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AN ISSUE PAPER FOR A STRATEGIC DEFENSE INITIATIVE ORGANIZATION SOFTWARE TEST AND EVALUATION POLICY

Bill R. Brykczynski
Christine Youngblut

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INSTITUTE FOR DEFENSE ANALYSES
1801 N. Beauregard Street, Alexandria, Virginia 22311-1772

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Bill R. Brykczynski, Christine Youngblut

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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The purpose of IDA Paper P-2266 is to document the goals and proposed contents of a software test and evaluation (T&E) policy for the Strategic Defense Initiative Organization (SDIO). Such a policy would enable SDIO to obtain consistent results from software T&E, obtain the maximum benefit from available T&E technology, and provide support for a Full-Scale Development decision. In general, the software T&E policy will be the mechanism for defining the activities and responsibilities of the various T&E participants in achieving the necessary change in practices and attitudes to ensure effective T&E. Findings, conclusions, and recommendations are listed.

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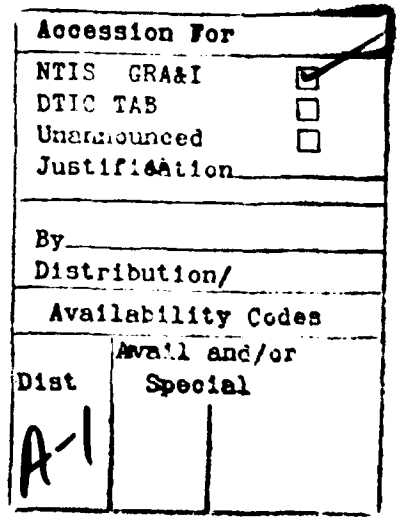

PREFACE

The purpose of IDA Paper P-2266, *An Issue Paper for a Strategic Defense Initiative Organization Software Test and Evaluation Policy*, is to describe the goals and proposed contents of a software test and evaluation (T&E) policy for the Strategic Defense Initiative Organization (SDIO). Such a policy would enable the SDIO to obtain consistent results from software testing and evaluation (T&E), obtain the maximum benefit from available T&E technology, and provide support for a Full-Scale Development decision.

This document partially fulfills the objective of Task Order T-R5-597.21, SDS Test and Evaluation, by providing draft guidelines for the integration of test and evaluation concerns throughout the software life cycle. P-2266 will be used to identify the goals and contents of a software T&E policy for the SDIO and is directed towards SDIO and element program managers.

The document was reviewed on August 11 and 18, 1989, by the members of the following CSED Peer Review: Cy D. Ardoin, James Baldo, Herbert R. Brown, Cathy Jo Linn, Katydean Price, and Richard Wexelblat.

1. INTRODUCTION

This paper describes the requirements for a Strategic Defense System (SDS) Software Test and Evaluation (T&E) Policy. The T&E[1] of SDS software is one of the key factors affecting the creation of a reliable SDS [1]. Currently, little DoD guidance is available to SDS contractors in this area. Although the software annex of the SDS Capstone Test and Evaluation Master Plan (TEMP) [2] and the element TEMPs provide plans relating test activities to required system characteristics, these planning documents are not appropriate places for providing the necessary T&E technology guidance. Instead, a single authoritative source of T&E technology guidance which augments the various TEMPs is required. The SDS Software T&E Policy will fill this need.

In accordance with the SDS Software Policy [3], the Software T&E policy will provide a strategy to promote a *change in attitudes, policies, and practices* concerning software testing. It will create and foster an aquisition and management environment which encourages, promotes, and rewards the use of modern software testing practices in the development of mission-critical development SDS software.[2]

The policy itself will be restricted to identifying requirements for software testing practices. The services and other implementing agents shall develop implementation documents that follow SDIO guidelines set forth therein. These documents shall be consistent with existing or planned software engineering practices. The SDIO will

1. Within this paper, the word "software" is an implied prefix to the abbreviation "T&E", unless otherwise qualified.
2. It must be remembered that mission-critical SDS software includes simulations, research, and support software in addition to operational software.

implement the policy for its own software development efforts, thus providing guidance for service implementation. The policy will be reviewed annually or as needed against evolving technology.

2. GOALS OF THE SOFTWARE T&E POLICY

The goals of the policy can be grouped into three general areas.

2.1 Provide consistency among diverse T&E efforts

Several different groups will be involved in SDS software T&E. For example, the SDS System Engineer will specify system requirements and conduct system integration and testing whereas the SDS element program offices are responsible for element-level testing. In addition to those who actually perform T&E, there are various organization which support these activities. Examples in this case include the National Test Bed and the Software Center. It is essential that each group understand the information and data provided by other groups. Moreover, consistency is a prerequisite for allowing related activities to cooperatively provide confidence in the reliability and suitability of the SDS without unnecessary duplication of effort.

The policy must fulfill two major objectives. First, it must provide for uniform expression of explicit, traceable T&E requirements. These requirements must support common interpretation by different groups and enforce at least a necessary minimum level of testing. Second, the policy must ensure consistent reporting of T&E results. Not only must they clearly indicate the success or failure of particular tests, but T&E results

must also provide unambiguous information about the status of the software. Furthermore, this information must provide feedback to both the development and T&E activities. Failure to achieve these objectives will severely limit the ability to demonstrate confidence in the reliability of the SDS.

2.2 Obtain the maximum benefit from available T&E technology

Traditionally, T&E is used simply as an acceptance challenge at the end of each development phase. Such an approach fails to exploit the potential of available T&E technology. Not only does late identification of errors adversely affect development costs and schedules, but reliability *cannot* be tested into software. Consequently, the policy must ensure that T&E is an integral part of development activities, not a final step to "get the bugs out."

Another key point to be addressed by the policy is automated support of T&E. Tools to support T&E planning, performance, analysis, and reporting are not merely desirable but increasingly indispensable. Indeed, many advanced testing techniques *cannot* be applied in the absence of suitable automated support. The current lack of production quality tools is one of the contributing factors to the extreme lag of current testing practice behind the state of the art. The policy must address the responsibilities and resources needed to ensure the availability of appropriate automated support to T&E performers.

2.3 Support a Full-Scale Development (FSD) decision

A crucial question in making the SDS FSD decision will be whether the necessary confidence in the correct and reliable operation of the software can be achieved, and at what cost this confidence can be obtained. If the decision to proceed is made, then the experience gained during previous T&E activities should be exploited in planning for FSD T&E. The key issue is the need for better understanding of the capabilities of available technology and how this understanding may be used to reason about the software. This understanding should be used to support both T&E and development activities.

The policy should specify the actions and responsibilities necessary for collecting and analyzing data on the costs and capabilities of specific T&E and development practices. It should also specify how the accumulated information will be fedback to improve T&E and development practices. With respect to the FSD decision, information on the capabilities of T&E technology should be interpreted in the light of trends in the practical experience with demonstration/validation software and the history of technology development.

3. REQUIREMENTS OF THE SOFTWARE T&E POLICY

In general, the policy will be the mechanism for defining the activities and responsibilities of the various T&E participants in achieving the necessary change in practices and attitudes to ensure effective T&E. The following requirements will provide an initial step toward achieving the above goals.

3.1 Define common terminology

The current lack of a common SDIO T&E terminology is a severe handicap in acquiring a consistent view of the status of the software and advancing the state of the practice. For example, the Army, Air Force, and Navy all have different definitions for *software reliability*. The policy must provide a single, authoritative source for T&E terminology which applies to all SDS software development efforts.

3.2 Integrate testing activities into development

To ensure that the necessary confidence in the software *can* be acquired (and at acceptable cost), software testing issues must be considered during the earliest development stages. As system requirements are allocated to software, explicit testing requirements must be identified in conjunction with functional and performance requirements. Not only must these testing requirements, along with the functional and performance requirements, be traceable through all development stages, but they must specify the types and extent of necessary testing for specific development products at each development stage. Additionally, as previously noted, the actual testing process must not be postponed until the final development stages. Indeed, in many cases (e.g., formal verification) the technology can *only* be effectively applied as an integral part of development activities. Consequently, SDS T&E must provide software developers with timely information that they can act on to ensure the development of reliable and quality products.

One approach for ensuring proper integration of testing into development activities will be to specify test articles throughout the life cycle, along with the test requirements

which determine the testing to be performed on those articles. The policy will provide suitable mechanisms for requiring the timely specification of such requirements and test articles and also for ensuring that the necessary test events are planned for and conducted. For example, the policy may make testing requirements a deliverable product. It is anticipated that the SDIO-implementing directive will provide an initial syntax and semantics for the testing requirements and specify the conduct of formal reviews to assure their appropriate use.

In addition to providing a common mechanism for determining the minimum levels of required testing for all development products, testing requirements will provide a foundation for T&E resource estimation and scheduling during both development and support phases. The policy will provide mechanisms for requiring timely resource estimation and scheduling while the SDIO implementing directive will likely specify suitable technology for performing these activities.

It is recommended that validation suites (similar in nature to those used in the Ada Compiler Validation Capability (ACVC) [4]) pertaining to particular testing requirement and development product combinations be evolved in the course of T&E activities. As demonstrated by the ACVC, the advantages offered by such validation suites are considerable. One is the ability to react to the discovery of an error, and tracing it back through a series of earlier development products if necessary. This ability will be invaluable for a system with the size and requirements evolvability of SDS. The policy will establish the appropriate mechanisms for requiring the development and use of validation suites, together with assigning responsibilities for the establishment and maintenance of necessary facilities.

3.3 Define information and data requirements for T&E activities

The prime mechanism for ensuring consistency of T&E information will be the specification of explicit data requirements. These data requirements must be designed to ensure the following:

- All pertinent issues will be considered during T&E planning and that planning documents will include all the information needed to provide sufficient guidance for actually conducting T&E activities. For example, test plans for particular test events must explicitly specify test completeness criteria.
- Testing activities will provide the data required for analyzing the T&E process and determining its effectiveness and adequacy.
- Test results will facilitate accurate understanding and communication of the software status.
- Test histories will facilitate efficient regression testing.

The policy will impose a mechanism for attaining the necessary data from T&E participants. It will also assign responsibilities for establishing and maintaining a T&E database.

3.4 Support a technology information base

Information which can guide the selection and application of available techniques and tools in all aspects of T&E planning, performance, analysis, and reporting is needed. Establishing a technology database is not within the scope of the policy—this is within the purview of the Software Center. However the policy should establish mechanisms which

require T&E participants to provide the necessary data and which encourage appropriate use of the information base.

3.5 Support for a tool repository

The encouragement of advanced testing practices must be supported by the provision of necessary automated tools. As in the case of the technology information base, the development of a tool repository does not fall under the purview of an T&E policy. However, the policy will identify who is responsible for establishing and maintaining the repository and provide mechanisms which assure the appropriate use of the available tools by T&E participants.

4. SUPPORTING DEVELOPMENT OF THE SOFTWARE T&E POLICY

Five actions must be performed either prior or in conjunction with development of the policy:

4.1 Establish contacts with T&E participants and assess current practices

It is necessary to determine (1) what T&E practices are currently in use, or are planned for use, and (2) the quality of these practices. This analysis will constitute a baseline of the relevant state of the practice which will assist in determining the necessary extent and rate of technology transition.

4.2 Discuss intent of policy with SDIO T&E organizations and T&E participants

The SDIO Test and Evaluation Working Group (TEWG) has recently established a

Software Subcommittee. This subcommittee will be the primary interface between prospective T&E participants and the developers of the policy. One of the objectives of initial meetings of the subcommittee will be to agree on the needs and objectives of the policy and solicit initial support for activities and responsibilities. The relationships and roles of the various groups in T&E planning, conduct, reporting, and the various support activities previously outlined must be clarified with the relationships and roles of testing agents and developers.

4.3 Coordinate policy with other SDIO policies and directives, and with applicable DoD standards

It may be necessary to provide tailoring of established standards.

4.4 Increase awareness of available technology

There are several advanced T&E technologies that are ready for transition into practice [5]. Nevertheless, before these techniques can be mandated for use, hard data is needed on their benefits and cost along with practical experience in their use. A series of demonstrations of suitable technologies should be undertaken.

4.5 Develop a technology research plan to address critical gaps in T&E technology

Many of the T&E challenges being faced by SDS also impact other large scale software development efforts. These challenges are recognized. Promising research is being conducted by academia, for example, the goal-directed measurement work at the University of Maryland [6], and organizations such as National Aeronautics Space

Administration (NASA) [7]. The SDIO should establish and maintain contact with these research communities to ensure that best use is made of available research dollars in attacking critical technology deficiencies.

In particular, the SDIO should support the development of a comprehensive testing environment. While a set of individual tools to support advanced testing techniques can be made available within the near future, the SDIO should work towards providing an integrated testing environment. This environment should provide a wide range of testing and analysis techniques, together with supporting tools such as test drivers, test data generators, and reporting mechanisms. It must also support the data collection and analysis activities called for in the policy requirements. Coordination with the software engineering environment efforts by the SDIO Software Center will enable development activities to be integrated with testing activities. In addition, there are a number of advanced design principles which are prerequisites for a suitable environment:

- An evolutionary architecture which facilitates growth as new testing, analysis or support techniques are developed (e.g., a tool fragment approach [8]).
- Persistent object management [9,10] which allows an evolving collection of tools to be applied to test objects.
- Incremental analysis capabilities so that testing and analysis can be performed on incomplete software products.
- Integrated application of testing and analysis techniques [11].

Additionally, the use of *process programs* which provide precise and rigorous description of software processes [12,13] should be investigated as a possible mechanism

for supporting these capabilities and providing developers with pro-active guidance in testing activities.

5. REFERENCES

[1] Parnas, D.L. "Software Aspects of Strategic Defense Systems." *Communications of the ACM* 28/12 (Dec 1985):#1327-1335.

[2] Strategic Defense System Test and Evaluation Master Plan (TEMP), 30 June 1987.

[3] Strategic Defense Initiative Organization. *Strategic Defense System Software Policy.* 16 November 1988. Draft

[4] Williams, R., and P. Brashear. "Ada Compiler Validation: Purpose and Practice." In *Proceedings of the 7th Annual National Conference on Ada Technology*, March 13-16, 1989, Atlantic City, NJ, 522-527. ACM Press.

[5] Youngblut, C., B. Brykczynski, K. Gordon, R.N. Meeson, and J. Salasin. *SDS Software Testing and Evaluation: A Review of the State-of-the-Art in Software Testing and Evaluation With Recommended R&D Tasks*. February 1989. Alexandria, VA: Institute for Defense Analyses. IDA Paper P-2132.

[6] Basili, V.R., and H.D. Rombach. "The TAME Project: Towards Improvement-Oriented Software Environments." *IEEE Transactions on Software Engineering* 14/6 (Jun 1988):#758-773.

[7] McGarry, F.E. "Recent SEL Studies." In *Proceedings of the 10th Annual Software Engineering Workshop*, December 1985, Greenbelt, MD. NASA/GSFC.

[8] Zeil, S.J., and E.C. Epp. *Interpretation in a Tool-Fragment Environment.* University of Massachusetts. COINS 87-108. Also published in *Proceedings of the 10th International Conference on Software Engineering*, April 11-15, October 1987, Singapore, 241-248. IEEE Press.

[9] Osterweil, L.J. "Toolpack – An Experimental Software Development Environment Research Project." *IEEE Transactions on Software Engineering* 9/6 (Nov 1983):#673-685.

[10] Wileden, J.C., A.L. Wolf, C. Fisher, and P. Tarr. "PGRAPHITE: An Experiment in Persistent Typed Object Management." In *Proceedings of the ACM SIGSOFT/SIGPLAN Software Engineering Symposium on Practical Software Development Environments*, November 28-30, 1989, Boston, MA, 130-142. ACM Press.

[11] Clarke, L.A., D.J. Richardson, and S.J. Zeil. "Team: A Support Environment for Testing, Evaluation, and Analysis." In *Proceedings of the ACM SIGSOFT/SIGPLAN Software Engineering Symposium on Practical Software Development Environments*, November 28-30, Boston, MA, 121-129. ACM Press.

[12] Osterweil, L.J. "Software Processes are Software Too." In *Proceedings of the 9th International Conference on Software Engineering*, March 30 - April 2, 1987, Monterey, CA, 2-13. IEEE Press.

[13] Rombach, H.D., and L. Mark. *Software Process and Product Specifications: A Basis for Generating Customized Software Engineering Information Bases.* University of Maryland. July, 1988, CS-TR-2062/UMIACS-TR-88-51.