototype Training, S5W Crew Training Westinghouse Bettis Facility, Auxiliary Systems and Component.

PROFESSIONAL EXPERIENCE

1977 - Present Essex Corporation, Harrisburg, PA: participating in the development of system levels and specific component level maintenance plans for hull, mechanical and auxiliary systems of the TRIDENT Ship System.

1971 - 1977 Metropolitan Edison Company: control room operator of Three Mile Island nuclear power plant. Qualified as control room operator on TMI-2 and as auxiliary operator "A" on TMI-1. Supervised six auxiliary operators. Developed operating procedures and controlled maintenance activities involving the operation of the Nuclear Reactor Plant. Gave instructions to and verified knowledge of qualifying auxiliary and control room operators. Monitored operating procedure and instruction manual development.

1967 - 1971 Public Service Company of Colorado: appliance repair; responsible for repair of domestic appliances and troubleshooting electrical problems in customers' homes.

1962 - 1966 U.S. Navy: assigned to Main Propulsion Division of an SSBN-616 Class nuclear submarine as a Nuclear Machinery Operator. Responsible for the operation, maintenance and reliability of main propulsion equipment, nuclear systems and components, R-11 air conditioning units and distilling systems.

ROBERT W. McGOUGH, JR.

TECHNICAL DISCIPLINES

Maintenance Management and Planning, Navy Maintenance and Material Management (3M) System, Hull, Mechanical and Electrical Systems Analysis, Maintenance Data Collection and Analysis, Material Inventory and Readiness.

EDUCATION

Completed the following schools and courses:

Operator Training for Three Mile Island Nuclear Power Plant
Basic Electricity and Electronics, Electricians Mate "A" School, Nuclear Power School, Nuclear Power Prototype Training, 400 Hz Motor Generator, Variable Speed Controller, Magnetic Amplifier, Electrical Distribution and Control, Repair Parts Petty Officer, and various 3M courses.

Upon discharge from active duty, obtained a diploma from Devry Institute of Technology for completion of their home study course in electronics.

PROFESSIONAL EXPERIENCE 8 YEARS

1. Development and presentation of lecture plans on various equipments and systems used in modern, industrial nuclear power plants. This encompassed technical development of lecture material on mechanical and electrical components, plus actual presentation of material.

2. Participated in the development of specific Maintenance Plans for Hull, Mechanical, Electrical and Auxiliary Systems, and status for Maintenance Plan Progress, for the TRIDENT Submarine Program.

3. Responsible for the development of status report for Maintenance Plan development progress in the TRIDENT Submarine Support Program.

4. Participated in the development and review of Systems Maintenance Plans and Procedures. Identified all planned maintenance requirements for select Mechanical and Electrical Systems and components, provided detailed procedures for accomplishing each requirement, established maintenance periodicities and assigned maintenance levels in consonance with the TRIDENT Submarine Maintenance Concept.

5. Participation in Logistic Support Analysis and various Maintenance Plans and Procedures program products.

6. Supervision and Operation of testing for Electrical, Mechanical and Auxiliary equipment during plant overhaul. Maintained records of, evaluated, and analyzed results of tests.

7. Actively supported extensive support training and review during overhaul period. This effort was directed at preparing and giving lectures, as well as review and analysis of others' lectures on shipboard components.

8. Maintained Performance Monitoring Records on selected equipment. Records identified equipment faults, procedure involved in correcting malfunction, and all parts utilized to reach operational readiness.

9. Developed format to control inventory of parts for Electrical Division onboard submarine. This record enabled future reference to a particular piece of equipment, to establish repair parts requirements of a particular job, for either preventive or corrective maintenance.

10. Instructed in classroom environment on TMI-2 systems. Qualified as auxiliary operator "A" on TMI-2, in doing so was responsible for developing and giving lectures on specific TMI-2 systems. Participated in verification of testing of both primary and secondary systems on TMI-2.

JEFFREY S. KOHL

EDUCATION:

1976 M.A. - Physiological Psychology, University of North Carolina at Greensboro

Twelve semester hours of Statistical Analysis and Experimental Design including some training in computer programming and its use in statistical analysis.

1967 B.A. - Psychology, North Carolina State University

DIRECTLY RELATED EXPERIENCE:

1973-Present ESSEX CORPORATION
Alexandria, Virginia

Human Factors Scientist - Duties include conducting an assessment of the applicability of human factors technologies, in the area of manning and training to ship systems design. Also wrote section on manning and training in Essex report on Human Factors Engineering technology for Ship acquisition, published in October 1976.

OTHER EXPERIENCE:

1973-Present ESSEX CORPORATION
Alexandria, Virginia

Principal Investigator - Contract with Department of Transportation - "Field Test Evaluation of Rear Lighting and Signalling Systems."

Research Associate - Contracted to Bell Laboratories Department 9131 for development and implementation of position subsystem testing of Loop Maintenance System. This position involved the design of simulation tests of new job positions in large computer systems, conduct of tests, collection of operator performance data and statistical analysis of human operator error. Recommendations for system improvements are presented from this analysis. Also developed training requirements for the reading and interpretation of AT&T Universal Service Orders.

1973-1974 UNIVERSITY OF NORTH CAROLINA
Greensboro, North Carolina

Graduate Teaching Assistant - Introductory Psychology.

1972-1973 UNIVERSITY OF NORTH CAROLINA
Greensboro, North Carolina

Graduate Research Assistant - Physiological Psychology. Involved in the design and execution of research studies in the physiological psychology of vision, including statistical analyses of the resulting data, both manually and via computer.

1971-1972 CENTER FOR OCCUPATIONAL EDUCATION
Raleigh, North Carolina

Graduate Research Assistant - Evaluation of Vocational Education Projects.

1969-1970 BEHAVIOR SYSTEMS, INC.
Raleigh, North Carolina

Research Associate - government contract (DOD) "Development of a Mass Screening Method." Literature review of classified material in the areas of Psychology and Anthropology, as well as design of methodology for this project.

Research Technician - responsible for care and training of animals for government contract (DOD), "Training of Dogs in Detection of Land Mines and Tunnels."

1966 CENTER FOR OCCUPATIONAL EDUCATION
Raleigh, North Carolina

Research Assistant - Achievement Measures Project; responsible for design, administration and interpretation of tests for use in vocal schools and community colleges. (Summer)

1965 NORTH CAROLINA STATE UNIVERSITY
Raleigh, North Carolina

Research Assistant - Social Psychology. Experimental design execution and statistical analysis of social psychology research studies using parametric and non-parametric statistical techniques.

PUBLICATIONS:

Visually Evoked Potential, Pattern Size, and Retinal Eccentricity, (Unpublished paper, presented at the meeting for the Southeastern Psychological Association Meeting, Atlanta, March 1975).

Personnel Subsystems Testing in the Man-Computer Environment: A Case Study with J. D. Williams, R. A. Zinke, L. G. Sharpe, M. F. Sink and M. VanderGaag. Bell Laboratories Technical Memorandum 16-9131, January 1976.

LMOS/MLT Personnel Subsystem Design with C. J. Benigno, G. L. Kubitsky, C. R. Martin and T. S. Tullis. Bell Laboratories Memorandum for File, March 1976.

Human Factors Engineering Evaluation of the Improved HAWK with Product Improvements ' h T. B. Malone, D. R. Eike and N. L. Shields. Final Report under Contract DA ^D07-C-0092, August 1977.

CLIFFORD C. BAKER

EDUCATION:

1976 B.S. - Psychology, University of Maryland, College Park.

EXPERIENCE:

March 1977-Present

ESSEX CORPORATION
Alexandria, Virginia

Research Scientist - Past and present activities include:

Definition of the Naval major weapon system acquisition process and identification of Training, Human Factors and personnel requirements therein. Review of available training, trade-off and human factors design techniques and methods suitable to fullfil training, human factors and design requirements.

As part of validation of Human Factors for Ship Acquisition program, have performed design and evaluation efforts for developing and existing ship systems, including definition of human operational and maintenance functions for the Mark-14 aircraft recovery gear and evaluation of man-machine allocations and interface design of catapult systems.

Determination of maintenance manning requirements for Mark-86 and SEAFIRE Gun Fire Control System Integration.

Human Factors Problem Identification of habitation by men and machines in extreme cold weather environments, as part of the development of a Test and Evaluation Manual for man-machine systems subject to Arctic environments.

Evaluation of alternate automobile rear lighting configuration by correlations with incidences of rear-end stop-related collisions. Responsible for computer-assisted data maintenance reduction and analysis of automobile lighting conditions before and after the incidences of accidents.

Computer-assisted statistical analysis of railroad locomotive simulator training and pre-constructed tests used as a selection device for appointing Railroad Engineers.

PUBLICATIONS:

Baker, C. C. and Kosmela, T., "Manning Requirements Estimation for Mark-86/SEAFIRE Gun Control System Integration". Technical report in preparation for the Naval Sea Systems Command.

Kirkpatrick, M., Malone, T. B., Baker, C. C. "Application of Magnitude Estimation Techniques in Estimating Human Reliability for Application to HFE Trade-off Analysis". Paper submitted for presentation at the 23rd Annual Meeting of the Human Factors Society.

Baker, C. C., Malone, M. T., Johnson, J. and Malone, T. B. "Identification of HFE Technology Gaps in Addressing HFE Requirements of the Navy Major Weapon System Acquisition Process". Paper submitted for presentation at the 23rd Annual Meeting of the Human Factors Society.

Baker, C. C., Johnson, J., Malone, M. T. and Malone, T. B. Human Factors Engineering Technology for Major Naval Weapon Systems Acquisition. March 1979. Report prepared under Contract N00024-76-C-6129.

Baker, C. C. and Malone, T. B. Human Factors Engineering Evaluation of Catapult Systems. Prepared for the Naval Sea Systems Command, January 1979.

Baker, C. C. and Malone, T. B. Human Factors Engineering Technology for the Mark-14 Carrier Arresting Gear. Prepared for the Naval Sea Systems Command, 1978.

Malone, T. B., Eike, D. R., Baker, C. C. and Andrews, A. S "Human Factors Engineering technology Integration into the Naval Ship Acquisition Process: Designing for Operability". Paper presented at the 22nd Annual Human Factors Society Meeting, November 1978.

Malone, T. B., Kirkpatrick, M., Kohl, J. S. and Baker, C. C. Field Test Evaluation of Rear Lighting Systems. Report prepared under Contract DOT-HS-5-01228, February 1978.

PROFESSIONAL MEMBERSHIPS:

American Society of Naval Engineers
Potomac Chapter, Human Factors Society

ROBIN WALKER

EDUCATION:

Present	M.A. - Candidate, Industrial Psychology, George Mason University
1976-1977	Prerequisite undergraduate courses required for admittance to Master's program in Psychology, George Mason University
1973	B.A. - English, University of South Florida

EXPERIENCE:

February 1978-
Present

ESSEX CORPORATION
Alexandria, Virginia

Research Associate - Responsibilities include research and review of literature on topics in the behavioral sciences, human factors and related areas, including: computer assisted instruction and educational technology; integration of women into the military; HF evaluation of instrumentation, controls and displays. Conduct information search and retrieval using the Lockheed DIALOG System among other information resources.

Technical writing and editing of technical proposals and reports for federally awarded contracts in the areas of human factors research, design and evaluation. Recruit technical personnel for in-house projects.

Data gathering and evaluation, including the monitoring of field research in driver education. Evaluated six experimental classroom treatments and the effectiveness of curriculum design, instructor presentation, materials and questionnaires in an effort to design a model Driver Improvement Program for nationwide use (DOT).

1977

FAIRFAX COUNTY MANPOWER SERVICES
CETA Summer Program
Bailey's Crossroads, Virginia

Counselor - In implementing federally funded program providing summer work experience for low income youth, responsibilities included: job development, recruitment of enrollees and job placement; determination of eligibility; counseling on job behaviors and work-related problems; liaison between workers and job site supervisors.

1975-
1977

SAMARITAN HOUSES OF MOUNT VERNON, INC.
Alexandria, Virginia

Counselor - In residential center for adolescent boys in foster care responsibilities were: development of program for operation and administration of the home; care and supervision of up to seven boys; coordination of involvement of social workers, school personnel and mental health staff; counseling and monitoring of progress of each boy.

MISCELLANEOUS:

Attended a tutorial entitled "A System Methodology for Behavioral Research" taught by David Meister at the Human Factors Society Annual Meeting, October 1978.

KEM B. ROBERTSON, III

EDUCATION:

1972	B.I.D. - Industrial Design, Auburn University
1968	Diploma, USAF Ground Radio Equipment Repairman School, Keesler AFB, Biloxi, Mississippi

EXPERIENCE:

1978-Present

ESSEX CORPORATION
Huntsville, Alabama

Project Designer - Responsible for technical contribution to various Marshall Space Flight Center contracts in areas of crew training and simulator hardware design. Current responsibility is design and supervision of fabrication of a Neutral Buoyancy mockup of the Space Telescope (ST).

Designed and supervised fabrication of full scale mockups of the Sklylab Multiple Docking Adapter (MDA) and part of the Teleoperator Retrieval System (TRS) for use in MSFC's six degree-of-freedom moving base simulator for a Skylab reboost docking study. Designed a full scale mockup of the TRS forward end for a docking lighting study. Designed a satellite capture device for retrieval of spacecraft by the TRS.

1977-1978

UNITED SPACE BOOSTERS, INC.
Huntsville, Alabama

Systems Engineer - Identified various discrepancies in electrical schematics and drawings for the solid rocket electrical systems. Prepared and maintained air/ground and vehicle/vehicle communication channelization list.

Responsible for updating Solid Rocket Booster (SRB) data in the Space Shuttle Program Master Measurement List. Updated and maintained records of changes to the SRB Instrumentation Program and Component List (IPCL) for reference by Marshall Space Flight Center and contractor personnel.

1976-1978

ESSEX CORPORATION
Huntsville, Alabama

Consultant/Industrial Designer - Translated design concepts and ideas to drawings that were subsequently used to produce mock-ups of space hardware for Marshall Space Flight Center's Neutral Buoyancy and 1-G Test Programs.

Designed full scale mock-ups of the Shuttle Orbiter Pallet and AMPS payload for Marshall Space Flight Center's Neutral Buoyancy Facility.

1975- Present	UNIVERSITY OF ALABAMA IN HUNTSVILLE Huntsville, Alabama
	Instructor - Engineering Drawing, UAH Division of Continuous Education.
1975- 1977	NORTHROP SERVICES, INC. Huntsville, Alabama
	Engineer Associate - Responsible for updating Solid Rocket Booster data in the Space Shuttle Program Master Measurement List. Maintained and updated records of changes to the SRB Instrumentation Program and Component List for reference by Marshall Space Flight Center and contractor personnel.
1974- 1975	URS/MATRIX COMPANY Huntsville, Alabama
	Industrial Designer and Systems Analyst - Performed statistical and critical incidents analyses of the Apollo Telescope Mount (ATM) man/machine interface for the Skylab 3 and 4 missions from a human performance and cost-effectiveness standpoint.
	Performed analysis of group habitability and human performance in limited space under extended periods of time in zero gravity.
	Designed and developed a display used to illustrate and provide information to the general public about the use, safety, and maintenance of the family car for a Department of Transportation/University of Alabama in Huntsville research project.
	Developed concepts for restraints and mobility aids for the Manned Maneuvering Unit (MMU) Mission Definition Study.
	Designed and developed a variety of marketing displays and corporate identity graphics used to illustrate and disseminate information about corporate and company structure and special capabilities.
	Developed elevation drawings, built model and took photographs of the ATM console as it is currently integrated into NASA/MSFC's Payload Crew Station concept. Drawings, model and photographs were utilized in a formal presentation to NASA/MSFC.
1972- 1974	HAYES INTERNATIONAL Huntsville, Alabama
	Graphic Engineer - Illustrated management information.
1968	UNITED STATES AIR FORCE NATIONAL GUARD
	Active Duty, February 1968 - November 1968. Intermittent duty for six years. Trained as a Ground Radio Repairman.

PROFESSIONAL SOCIETIES:

Member - National Human Factors Society

PUBLICATIONS:

Pruett, E.C., Robertson, Kem B. III and Loughead, Tomas E. Development of Concepts for Satellite Retrieval Devices, Final Report, NASA/MSFC Contract Number NAS 8-33073, February 8, 1979.