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FINAL REPORT

METHODOLOGY INVESTIGATION OF AI TEST OFFICER SUPPORT TOOL

VOLUME I

BY

ROBERT HARDER

Software and Interoperability Division
Electronic Technology Test Directorate

US ARMY ELECTRONIC PROVING GROUND
FORT HUACHUCA, ARIZONA 85613-7110

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SUBJECT: Final Report Methodology Investigation of AI Test Officer Support Tool, Volume I, TECOM Project No. 7-CO-R88-EPO-008

1. Subject report is approved.

2. Point of contact, this headquarters, is Mr. Richard V. Haire, AMSTE-TC-M, amstetcm@apg-emh4.apg.army.mil, AV 298-3677/2170.

FOR THE COMMANDER:

GROVER H. SHELTON
Chief, Meth Imprv Div
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This report covers the application of Artificial Intelligence Techniques to the problem of creating automated tools to assist officers; it also examines the use of an emerging AI field, neural computing, as it might be applied to this problem domain.

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This volume of the report on the AI Test Officer Support Tool investigation covers the application of Artificial Intelligence (AI) techniques to the problem of creating automated tools to assist the test officer. Volume II examines the use of an emerging AI field, neural computing, as it might be applied to this problem domain.

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SECTION 1. SUMMARY

1.1 BACKGROUND

Test design and planning for modern Command, Control, Communications and Intelligence (C^3I) systems is becoming an increasingly complex task. More sophisticated systems are requiring more complex testing, in an environment with more demands and tighter budget constraints. At the heart of this problem is the increasing use of electronics, computers, and communications in systems with large, distributed architectures. Because of the exploitation of advanced technology even for relatively small test items, more testing is required today than previously. The increased test load involves more types of testing, such as software tests for the embedded microcomputer, and more automated test instrumentation.

The indirect effects are nearly as great, if not larger. Modern technology imposes new demands on the tester indirectly through more complex security, safety, budget, and environmental considerations. The consequence of this situation is that testing is rapidly reaching a point where the expertise required is too great for any one individual to handle effectively. By the time expertise is acquired in any one area, requirements are likely to change, or the individual may retire, leave, or transfer out of the organization.

The U.S. Army Electronic Proving Ground (USAEPG) has positioned itself to alleviate some of the problems faced by today's test officer, by exploiting some of the very technology which is partly responsible for this dilemma: artificial intelligence (AI) and the much improved microcomputer. Previous investigations at USAEPG, sponsored by the Department of Defense (DoD) Software Technology for Adaptable, Reliable Systems (STARS) program (reference 1), identified some aspects of AI which were sufficiently mature to insert in test tools. One of these technologies, AI expert systems, was explored in depth.

Prototype expert systems were developed to demonstrate capabilities and potential benefits. One of the first systems built was (and currently is) used to assess the suitability of proposed applications, as some problems are best addressed with conventional software techniques. After the expertise was established to build small expert systems, a workshop was conducted. This workshop served to link up the knowledge engineers (AI experts skilled at using AI software tools) with domain experts (the people who understand the problems and are skilled at providing solutions). The workshop approach provided the attendees and their managers with the familiarity which is vital to the successful use of any new technology.

Many ideas for expert systems were produced as a res 't of the workshop, and a few of the workshop projects evolved into larger prototype versions. Perhaps of more importance than the actual systems developed, were some of the lessons learned. While previous expert systems had been hosted on large minicomputers or specialized AI machines, the tools used in the workshop were meant for both development and use on microcomputers. Once the feasibility of building expert systems for the widely available microcomputers was established, the potential usefulness and possible applications of this AI technology increased dramatically. Given this rather fortuitous situation, USAEPG was afforded the opportunity to exploit AI technology for solving the everyday problems of the test officer.

1.2 OBJECTIVE

1.2.1 Applications.

The objective of this investigation was to provide the test officer with automated support tools by inserting AI technology in appropriate applications. Objectives for the development of these tools included:

a. Orientation toward the test officer as primary user.

b. Wide usability to satisfy the needs of the approximately 100 test officers at the USAEPG.

c. Ready availability (microcomputer based).

d. Reduction in time to perform a given task and/or improved quality of the result.

e. Education of the user (test officer) in addition to merely providing a solution.

1.2.2 Neural Computing.

An ancillary goal was to maintain awareness of developments in the AI arena which may prove useful in future phases of the investigation. One area of AI, which was examined in some detail, was the field of neural computing.

1.2.3 Testing.

Finally, as testers, a goal of every investigation is to identify any test methodology requirements which surface. Therefore, another objective was to assess the adequacy of current test methodology for the test and assessment of systems containing AI.

1.3 SUMMARY OF PROCEDURES

1.3.1 Applications.

Lessons learned from earlier work on expert system development were applied to restructure the proposed approach. Rather than develop a single test officer tool on the one available AI machine, an approach more in consonance with the objectives was established. This approach called for the development of a numb-- of small tools, with a greater overall probability of success than that of a single large tool. The development of smaller tools hosted on microcomputers also provided a more flexible means of adjusting to various constraints, while also benefiting from the experience gained during previous efforts.

The resulting approach consolidated efforts of the expert systems workshop, by furthering development of the Test Plan Drafter (TPD) and Environmental Impact Assessment (EVA) systems. From this initial base, new ideas were developed in the areas of meteorological support, budget, and security. Systems addressing these problem domains were developed using the workshop methodology: problem domain experts and knowledge engineers were paired to develop AI-based test officer support tools.

1.3.2 Neural Computing.

An examination of emerging AI technology led to the further investigation of neural computing. While the foundations for neural computing were established when AI was still in its infancy, only recently has the technology matured to the point where application has been possible outside the research milieu.

1.3.3 Testing.

Finally, the issue of testing AI systems was explored to a limited extent; first, because the development of expert system-based tools required an in-house test philosophy; and second, because test items employing AI technology are likely to appear in the near future. One initiative in this area was to develop interest within the AI community in addressing testing issues.

1.4 SUMMARY OF RESULTS

1.4.1 Applications.

A number of AI expert systems were developed to aid the test officer in performing duties associated with testing. With respect to the application objectives in section 1.2.1, these systems possessed the following characteristics to the extent noted.

a. The knowledge domains of the expert systems centered on areas of expertise of which an experienced test officer would be cognizant, but not necessarily an expert. In other words, a test officer might be familiar with certain test planning requirements, such as drafting test plans or examining potential environmental impacts, but would still require considerable consultation with a domain expert to satisfy the requirements for a new test. The prototype systems built during this phase of the investigation were intended to assist test officers by providing the preliminary advice normally obtained from the domain expert during test planning.

b. Most of the systems developed are still in the evaluation phase and therefore have been installed on a limited number of computer systems. The EVA and Meteorological (MET) expert systems are presently installed on several microcomputers located throughout the various organizations; while other expert systems, such as the TPD, are installed in the expert's office. All of the domain experts have the expert systems installed on their personal machines, for use and evaluation whenever a test officer consulting them has not previously used one of the systems for a particular test project. This arrangement also allows the experts to verify system performance and recommend changes, to address unique requirements or to adjust for inadequately covered areas of the problem domain.

c. All of the systems were targeted for the microcomputers available at USAEPG. Because of the different configurations in use, some constraints exist as to which functions can be used while still retaining compatibility with a majority of the microcomputer base. Primarily these constraints have concerned disk and memory size, graphics capabilities, and hardware accelerators for floating point operations. From a practical standpoint, little functionality has been lost in conforming to the minimal configuration. Only one expert system, the TPD, requires licenses for supporting software functions; and this is because of non-AI functional requirements (i.e., extensive data base management capability and document comparison functions).

d. An assessment of time savings or improved quality, due to the use of expert system aids, can only be done qualitatively, since all of the systems are just now being evaluated using actual test project parameters. Projected savings are considerable in some cases; the TPD should reduce the time to prepare test plans from several days to a few hours. Other expert systems, such as the EVA, have demonstrated the benefit of providing preliminary assistance in what can be a complex task. At a minimum, they can enforce the collection and consistent presentation of necessary documentation. All of the systems have demonstrated the ability to retain, and even combine, expertise from human domain experts.

e. The present suite of support tools all serve to train the test officer to some degree. After running the expert systems a few times, the user begins to understand which parameters are significant for given situations. Also, all of the systems provide an on-line 'help' function to inform the user of the nature of, and appropriate response to, the various queries encountered. Although the expert system shells have an explanation capability, in terms of the knowledge base rules used to reach a conclusion, this feature is not called upon by the average user. Most of the advice offered by the systems provides both the necessary action and the reason for the action; e.g., use of incendiary devices requires filing a fire plan with the post fire marshal.

1.4.2 Neural Computing.

Neural computing technology was examined sufficiently to gain familiarity with the fundamentals, identify potential testing applications, and suggest a course of action for further investigation.

1.4.3 Testing.

Test technology for AI expert systems is almost nonexistent. Rudimentary procedures were established for in-house use, with the hope that these may lead to adding a more formal test dimension to expert system development activities. Not much progress has been made by others in the field either, although quite a lot of interest in testing issues was expressed by attendees at an expert system workshop held in conjunction with the 1988 annual American Association for Artificial Intelligence (AAAI) conference. All indications suggest that future conferences will continue to support this attempt to provide test technology corresponding to advances in AI technology.

1.5 ANALYSIS

1.5.1 Applications.

The development of various expert systems to aid the test officer demonstrates the applicability of this AI technology to problems in the testing environment. The systems are still being evaluated, and will probably continue to evolve to support more of the domain knowledge. However, the potential utility of the development methodology used is readily apparent. Besides the obvious benefits, such as retained knowledge and combined expertise of multiple experts, this methodology showed the feasibility of developing and using expert system technology with existing microcomputer resources. In addition, improved productivity and quality of work can be expected from both the test officers and the domain experts. With increasing emphasis on efficiency being dictated by leaner budgets, these last two considerations may overshadow other potential advantages of AI.

The prototype systems developed for the investigation addressed individual problem domains within the testing milieu. Since many of these domains share commonality of information (here meaning both data and knowledge) about test resources, techniques, and requirements, a broader analysis of test support requirements is appropriate. An early examination of the testing infrastructure, with subsequent incorporation of global requirements into a supporting structure (i.e., data bases, networks, geographic information systems, and standard information elements), could eventually lead to an integrated set of cooperating support tools.

1.5.2 Neural Computing.

Neural computing technology has evolved to a point of limited practical applicability, much as expert system technology did a few years ago. As with the early commercialization of expert systems, neural networks will probably suffer from being oversold and applied indiscriminately with overoptimistic expectations. However, like expert system technology, neural computing methods will most likely prove to be practical for small, well-defined problem areas. For many applications, this will mean that the neural network will be merely a component of a larger system comprised of conventional software (procedural code, data bases, and, by then, expert systems). The treatment of large problems, with specialized hardware to allow reasonable execution times, will best be left to the research environment for the near term. There is little doubt, however, that this technology will find its niche in system developers' toolkits.

1.5.3 Testing.

The application of AI has not awaited the development of adequate test methodologies. This has occurred with expert systems, and will also be the case for neural networks. Premature use of such technology presumes the existence of benefits which outweigh the risks incurred by lack of formal testing techniques. One obvious issue which arises is a comparison of the performance of AI components to similar functionality (if possible) provided by conventional technology. In partial defense of this use of technology just out of the laboratory, it should be realized that more conventional software techniques are routinely used without mature test methodologies (e.g., distributed data bases), or at least without methods which are both comprehensive and cost effective.

1.6 CONCLUSIONS

1.6.1 Applications.

The investigation demonstrated the viability of AI-based automated tools to assist the test officer. This was accomplished with existing microcomputer resources, which increased the availability while minimizing implementation costs. Further validation of this microcomputer-based expert system development methodology would require completion of the evaluation phase, with subsequent distribution of the systems throughout the organization. Solving the infrastructure problem in conjunction with development of expert systems is too large an effort to be absorbed by follow-on phases of this investigation. However, some consideration should be given to the eventual integration of the support tools.

1.6.2 Neural Computing.

Neural computing appears to offer substantial benefits, especially if viewed as merely another AI technique to be used in conjunction with other methods. Both the advantages of neural networks in test tools and their potential use in test items make it prudent to maintain awareness of developments in this area.

1.6.3 Testing.

Since systems are already being developed which employ expert system technology, it is imperative that adequate test techniques be developed immediately. Test procedures and test issues should be established for the various types of AI technology, different methods of implementation, and typical operational characteristics.

1.7 RECOMMENDATIONS

1.7.1 Applications.

Further investigation is recommended in the following areas:

a. The tool base developed during the initial phase should continue through the evaluation phase to further validate the results. Widespread distribution and operational considerations should be addressed, and maintenance of the knowledge bases should be investigated. Further development of test officer support tools should also factor in infrastructure requirements to the extent possible.

b. A separate investigation is required to analyze the requirements for establishing and maintaining an automated testing infrastructure.

1.7.2 Neural Computing.

Neural computing should be investigated further, either as a separate investigation, or by the application of increased resources to follow-on efforts of this investigation.

1.7.3 Testing.

An investigation is required to develop test procedures for AI.

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SECTION 2. DETAILS OF INVESTIGATION

2.1 APPLICATION OF AI

One of the spin-offs of AI research has been the development of tools known as expert system shells to assist in the construction of rule-based expert systems. These expert system shells allow a knowledge engineer to codify logical inferences (rules) about a given domain, and process the resulting knowledge base to provide expertise to the user. This investigation examined the potential of applying this technology to assist the test officer by developing various AI-based support tools.

2.1.1 Approach.

Historically, most expert systems have been developed by a team consisting of AI experts and domain experts, although in a few instances the domain experts acted as their own knowledge engineers. It is the job of the knowledge engineer to obtain knowledge about a particular domain through consultation with one or more experts, documented information, or some combination of these sources. This knowledge is then incorporated into an automated tool which uses this expertise in solving problems within the domain. Expert system shells have considerably eased the task of developing expert system tools, by providing a means to enter and exercise logical rules about a given domain. In this sense, these tools are similar to the capability offered by conventional software language compilers/interpreters.

Recent developments in expert system shells have resulted in a number of tools which are relatively easy to use, and do not require extensive programming skills such as those normally associated with using symbolic programming languages. These shells have made it possible for some domain experts to build expert systems without assistance. However, knowledge engineering encompasses more than merely entering rules in the proper format. One need for knowledge engineers arises when the complete system includes conventional software components. In these situations the knowledge engineer, who is usually skilled in software development, can develop a design which will satisfy all of the system requirements.

USAEPG used the knowledge engineer/domain expert team concept in developing support tools for the test officer. Part of the approach involved conducting an expert system workshop to familiarize personnel with the technology and to solicit ideas for further development. The workshop included six teams, each of which built a small expert system as a class exercise. Of these, three systems were selected for development of a prototype system, based on a management review of the class projects. Other support tools were conceived after the workshop concepts had evolved and ideas for potential applications became more apparent. One side benefit was the exposure of both management and test experts to the capabilities and limitations of expert systems.

Applications proposed for test officer support tools were further screened by an existing tool which determines the probable success of a proposed system by analyzing various parameters of the project. This system, the Expert System Selector (ES^2), is itself an expert system. ES^2 examines such factors as the availability of expertise, and supporting development and runtime tools; and the suitability and feasibility of an expert system solution. It then provides a qualitative score of the overall success potential. Proposed concepts were required to be sufficiently well defined to be graded by the ES^2 before being considered for development. This approach, in fact, was used to screen ideas for the initial workshop, and was responsible for the elimination of what would have been poorly suited or overly ambitious suggestions.

2.1.2 Environment.

The computing resources of USAEPG are considerable, and include a variety of mainframe, mini, micro, and special-purpose computers. The sophisticated machines tailored to AI applications are not readily available to the test officer, however. For administrative functions, including test planning activities, microcomputers are the primary computing resource. Earlier AI efforts at USAEPG relied on large minicomputers or symbolic processors. However, the emergence of microcomputer-based expert system development tools was noted, and some shells were acquired to determine the practicality of AI systems targeted for the smaller machines. Earlier products had been too slow, many impractical, even when implemented on the larger machines.

2.1.3 Characteristics of Testing Organization.

USAEPG, like the other subordinate elements of the U.S. Army Test and Evaluation Command (TECOM), assigns action officers to oversee the activities associated with test directives. These test officers must wear a number of hats in performing their duties. Besides test planning, the test officer is responsible for monitoring actual test conduct, and of course analyzing and reporting the results. With test items increasing in complexity due to the increased use of electronics, computers, and communications, more types of tests, of a greater variety, must be performed in today's testing environment. This would be sufficiently challenging without the additional burden of reduced budgets and increased documentation requirements. At USAEPG alone, approximately 100 personnel are designated as test officers, with responsibility for conforming to all of the appropriate directives, regulations, and guidelines without losing sight of the primary mission.

2.1.4 Knowledge Infrastructure.

Expert systems designed to provide advice and assistance in policy and procedure within the context of a large organization require at least two types of knowledge. The first type, knowledge of the domain in which the system is to advise and assist, is termed domain expertise, and is the object of the knowledge acquisition effort as commonly described in AI literature. The second type involves information concerning the administrative, organizational, and regulatory environment within which the expert and system must operate. This knowledge bears a relationship to domain expertise analogous to that between a given industrial, business, or administrative facility and the complex suite of transportation, communication, and utility facilities, standards, and administrative provisions necessary to their operation. The term infrastructure has been borrowed from the economic and geopolitical literature to describe this knowledge.

Within USAEPG, requisite information is widely available, but from a wide variety of sources. At this time, there is no central point for maintenance of or access to this information. Examples of the types of information involved include:

a. Organization, Mission, and Functions manual.

b. Organization charts for USAEPG and related organizations.

c. Lists of DoD, Army, AMC, TECOM, and USAEPG publications.

d. Lists of non-DoD and industry standards and related publications.

e. Project/topic/system point-of-contact lists.

f. Standard distribution lists.

g. Acronym/abbreviation lists, etc.

2.2 AI EXPERT SYSTEM APPLICATIONS

An AI expert system development methodology for test officer support tools was synthesized from the lessons learned from previous projects, AI technology capabilities, computer resource availability, elements of the testing environment and test officer duties, and characteristics of the domains deemed suitable. This resulted in an approach similar to those used by industry for smaller AI applications:

a. Acquisition of microcomputer development tools and related personnel skills.

b. Identification of suitable applications.

c. Teaming of a knowledge engineer and domain expert(s).

d. Prototyping and iterative development of the expert systems.

The result of implementing this methodology was the generation of a number of small expert systems which address problems encountered by the test officer. Most of the systems deal with requirements during the planning phases of a test. This is not an indication that expert systems are not suitable for test conduct or reporting activities, but probably does reflect the greater stability and better defined nature of the planning stage. That is, test plans and environmental documentation are always required, regardless of other variations in the test activity.

The prototype test officer support tools built during the investigation are described below. For each system, the purpose and goals, domain, requirements, description, design characteristics, benefits, and status are briefly described.

2.2.1 Test Plan Drafter.

2.2.1.1 Purpose/Goals. The near-term goal of the TPD is to automate the current manual assembly of boilerplate for an initial draft of a detailed test plan (DTP). This is a time-consuming effort consisting of much cut-and-paste work from old test plans, but little real intellectual effort. It is intended to result in a strawman version for distribution to specific subtest domain experts for further editing.

A longer term goal of the effort is to create a prototype knowledge infrastructure, i.e., a structure for centralized maintenance of both specific information pertaining to a given test and general information needed in test planning.

2.2.1.2 Domain/Expertise. The initial knowledge acquisition for TPD involved determining the structure and composition of a DTP. This is specified in part by reference 2. Further detail was provided through review of local policy and interviews with test officers and with USAEPG's Technical Publications Division personnel responsible for preparing and publishing test plans.

Subsequent efforts involved acquisition of previously drafted boilerplate for specific subtests and review of Army, AMC, TECOM, and USAEPG publications to refine the knowledge of test plan composition and of the overall test and evaluation process in the Army. This latter knowledge, in addition to aiding in understanding the test planning process, is essential to realize the desired training benefits from use of the intended tool.

2.2.1.3 Requirements. The general requirements laid on all the application efforts selected were that they be of wide utility and also aid in training of personnel. Requirements specific to TPD were that it reduce the manual and telephonic work required to reach the strawman stage for a DTP, that it provide information on test plan structure and component descriptions, and that it assist the novice test officer in understanding the test and evaluation process. Requirements added during the prototype development were that it assist in draft DTP preparation and in the mechanics of the DTP review process.

A requirement of the TPD infrastructure was that it be maintainable in a form accessible to a broad range of offices. For this reason, the tool selected to create and maintain these components should be one that is widely available and understood by personnel not necessarily involved in or familiar with expert system or AI development.

2.2.1.4 Description. The current TPD prototype performs four functions:

a. It provides a simple mechanism for entering and maintaining standard information pertinent to a specific test.

b. It creates a partial strawman DTP from the information entered;

c. It provides background information on the test and evaluation process in general, as well as on specific components of a test plan.

d. It provides a mechanism for preparing a draft DTP and limited assistance in review thereof.

2.2.1.5 Design/Development Characteristics. The primary development environment selected for TPD was dBASE III. This environment allows attainment of the infrastructure goals without having to retrofit the infrastructure at a later time. The AI-related tools used are HYPE, from Knowledge Garden, Inc., and EXSYS (Expert System Development Package), obtained from California Intelligence, Inc. HYPE allows use of the hypertext paradigm for help and explanation functions. EXSYS allows development of expert system components. One further tool, DOCUCOMP, from Advanced Software, Inc., provides a document comparison facility for identifying changes made to a standard subtest to tailor it for a specific system. This is the limited assistance provided in draft DTP preparation and in the mechanics of the DTP review process (section 2.2.1.3).

The initial TPD prototype consists entirely of the dBASE III and HYPE files and software dealing with creation and maintenance of test plan information, and associated help and explanation files. The dBASE III application software drives the application, invoking HYPE and DOCUCOMP where appropriate.

Figure 2-1 shows the current and currently planned TPD products and their status. Figure 2-2 shows the overall data flow for the application.

2.2.1.6 Benefits/Use. TPD is designed to be used primarily by a test officer for a specific system, to assist in preparing a strawman DTP. Another potential user is the manager evaluating a proposed test outline for a potential customer.

The current TPD prototype is installed in the Command and Control Division of the Command, Control, and Communications (C^3) Test Directorate. It has been used in production of several strawman DTPs, and the current users have made several suggestions for improvement.

The most obvious benefit to be gained from the TPD is time. Current users and others to whom TPD has been demonstrated indicate that the current manual method of strawman draft plan composition can take from two days to two weeks. The TPD output is available within 15 to 30 minutes. While the resulting product is not complete, it accounts for perhaps as much as 30 to 50 percent of the content of such a strawman. Some increase in this percentage will accrue from growth in the archive of standard subtests, while some must await implementation of further planned functions.

Component: Plan administrative data
Strawman: Yes
Draft: Yes
Function: Records details of asgnd test officer, date of plan start, title, etc.
Implemented: Yes

Component: Introduction
Strawman: No – data unavailable
Draft: Undecided
Function: Contains test item project history and technical description.
Implemented: No

Component: Reference appendix
Strawman: Boilerplate references
Draft: Full references
Function: Records documents re–ferred to in test plan
Implemented: No

Component: Project number breakout
Strawman: Yes
Draft: Yes
Function: Provides information on test item technology and application.
Implemented: Yes

Component: Subtest text(s)
Strawman: Boilerplate from archive
Draft: Edited/new subtest text
Function: Records specific test pro–cedures & requirements
Implemented: Yes

Component: Acronym appendix
Strawman: Boilerplate acronyms
Draft: Full list
Function: Records acronyms, ab–breviations, short names, etc.
Implemented: No

Component: Subtest selection matrix
Strawman: Yes
Draft: Yes
Function: Global view of standard subtests selected for this project
Implemented: Yes

Component: Subtest text comparison
Strawman: No
Draft: Yes
Function: Comparison of edited sub–test text to boilerplate for review
Implemented: Yes

Component: Other appendices
Strawman: Title page/placeholder
Draft: Full text, where available
Function: Records test information too voluminous for main text
Implemented: No

Component: Test plan cover sheet
Strawman: Yes – draft form
Draft: Yes – draft form
Function: Records basic test data as it will be displayed on test plan cover.
Implemented: Yes

Component: Coord. recommendations
Strawman: Yes – draft form
Draft: Yes – draft form
Expert System Component
Function: Indicates generic coord. rqmts based on tests selected
Implemented: Yes – prototype form

Figure 2-1. Test Plan Drafter Components.

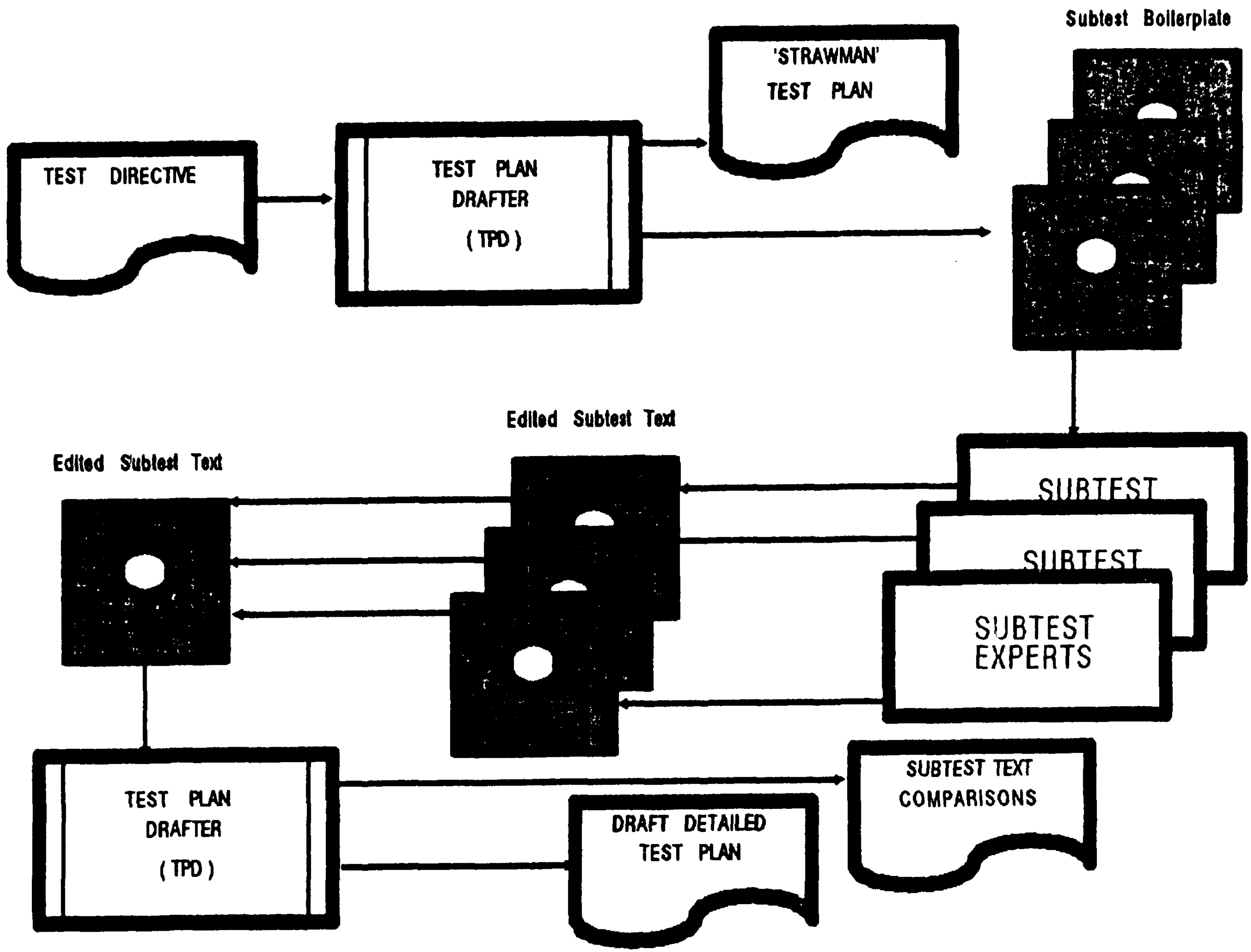

Figure 2-2. Test Plan Drafter Data Flow.

Less obvious is the training and standardization benefit. The hypertext provided with TPD makes available to the novice much information previously available only by laborious searching through assorted regulations and pamphlets. It also indicates sources for further information. Moreover, while in the past the differing backgrounds and levels of experience among test officers have sometimes led to irregularities in DTP and subtest format, more widespread use of a single tool offers the promise of improved adherence to TECOM and local guidance with less administrative review and rewriting effort. This will allow test officers, test engineers, and managers to devote more of their time and effort to substantive test issues.

2.2.1.7 Development Status. TPD prototype functionality, as indicated in figure 2-1, is roughly 70 percent complete. Addition of the expert system components for subtest recommendations and coordination requirements will bring the system to a level that will permit initial formal evaluation of its utility. This will require making the tool more widely available to test officers, which will in turn require additional copies of supporting software.

2.2.1.8 Future. Given that the TPD proves worthy of continued development, three major lines of development are foreseen. The first is expansion and refinement of the knowledge-based portion of the system, i.e., the hypertext and expert system components. These offer considerable potential for expansion into expert test planning areas, such as costing and scheduling, as well as tutorial and advisory components for test officer training.

The second area involves the conventional, infrastructure component. The knowledge infrastructure issue is documented at paragraph 2.1.4 above. It is important here to note only that this effort has created a skeletal infrastructure in conventional code to investigate the maintenance and integration problems that might arise.

The third line of development involves support tool integration. The use of a conventional basis for this tool, and development of a standard shell for passing the information contained in a test-specific data base to an expert system component, constitutes an example of one integration approach. Further refinement of this mechanism, and comparison with others, is essential to allow integration of the support tools into a single package for use by the test officer.

2.2.2 Environmental Impact Assessment Expert System.

2.2.2.1 Purpose/Goals. The purpose of EVA is to assist the test officer and environmental personnel in collecting accurate environmental information during the early planning phases of test activities, and in making appropriate recommendations based on characteristics of the proposed activities. Specific goals of the system were to:

a. Identify tests with minimal or no environmental impacts, and streamline the documentation process.

b. Identify possible environmental impacts and the resources that could be affected (e.g., water, wildlife, cultural, historical).

c. Improve the quality, detail, and timeliness of information provided to environmental personnel during the initial stages of a test project.

d. Incorporate environmental information into the initial decision-making stages of a project.

e. Guide activity proponents through the environmental assessment process, and list points of contact for action items and regulatory requirements.

2.2.2.2 Domain/Expertise. The domain of EVA covers that area of knowledge required to identify potential environmental impacts, recognize categorical exclusions from the rules for certain damaging activities, and perform a preliminary screening to determine the probable environmental documentation requirements. This expertise resides with the USAEPG environmental quality coordinator and environmental specialists attached to the post garrison. These experts in turn consult specialists in more narrow domains when necessary.

As EVA evolved through various prototype stages, additional information from documented sources was incorporated into the design. This information consisted more of quantitative impact factors, rather than intuitive knowledge about the domains. The inferences about this data were supplied by the human domain experts.

At the end of prototype development the following sources had been used in generating the data bases and rules of EVA:

a. U. S. Army Corps of Engineers
   1. Construction Engineering Research Laboratory reports
   2. Archaeologist

b. U. S. Department of Agriculture, Soil Conservation Service

c. U. S. Army Environmental Hygiene Agency

d. Fort Huachuca
   1. Forester
   2. Wildlife Biologist
   3. Fish Biologist
   4. Environmental Specialist

Much credit is due the post environmental specialist for identifying sources of information and eliciting knowledge from subdomain experts. This effort exceeded the scope of the normal participation of an expert, and aided tremendously in knowledge acquisition activities.

2.2.2.3 Requirements. USAEPG is required to conform to federal and state environmental regulations as well as Army and DoD policy in these matters. Every proponent of an exercise or test at Fort Huachuca is required to address the environmental issues associated with the activity. USAEPG test officers have the additional responsibility for assessing potential environmental impacts for any activity resulting from a test directive, regardless of the nature of the testing.

The result of the preliminary impact assessment is a record of environmental consideration (REC). The REC documents the consideration of environmental impacts; possible outcomes are that the activity is adequately covered by existing documentation, qualifies for an established categorical exclusion or other exemption, or requires an environmental assessment Environmental assessments subsequently result in a "finding of no significant impact" or indicate that an extensive environmental impact statement is required.

Most of USAEPG's activities are conducted at locations specifically designated and documented for that type of activity, or are conducted entirely within an enclosed facility, such as computer simulation and modeling. Thus, the major requirement of a preliminary environmental screening is to discriminate as early as possible between typical situations requiring little further documentation, and those requiring a significant environmental impact study.

2.2.2.4 Description. The EVA elicits information about a proposed activity from the test officer, and reaches a preliminary conclusion on the actions required. It then generates a report containing action items, and summary and detail characteristics of the activity, with corresponding environmental impacts. Activities which have already been documented or qualify for a categorical exclusion are quickly identified (i.e., a minimum of user input is required), and the necessary REC report is generated. For activities where the potential environmental impact is greater, the user may elect to examine the environmental resources most affected and, if possible, modify characteristics of the proposed activity to minimize the impact and associated documentation. In any event, information from the report is used by the environmental quality coordinator in completing the environmental requirements.

2.2.2.5 Design/Development Characteristics. The EVA system consists of an expert system which provides the user interface, contains the rules used to make decisions, generates reports, and interfaces with other tools for additional capabilities. These other tools supply such functions as access to data bases and graphic display of map information. Other components include supporting information such as help, system parameter, map, point-of-contact, and report specification files. The expert system shell, EXSYS, allows a means to interface with the other tools and files so efficiently that the user is generally unaware of the individual components. To further isolate the user from having to contend with directory structures and operating system commands, a set of command files was created to simplify the installation and operation of EVA. The user merely enters one command to run the system and display and print the results.

The main expert component of EVA contains about 120 IF-THEN rules in the knowledge base. When processed by the EXSYS inference engine, the rules serve to collect the necessary information to reach the final conclusion on the environmental impacts of the proposed activity. Forward chaining, a technique which determines how the rules are processed, also allows some control over the sequence in which events take place. Thus, the user can be presented with queries in the same relative order, even though the knowledge base and supporting data bases may have changed from previous versions.

Although all of the rules may apply to a given scenario, only those which rely upon unknown information will request the user to enter needed data. Besides background information such as project number and description, which are always requested, firing (processing) of the rules may trigger queries on up to 150 numerical or textual variables, and up to 35 multiple-choice questions. For example, if the activity will include aircraft, then information is requested on the number of aircraft, number of flight hours, and time of day and altitude of the flights. Because only essential information is requrested, and EVA session can last anywhere from 5 to 45 minutes.

Part of the development philosophy was to minimize the amount of knowledge to be included in the rules about a specific installation. Information on the location of sensitive resources, period of sensitivity if not constant throughout the year, and qualitative damage factors associated with particular activities, were placed in ten data bases. These data bases were designed to be readily understood and modified by the domain experts without first having to obtain knowledge engineering skills. Likewise, user help screens, point-of-contact information, etc., which contained installation-specific material, were kept in separate files. This approach may provide a ready means of porting the system to other installations, but was chosen primarily to reduce development and maintenance costs. Information contained in the various data bases and files could have easily been encoded into rules, and some expert development packages provide the capability to do just that when fed tabular data. The problem with a pure expert system solution, with all of the knowledge embedded in rules, concerns the size of the resultant rule base. It was estimated that to incorporate the knowledge in the data bases alone into rules would add another three to four hundred rules. Further development and maintenance of such an unwieldy knowledge base would have significantly impeded progress, with no known advantages.

2.2.2.6 Benefits/Use. EVA offers benefits to the test officer, environmental quality coordinator, and program managers. Test officers are given the opportunity to compare environmental effects of different activities at various locations and times. With little prior knowledge of environmental concerns, the test officer using EVA can quickly gain an appreciation of the relative impact of various activities through the questions asked, the associated help text, and the outcome of the proposed scenarios. Less experienced test officers also benefit from the action items and notes related to the proposed activity; e.g., contacting the fire marshal and filing a fire plan if incendiary devices are used, or coordinating tree and brush removal with the post forester. These serve as reminders even for seasoned test officers, and both inexperienced and experienced users of the system benefit from reduced paperwork and coordination.

EVA does not make complicated environmental decisions, write environmental assessments or environmental impact statements, or replace environmental personnel. In fact, environmental quality coordinators themselves can use EVA to refine the work initiated by test officers, or as a method of automating and documenting activities in a standard fashion. Tests with minimal environmental impact are identified with a savings of paperwork and time. Even for large activities not fully handled by EVA, the quality, consistency, and detail of information presented to environmental personnel is greatly improved. Without EVA, many preliminary meetings are required between the test officer and environmental quality coordinator, merely to establish what information is needed, and then the data is rarely available in an organized format.

Sponsors of testing activities may gain the most from the use of EVA, albeit somewhat indirectly. Because extensive environmental documentation requirements can cause lengthy and expensive delays, it is important to identify potential impacts as early as possible, and develop alternative test scenarios which are more environmentally benign. Advance warning of potentially expensive activities, such as disposal of hazardous materials (e.g., expended batteries), may, if given in time, allow implementation of more cost-effective solutions.

2.2.2.7 Development Status. EVA is currently installed on several microcomputer systems at Fort Huachuca; about 20 test officers have been formally trained in its use. Presently the system is in an evaluation phase, where feedback is being obtained concerning its use in test operations.

2.2.2.8 Future. A number of ideas for further development of EVA have been proposed. During its construction, the development team identified a number of desirable features which could not be implemented because of time constraints. Other valuable ideas emerged from the test officer training sessions. However, the actual usefulness and benefits to be realized must be determined from the results of the ongoing evaluation. Some of the more significant limitations and improvements to be considered in future efforts are the following:

a. Some of the knowledge in EVA is in a preliminary state, having been added to determine the feasibility and desirability of certain features (e.g., a component to address hazardous materials). Those features deemed desirable should be expanded, along with the rest of the system, into a fully operational form.

b. The potential for porting the system to other installations should be explored further. This would require an initial analysis of the requirements of other installations, to see if enough commonality exists in the knowledge domains to make this approach feasible. Such an investigation might also shed some light on the commonality of other requirements, such as test resource management and safety.

c. The prototype system has the limitation that only one map area can be entered as the location of activity. Although areas may be arbitrarily defined as large or small as desired, a cumbersome situation occurs with activities consisting of 100 or more sites with minimal impact at each location. Even smaller activities may be handled better if multiple locations, or if unrestricted boundaries are allowed.

d. A feature which would allow saving all of the input information, to be used later to examine the impact of different test scenarios, is desirable. Such a capability was partially implemented, but had to be disabled because of a software discrepancy in the expert system tool. Along these same lines, many users expressed the desire to be able to modify an entry that had just been made. Both seem to be necessary features for practical use in an operational environment.

e. Most of the data bases of EVA are indexed by location. Geographic information also plays an important part in many other functions at Fort Huachuca. A solution to many of these needs for information associated with geographic position would be a geographic information system. This is also a requirement of many other proposed test tools. While implementation and maintenance of such a system is well beyond the scope of this investigation, the potential usefulness is great enough to warrant development by other means.

f. The actual users of EVA range from inexperienced test officers to qualified environmental personnel. Because of the disparity in experience, a system tailored to a given skill level will be somewhat frustrating for users of a different level. Experienced users quickly tire of a system oriented toward the novice, while inexperienced users may find a system written for the expert to be much too difficult. A possible solution to this dilemma was discovered during the EVA development, but too late to fully evaluate. Basically, this approach, if implemented, would call for multiple levels of rules, help, and queries. A 'don't understand' option is provided on higher level queries. When invoked by the novice, this option fires lower level rules which elicit a number of simpler details from the user. These details are then formulated by the lower level rules into facts which satisfy the original, 'difficult' query. Such an approach is best implemented on mature knowledge bases because of the growth in size and commensurate decline in maintainability. For a system with a diverse user base, further examination of this technique may prove useful.

2.2.3 Meteorological Expert System.

2.2.3.1 Purpose/Goals. The Meteorological expert system (MET) began originally as a manual paper checklist for test officers to use in preparing for upcoming tests at Fort Huachuca. It is designed to emphasize the need for meteorological data in planning and reporting tests within USAEPG. MET also indicates that various meteorological measurements and advisories are available from the Atmospheric Sciences Laboratory (ASL) weather station at Fort Huachuca, and from other sites located on the Fort Huachuca ranges.

2.2.3.2 Domain/Expertise. This expert system deals with the knowledge encompassing meteorological measurements and/or those weather events which affect test operations on the ground or in the atmosphere where testing will take place. Generally these measurements or observations are provided by ASL.

2.2.3.3 Requirements. From the standpoint of the test officer, the need for an expert system on weather is that it can educate and inform the test officer about meteorological data requirements and available resources for a test. The need for such data comes primarily when the test will be conducted outdoors. The expert system will make clear that the officer will need to have weather predictions before the test in order to plan for conditions such as cold or heat, rain or snow, and wind or lightning. Weather advisories and weather alerts from ASL can warn the test officer in the field of impending sudden weather changes that could endanger personnel and equipment.

2.2.3.4 Description. The MET system educates the test officer as to possible weather-related needs, and informs the officer on how to obtain needed measurements to prepare for the test, how to run the test more effectively, and how to obtain weather station support in reporting the test outcome.

Measurements and predictions of temperature, dew point, rain, snow, thunderstorm activity, and winds in the lower atmosphere, may be needed. Predictions may be needed as to meteorological conditions such as sunspot activity and atmospheric index of refraction. MET informs the test officer whether, during on-site test activities, weather advisories and reports of selected meteorological values are available and may be needed. Also the ASL weather station's ability to support test reporting is covered.

The result of using the MET system is that the test officer can produce better test data by being prepared with needed meteorological data, both in measurements that directly supply parameters needed in the calibration of equipment such as radar, and in supplying measurements for the test, as well as weather advisories that assist in day-to-day running of test operations.

Without MET, the test officer must know to inform ASL of test requirements far enough in advance to prepare them to supply information needed for the test. ASL may need to prepare ahead of time to be able to make measurements during the test, and will need to know what data are needed for the test report. ASL can supply reports of the meteorological conditions that existed during testing.

2.2.3.5 Design/Development Characteristics. The MET system is composed of a series of questions which are presented to a test officer from within the EXSYS shell. The questions asked in this prototype version of MET determine, for example, whether lasers will be used in the atmosphere, whether any radar or unmanned aeronautical vehicles (UAV) will be used, whether personnel and/or equipment will be in the field, and whether heavy rain or snow will be a problem. From such factors, MET can then advise that meteorological measurements will be needed to support these activities. For example:

a. Aerosol density in the atmosphere or optical scintillation measurements may be needed for a test involving lasers.

b. Meteorological data used in radar calibration may be needed for a test using or testing radar.

c. Measurements of upper air winds and turbulence could be needed for a test using UAVs.

d. Weather advisories would be wise to have during test activities.

MET automates the original weather/meteorological checklist into a system in which the questions are presented on the computer monitor for decision, help is provided by way of a computer-stored text file for each question, and the answers are stored in computer memory until the sessions end, when a report including all input answers is produced. The report is displayed on the computer monitor and printed on the line printer, under operator control.

2.2.3.6 Benefits/Use. The benefit of using the MET system is that the test officer becomes better informed about available support from the ASL weather station, and learns what weather conditions require special preparation. The test officer can then more likely plan the test so as to produce a more accurate result, and will be able to write a more correct and informative report. This all adds up to savings in time and money.

2.2.3.7 Development Status. MET has been developed only to the initial evaluation stage. In this prototype version, MET has been placed on 10 microcomputers in the USAEPG and ASL offices at Fort Huachuca, so as to be available for use by all test officers. Statistics on system usage and comments on deficiencies or possible improvements have not yet been collected.

2.2.3.8 Future. After evaluation, the MET prototype will be modified to eliminate any discrepancies found, and to enhance the system's capabilities to better serve test officer needs. Questions will be improved to clarify their meaning. The MET help file will be changed, as needed, to make explanations more useful to the user. The sequence of questions presented to each test officer will be determined by previous answers to prevent redundancies.

2.3 NEW TECHNOLOGY (NEURAL COMPUTING)

Preliminary efforts on this investigation focused on the application of AI expert system technology because this area is more mature than other AI techniques and technologies. However, rapid progress is being made in the other areas. The next major technology to emerge from AI laboratories will probably be from the category of AI known as neural computing. Since the products of neural computing, neural networks, are beginning to appear in commercial applications, it was felt that this aspect of AI should be investigated further. To this end, an initial investigation into neural computing was performed to assess the feasibility of employing neural networks in future tools. The findings of this effort are documented in volume II of this report.

2.4 TESTING AI ISSUES.

In dealing with issues related to testing of AI-based systems, USAEPG has addressed them at two levels. On the one hand, USAEPG has been faced with the problems of test and evaluation of its own expert system development efforts. On the other hand, it has attempted, through literature reviews, participation in professional exchanges and small business innovative search (SBIR) efforts, to identify or encourage research and development efforts leading to test techniques and methodologies for such systems. In both cases, the attention has been directed almost entirely towards test and evaluation of expert systems, as they are the most widely implemented and most highly evolved of AI-related technologies.

2.4.1 In-House Philosophy.

As indicated in reference 1, well-founded techniques and implementing technologies for test and evaluation of expert systems are virtually nonexistent. While the past year has witnessed the appearance of a number of prototype techniques, and an even wider range of proposals, none of these is at the stage of development which would allow acquisition of implementing software tools for generic systems. For this reason, USAEPG's test and evaluation of its own development efforts have been limited to expert and developer "walk-throughs" of the respective knowledge bases, and direct comparison of human expert and expert system performance on test cases.

For most of the systems developed by USAEPG, limitation to these test and evaluation techniques has been less problematic, in that most of the systems involved have been developed in large part from domain knowledge in published form. Thus much of the organization into a readily assimilable form has already been accomplished, including examples or exercises which may serve as initial test cases, making both development and review much simpler.

2.4.2 Test Items with AI.

USAEPG has a long-term goal of identifying and investigating techniques applicable to test items containing AI-based components. Current efforts have been directed at techniques applicable to expert systems which may appear as embedded software in battlefield automated systems (BAS).

Four techniques are in use at present and have some potential for application to BAS. These include:

a. Developer/expert review (walk-through) of the knowledge base.

b. Comparison of system performance against human expert or expert panel performance on a set of test cases.

c. Comparison of system performance against that of an existing conventional system or technique.

d. Prediction of desirable or undesirable system characteristics from analysis of the knowledge base and inference method, and testing for the predicted characteristics.

As indicated above, the first and second techniques have been used to assess the performance of systems developed by USAEPG. The second and fourth techniques were used to a limited extent, in an observation of a prototype expert system developed by the Army under the Very Intelligent Surveillance and Target Acquisition program. All of the techniques have been applied by one or more organizations and found useful, although they are all manpower intensive and involve dedication of highly skilled personnel for their application.

A number of research efforts are under way to create automated aids for checking various characteristics of a knowledge base at both local and global levels. While most of these are directed at creation of sophisticated development aids, their utility in a testing environment would be immense. The greatest impediment to applying these techniques to expert systems embedded in BAS is the lack of standards of knowledge representation, inference mechanism definition, and actual implementation representation. The tools being developed are targeted for a narrow range of development environments, and the portability of the techniques is an open issue. To address this, USAEPG has submitted SBIR proposals to investigate creation of a taxonomy, to include standard definitions of expert system technologies, as well as to investigate a standard for expert system knowledge base representation. In addition, an SBIR phase II effort is now under way, examining existing and proposed expert system test techniques in some detail.

In order to foster greater cooperation among researchers in this area, and to bring together some of the existing efforts, a USAEPG representative acted as cochairperson of a workshop on test and validation of expert systems, which was held at the annual AAAI conference in August 1988 in St. Paul, Minnesota. Over forty researchers attended, and some twenty presented papers. The full formal proceedings of the workshop are in preparation. In addition to allowing new points of contact, the workshop was responsible for several new coordinated efforts, bringing together researchers not previously familiar with one another's work.

As a result of the workshop, USAEPG has established direct contact with a number of the principle researchers investigating test and validation of expert systems, as well with the other organizations funding such research. The proceedings will provide a snapshot of the state of the art at this point in time, and an independent check to apply to the results of the SBIR efforts when those are received.

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SECTION 3. APPENDIXES

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APPENDIX A. METHODOLOGY INVESTIGATION PROPOSAL

28 August 1987

METHODOLOGY INVESTIGATION PROPOSAL

1. TITLE. AI Test Officer Support Tool

2. INSTALLATION OR FIELD OPERATING ACTIVITY. US Army Electronic Proving Ground, Fort Huachuca, Arizona 85613-7110.

3. PRINCIPAL INVESTIGATOR. Mr. Robert Harder, Software and Automation Branch, STEEP-MT-DA, AUTOVON 879-1879/1870.

4. BACKGROUND. Test design and planning for modern C^3I systems require familiarity with a number of test operating procedures (TOPs) as well as detailed knowledge of specific test tool capabilities. A wide variety of tests must be designed, planned, and scheduled in order to efficiently conduct testing. Interrelationships among test groups and tools, common data requirements and data reduction and analysis requirements, lead time to prepare instrumentation, and required availability of the test item must be well understood in order to efficiently conduct tests within allocated time constraints.

USAEPG has explored the feasibility of an automated system to support the test officer. Using Independent Laboratory In-house Research (ILIR) funds, a prototype system was developed using AI technology. The prototype addressed tests performed by the Simulation and Interference Branch primarily, but could be expanded for other test areas.

5. PROBLEM. Testing C^3I systems involves designing and planning tasks which are becoming increasingly complex. Advances in technology such as microprocessor design, distributed real-time architectures, artificial intelligence, and electro-optics are appearing in new C^3I developments. While this sophisticated technology offers benefits to the developer, it is becoming a considerable burden to the tester. Test officers are required to identify appropriate test methods and associated instrumentation and data acquisition requirements for each emerging technological area. This requires a level of expertise which is rarely found in any one individual. Besides being distributed among individuals, and therefore less available, this hard-earned expertise is frequently lost to the organization because of personnel reassignment or attrition.

6. OBJECTIVE. To improve test methodology by providing the test officer with an automated support tool.

7. MISSION AREA(S) SUPPORTED. All DA mission areas for systems containing embedded computer resources (ECR) are supported. The 'Big 5' program categories (C3, RSTA, etc.) are accommodated by the nonsystem-specific nature of the methodology.

8. PROCEDURES.

a. Summary. The investigation will draw upon previous ILIR efforts by expanding the level of detail and the scope. The result will be an enhanced tool supporting the test officer in specific domains such as electromagnetic compatibility, software testing, and general test mechanisms. Other domain categories will be explored as time permits.

b. Detailed Approach. The USAEPG will:

(1) Extract and codify knowledge from cognizant individuals in fields including electromagnetic and software testing.

(2) Examine other test areas to identify tests performed, responsible branches, test instrumentation capabilities, and characteristic test requirements. Commonality among these various factors will be identified to form a framework which will accommodate all test functions, instrumentation, and resources. Following implementation of the generalized framework, specific test areas (knowledge domains) will be analyzed in depth and incorporated into the tool.

c. Final Product(s).

(1) An AI test officer support tool with enhanced capability--more "smarts" in the existing area of coverage, and additional test areas covered.

(2) Requirements and recommendations for automation of test design and planning functions.

d. Coordination. Extensive coordination with the various test groups of the USAEPG is an inherent characteristic of the investigation. To the extent that test areas covered overlap the areas of interest of other I/FOAs, coordination will be accomplished through existing mechanisms such as the TECOM Software Technical Committee (TSOTEC).

e. Environmental Impact Statement. Execution of this task will not have an adverse impact on the quality of the environment.

f. Health Hazard Statement. Execution of this task will not involve health hazards to personnel.

9. JUSTIFICATION/IMPACT

a. Association with Mission. This investigation directly supports USAEPG's mission relative to test and evaluation. Providing test officers with automated support tools will improve the efficiency and effectiveness of testing.

b. Association with Methodology/Instrumentation Program. This project supports thrusts of the TECOM Methodology Program to improve the quality of testing as well as test process.

c. Present Capability, Limitations, Improvement, and Impact on Testing if not Approved.

(1) Present Capability. TOPs and guidelines, such as the USAEPG Test Officers Handbook, provide static information on test methods and checklists for test planning purposes.

(2) Limitations. Current guidelines often do not provide the level of detail required for optimized application of scarce test resources. Also, the information is static; status of test instrumentation, competition for resources among different test items, and the impact of not performing some test (or lack of test material such as certain documentation) is poorly handled unless the test officer's experience has included similar situations.

(3) Improvement. Using AI techniques to develop a support tool can provide the test officer sufficiently detailed and flexible guidelines. Beside being adaptable to the needs of a specific test item and current with respect to test instrumentation availability, the proposed approach would be sensitive to data requirements and be able to anticipate the impact if tests are not performed. Supported over time, such a tool could accumulate expertise which is presently distributed and too frequently lost.

(4) Impact on Testing if not Approved. The expertise required of test officers is rapidly expanding in scope as innovative technologies are increasingly employed by developers. The corresponding increase in complexity of test methods and instrumentation demands a commensurate improvement in support tools if test resources are to be effectively and efficiently used. Also, without permanent storage and readily available access to "lessons learned", the corporate memory of an activity suffers each time an experienced individual leaves the organization.

10. DOLLAR SAVINGS. No directly supportable dollar savings can be projected at this time. Indirect benefits include improving the quality of testing and evaluation leading to improved quality of fielded systems. Equally difficult to quantify is the retention, concentration, and increased availability of expertise, which is potentially a significant amount.

II. RESOURCES.

a. Financial.

	Dollars (Thousands) FY88		Dollars (Thousands) FY89	
	In-House	Out-of-House	In-House	Out-of-House
Personnel Compensation	10.0		12.0	
Travel	3.5		4.0	
Contractual Support		84.5		42.5
Materials & Supplies	2.0		1.5	
Subtotals	15.5	84.5	17.5	42.5
FY Totals	100.0		60.0	

b. Explanation of Cost Categories.

(1) Personnel Compensation. This cost represents compensation chargeable to the investigation for using technical or other civilian personnel assigned to the investigation.

(2) Travel. This represents costs incurred while visiting government and industry facilities.

(3) Contractual Support. Performance of the investigation will be accomplished with resources provided under an existing support contract.

c. Obligation Plan (FY89).

FQ	1	2	3	4	Total
Obligation Rate (Thousands)	45.0	5.0	5.0	5.0	60.0

d. Man-Hours Required.

In-House:

Contract:

12. ASSOCIATION WITH TOP PROGRAM. This investigation will not directly produce a TOP. However, various TOPs may require review and revision based on the findings.

FOR THE COMMANDER:

(signed)
ROBERT E. REINER
Chief, Modernization and
Advanced Concepts Division

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APPENDIX B. REFERENCES

1. Methodology Investigation for Software Technology for Adaptable, Reliable Systems (STARS), Final Report: Test Methodology with Artificial Intelligence, Harder, et al., U.S. Army Electronic Proving Ground, Fort Huachuca, Arizona, March 1987.

2. TECOM Regulation 70-24, Documenting TECOM Testing, 22 June 1981.

Note: Domain-specific references are available upon request.

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APPENDIX C. ACRONYMS AND ABBREVIATIONS

AAAI........... American Association for Artificial Intelligence
AI............. Artificial Intelligence
AMC............ United States Army Materiel Command
ASL............ Atmospheric Sciences Laboratory
BAS............ Battlefield Automated System
C3............. Command, Control, and Communications
C^3I........... Command, Control, Communications and Intelligence
DoD............ Department of Defense
DTP............ Detailed Test Plan
ES^2............ Expert System Selector
EVA............ Environmental Impact Assessment Expert System
EXSYS.......... Expert System Development Package
I/FOA.......... Installation Field Operating Activity
MET............ Meteorological Expert System
REC............ Record of Environmental Consideration
SBIR........... Small Business Innovative Research
STARS.......... Software Technology for Adaptable, Reliable Systems
TECOM.......... United States Army Test and Evaluation Command
TPD............ Test Plan Drafter
TSOTEC......... TECOM Software Technical Committee
UAV............ Unmanned Aeronautical Vehicle
USAEPG......... United States Army Electronic Proving Ground

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APPENDIX D. DISTRIBUTION

Addressee	Number of Copies
Director US Army Materiel Systems Analysis Activity ATTN: AMXSY-CA (Herbert Cohen) Aberdeen Proving Ground, MD 21005-5071	1
Commander US Army Test and Evaluation Command ATTN: AMSTE-TA-W	1
AMSTE-TC-M	3
AMSTE-TA	6
AMSTE-SI Aberdeen Proving Ground, MD 21005-5055	2
Administer Defense Technical Information Center ATTN: DDA Cameron Station Alexandria, VA 22304-6145	2
Commander US Army Cold Regions Test Center ATTN: STECR-TM APO Seattle, WA 98733-5000	1
Commander US Army Combat Systems Test Activity ATTN: STECS-DA-M Aberdeen Proving Ground, MD 21005-5000	2
Commander US Army Dugway Proving Ground ATTN: STEDP-PO-P Dugway, UT 84022-5000	1
Commander US Army Electronic Proving Ground ATTN: STEEP-TD	1
STEEP-ET	1
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