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CONTRACTING AND MANAGEMENT GUIDE FOR SNEAK CIRCUIT ANALYSIS (SC--ETC(U)

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SEPT 1980

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FOREWORD

Sneak Circuit Analysis (SCA) is a technique for evaluating hardware systems and software programs. The purpose of this analysis technique is to identify latent circuits and conditions that could inhibit desired functions or cause undesired functions to occur. By definition, sneak conditions are not caused by failures, but rather they represent conditions inadvertently designed into the hardware system or software program.

The SCA technique, by that name, is a relatively modern innovation, but many facets of the analysis are similar to long standing techniques. The SCA is unique in that it represents a very formalized, structured, and orderly process providing a high degree of confidence that unintended conditions have not been introduced into the hardware or software. As such, it complements, but does not replace or supersede, other common design analysis techniques such as the failure modes and effects analysis (FMEA), safety hazard analysis, component stress analysis, etc.

Sneak conditions may result from several factors, but the primary causes are lack of total system overview, integration of changes, and just plain human error or oversight. As hardware systems and software programs become increasingly more sophisticated and complex, inevitably involving more interfaces between hardware elements, software elements, and human elements, the need for the SCA (or equivalent techniques) becomes more pronounced.

Management and engineering personnel involved in the design and development of systems and equipment should be sufficiently familiar with the SCA technique to permit them to make appropriate decisions regarding its applicability to their programs, as well as to effectively manage the effort for the greatest return on investment.

The decision to require the SCA (or not to require it) on a given program involves rather complex trade-offs. Among these are cost versus potential benefits, system criticality, system complexity, and comprehensiveness of other planned analyses and test programs. Accordingly, the intent of this document is to explain the SCA process in terms of what it is designed to accomplish, with consideration given to potential benefits as well as penalties. Further, the document provides guidelines for the ordering and management of the SCA as well as methods for evaluation of prospective SCA contractors and the results of their analyses.

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Philadelphia, Pennsylvania 19120

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Prepared by: Naval Sea Systems Command
SEA 6151
Washington, D.C. 20362
September 1980

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1.0 SCOPE

1.1 General. This guide presents a description of the Sneak Circuit Analysis (SCA) with primary emphasis on its purpose and potential benefits, as well as cost factors and trade-offs. It is not the intent of the guide to define the exact methods or techniques for the performance of the analysis. The following topics relating to the SCA are addressed:

a. What is a Sneak Circuit Analysis?
b. Why would the SCA be performed?
c. Who performs/participates in the SCA?
d. When should the SCA be performed?
e. How is the SCA ordered and managed?
f. What are the associated cost factors?

1.2 Purpose. The purpose of this guide is to familiarize management and engineering personnel responsible for the design and development of systems and equipment with the SCA concept, and thus enable them to make appropriate decisions regarding its applicability to a given program. Guidelines are provided for the management and implementation of the SCA.

1.3 Application. The SCA concept has potential applications in any design or development program for systems, equipment, or software and its merits should be evaluated as part of the development planning effort. In the past, the SCA was generally considered applicable only to electrical and electronic circuits, but the concept has evolved to where it can be used to evaluate other systems, including mechanical, pneumatic, hydraulic, power generation, etc. The complexity and criticality of such systems or equipments, the extent of other analyses and test programs, and the associated cost factors are the primary determinants in the decision to require (or not to require) the SCA.

1.4 Organization. This guide has been organized in a manner intended to be most useful to those personnel who participate in the decision making process as to whether or not the technique is appropriate, and then to those who are to implement the process. Accordingly, the program or project manager should not find it necessary to read beyond the FOREWORD, SCOPE, and Section 4.0 to make decisions such as (1) non-applicable, (2) further study by appropriate engineering disciplines is warranted or (3) definitely applicable, extent to be established. If the technique is determined to be potentially applicable in a given situation, the program or project manager should per use the discussions of cost and schedule, presented in Section 7.0 and 9.0. The decision to require or not require the SCA does not differ substantially from other program decisions, in that potential benefits, relationships to other efforts, costs, availability of resources, schedule impact, and penalties or risks of not performing this effort, must be considered.

2.0 APPLICABLE DOCUMENTS

2.1 Specifications and standards. The following documents, of the issue in effect on the date of invitations for bid or requests for proposals, form a part of this guide to the extent specified herein:

Specifications, Military:

MIL-M-24100 - Manual, Technical, Functionally Oriented Maintenance Manuals (FOMM), for Equipments and Systems

Standards, Military:

MIL-STD-280 - Definitions of Item Levels, Item Exchangeability, Models, and Related Terms

MIL-STD-721 - Definitions of Effectiveness Terms for Reliability, Maintainability, Human Factors, and Safety

MIL-STD-785 - Reliability Program for System and Equipment, Development and Production

MIL-STD-882 System Safety Program Requirements

MIL-STD-1472 - Human Engineering Design Criteria for Military Systems, Equipments, and Facilities

MIL-STD-1679 - Weapon System Software Development

(Copies of specifications, standards, and other publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3.0 DEFINITIONS

3.1 General. Definitions of terms used in this guide are in accordance with MIL-STD-280 and MIL-STD-721. Specialized terms unique to the SCA technique are defined in the following subparagraphs in the context used in this publication.

3.1.1 Clue. A known relationship between a historically observed sneak circuit condition and the underlying causes which created it. Clues are used to evaluate other systems for possible sneak circuit conditions.

3.1.2 Contractor. An activity (agency) used to perform some service to a government agency. As used herein, contractor may refer to another government activity.

3.1.3 Glitch. An anomolous circuit response which occurs without apparent reason, generally due to signal overlap or timing problems.

3.1.4 Highlight. The process of isolating a particular design feature which is likely to generate a system malfunction, so that it can be subjected to intensive analysis.

3.1.5 Manual SCA procedures. SCA procedures that are performed without computer assistance.

3.1.6 Network. A group of interconnnected elements intended to perform some system function. Elements may be electrical components, electromechanical components, computer program instructions, operator actions, procedures, mechanical or pneumatic functions, or any other portion of a system that can be considered as an independent entity. Although the networks most frequently considered in SCA consist of electrical and electromechanical components, the definition is not restricted to networks of this type.

3.1.7 Path search. A process of searching out all possible paths through a network.

3.1.8 Software. A computer program which may be either an independent (stand-alone) program or an embedded (within other system hardware) program.

3.1.9 Tailoring. The process of adapting a specification to fit the constraints of a particular program.

3.1.10 Topological methods. Sneak circuit analysis procedures which are based primarily on the relationship between known sneak conditions and the network patterns they display in a schematic diagram.

3.1.11 Trade-off. The process of comparing the relative advantages and disadvantages of different courses of action.

3.1.12 V&V. Verification and Validation, generally referring to those activities in a software development program that serve to assure the adequacy and the accuracy of the software.

4.0 GENERAL DESCRIPTION

4.1 Sneak circuit. A sneak circuit is an unexpected path or logic flow within a system which, under certain conditions, can initiate an undesired function or inhibit a desired function. The path may consist of hardware, software, operator actions, or combinations of these elements. Sneak circuits are not the result of hardware failure but are latent conditions, inadvertently designed into the system or coded into the software program, which can cause it to malfunction under certain conditions. Categories of sneak circuits are:

a. Sneak paths which cause current, energy, or logical sequence to flow along an unexpected path or in an unintended direction.

b. Sneak timing in which events occur in an unexpected or conflicting sequence.

c. Sneak indications which cause an ambiguous or false display of system operating conditions and thus may result in an undesired action taken by an operator.

d. Sneak labels which incorrectly or imprecisely label system functions, e.g., system inputs, controls, displays, buses, etc., and thus may mislead an operator into applying an incorrect stimulus to the system.

Figure 1 depicts a simple sneak circuit example. With the ignition off, the radio turned to the on position, the brake pedal depressed and the hazard switch engaged the radio will power on with the flash of the brake lights.

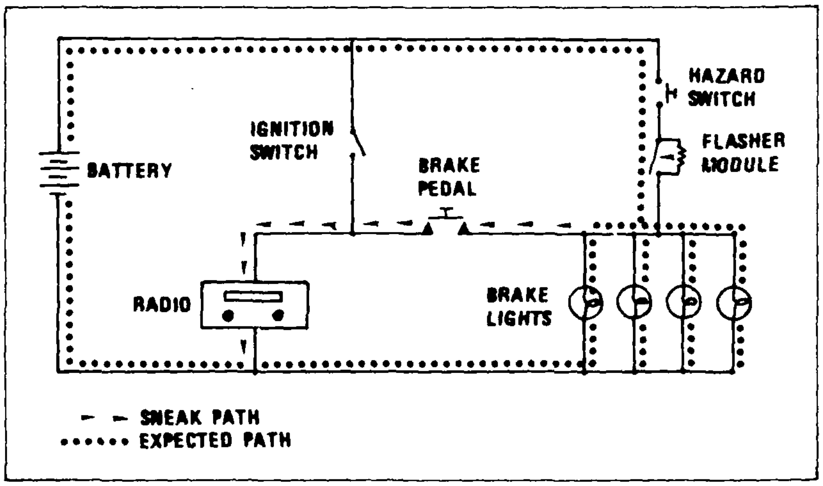


Figure 1. Automotive Sneak Circuit.

4.2 Sneak circuit analysis (SCA). Sneak circuit analysis is the term that has been applied to a group of analytical techniques which are intended to methodically identify sneak circuits in systems. SCA techniques may be either manual or computer-assisted, depending on system complexity. Current SCA techniques which have proven useful in identifying sneak circuits in systems include:

a. Sneak path analysis - A methodical investigation of all possible electrical paths in a hardware system. Sneak path analysis is a technique used for detecting sneak circuits in hardware systems, primarily power distribution, control, switching networks, and analog circuits. The technique is based on known topological similarities of sneak circuits in these types of hardware systems.

b. Digital sneak circuit analysis - An analysis of digital hardware networks for sneak conditions, operating modes, timing races, logical errors, and inconsistencies. Depending on system complexity, digital SCA may involve the use of sneak path analysis techniques, manual or graphical analysis, computerized logic simulators or computer-aided design (CAD) circuit analysis.

c. Software sneak path analysis - An adaptation of sneak path analysis to computer program logical flows. The technique is used to analyze software logical flows by comparing their topologies to those with known sneak path conditions in them.

d. Other sneak circuit analysis techniques - Because the technology of hardware and software systems is evolving at a rapid rate, new SCA techniques will undoubtedly evolve as well. The technique will also find use in analysis of other than electrical, or electronic systems (such as mechanical, hydraulic, pneumatic, etc.), where analogous situations of energy flow, logic timing, etc. are encountered.

4.3 Sources of sneak conditions. Sneak conditions result from the following three primary sources: system complexity, system changes, and user operations. Hardware or software system complexity results in numerous subsystem interfaces that may obscure the intended functions or produce unintended functions. The effects of even minor wiring or software changes to specific subsystems may result in undesired system operations. A system that is relatively sneak free can be made to circumvent desired functions or generate undesired functions as a consequence of improper user operations or procedures. As systems become more complex, the number of human interfaces multiply because of the involvement of more design groups, subcontractors, and suppliers, and the probability of overlooking potentially undesirable conditions is increased proportionately.

4.4 Historical development. Systems analysis techniques, in one form or another, have been employed throughout the evolution of the various technologies. As systems become more and more complex, and as greater emphasis is placed on safety and reliability, the need for more sophisticated techniques evolves. The development of the SCA, as a unique analytical technique under that name, came about when it was recognized that conventional analytical methods did not identify certain subtle anomalies in systems design. The first investigations using SCA techniques were initiated in the 1960s by NASA to identify sneak conditions in missile launch command and control electrical subsystems. An SCA technique was developed that would reveal sneak circuits in these type systems, and it was successfully used on the Apollo space program. SCA was later expanded to encompass analog systems and digital logic, and subsequently to include software and software/hardware integration. The SCA technique can also be applied to hydraulic, pneumatic, and other analogous systems and has been used in the analysis of detailed system operating procedures.

4.5 Relation to other analyses. A major consideration in other analyses is the potential effect of component and/or subsystem failures, and methods for preventing or mitigating such effects. On the other hand, the SCA considers the potential that an undesired function may occur, or that a desired function may be inhibited, given that the system is performing as designed. Thus, the SCA looks at the system from a different perspective, and complements these other techniques, but does not replace them. To an extent, the SCA will identify many of the same potential problems as the other techniques and might therefore be considered somewhat redundant, or it might be considered a desirable "double-check" for these aspects, depending on how one views it.

4.6 Relation to test programs. Most test programs are designed to determine if desired functions occur under given conditions. It is seldom feasible to test all combinations of conditions that might result in undesirable or unexpected functions. Tests frequently can be performed on only a limited number of items, which typically will not represent the range of variables that may be inherently present in the total population of a given item. Tests are expensive, and in many instances, destructive in nature. Thus, test programs are not a viable substitute for analyses of any type. However, the results of analyses (such as SCA) may identify potential problems, allowing the test program to be structured such that if these problems are present, they will be detected.

4.7 SCA techniques. SCA has been successfully applied to a variety of system types. Somewhat different SCA techniques are appropriate to each of the different types of systems, e.g., computerized path search methods are particularly useful in analyzing relay switching systems and power distribution circuits, but are not completely sufficient in analyzing digital circuits. As new hardware technologies have evolved, SCA techniques have been adapted and improved in order to identify unwanted or unexpected system operating modes before they are propagated into the deliverable hardware. Different contractors may approach the problem in different but more or less equivalent ways. At least three types of SCA are in current use; (1) sneak path analysis, (2) digital SCA, and (3) software sneak path analysis. Several other methods have also been postulated.

4.7.1 Sneak path analysis. This method of SCA attempts to discover sneak circuit conditions by means of methodical analysis of all possible electrical paths through a network. Because of the large volume of data involved, sneak path analysis normally mandates computer data processing. It has been found that sneak circuit conditions generally have certain common characteristics which are directly related to topological patterns within the network. Sneak path analysis uses these common characteristics as "clues" to look for sneak circuits in the system being analyzed.

4.7.2 Digital SCA. This method of SCA is intended to discover sneak circuit conditions in digital systems. Digital SCA may involve some features of sneak path analysis, but it may also involve additional computer assisted techniques such as computerized logic simulation, timing analysis, etc., to handle the multiplicity of system states encountered in modern digital designs. In general, digital SCA will identify the following types of anomalies:

a. Logic inconsistencies and errors,

b. Sneak timing, that is, a convergence of signals which causes an erroneous output due to differing time delays along different signal paths through a digital network,

c. Excessive signal loading or fan-out, and

d. Power supply cross-ties, grounding, or other misconnections of signal pins.

4.7.3 Software sneak path analysis. Software sneak path analysis was adapted from hardware sneak path analysis. It was found that computer program flow diagrams which contained known sneak paths were most often associated with certain common flow diagram topologies and had other common characteristics. These common characteristics served as a basis for establishing "clues" which could be used to analyze new computer program flow diagrams. Computerized path search programs developed to do SCA on hardware were adapted or rewritten to accept software logical flows, and new clues were developed to analyze them. Software SCA can be done either manually or with computer assistance, depending primarily on the size and complexity of the software. It may be combined with the hardware SCA and is most often used on embedded software in a complete minicomputer or microcomputer-controlled hardware system. It has been used on both assembly language and higher order language programs.

4.7.4 Other SCA techniques. Variations of the SCA have been developed to analyze particular types or combinations of systems, such as hardware/software interfaces. The application of any new SCA procedure to a particular system or situation must be judged on its demonstrated effectiveness in detecting sneak circuits in similar cases or on its anticipated benefit in the specific situation being considered. This guide cannot explicitly predefine a course of action for handling new SCA types which may emerge, but the general ground rules for evaluating applicability will apply.

4.8 Manual vs. computer-aided SCA. All of the defined types of SCA, i.e., sneak path analysis, digital SCA, and software sneak path analysis may be performed manually under some limited conditions. Computer-assisted SCA data processing is also possible with each of these types and is absolutely essential for more complex systems. The availability and thoroughness of computer aids would strongly influence the selection of a contractor to perform SCA on a complex system.

4.8.1 Typical computer aids. Computer aids which may be used to assist in performing SCA tasks on large systems include:

a. Configuration management programs to handle large volumes of system configuration data.

b. Automated path search, network plotting, and "clue" evaluation programs used in sneak path analysis.

c. Digital logic analyzer programs used on complex digital systems.

d. Circuit analysis and design programs used to analyze sub-circuits and functions.

e. Code analyzers, and in some cases, compilers for software programs.

f. Report generation programs.

4.8.2 Integration with other techniques. Some contractors may integrate their computer-aided SCA programs with CAD or circuit analysis programs which perform other functions that are not specifically SCA procedures, such as, stress analysis, worst case design analysis, failure modes analysis, or even with automatic wire-wrap software. These other features may influence the selection of a contractor to perform SCA because of cost efficiencies to be realized.

4.8.3 Manual techniques. One technique that has been effective in identification of some of the same types of anomalies that are disclosed by the SCA is the development of the functional logic diagrams and the associated baseline data required in the preparation of Functionally Oriented Maintenance Manuals in accordance with MIL-M-24100. For systems requiring such manuals, the baseline data would serve as an input to the SCA, and could be considered adequate in lieu of the SCA, in some situations. Other manual techniques, such as the construction of graphic logic diagrams, have been used successfully. Generally, however, manual techniques are not viable on other than rather simple systems.

5.0 PURPOSE, BENEFITS, TRADE-OFFS

5.1 Benefits of SCA. Sneak Circuit Analysis offers three principal benefits in the analysis of systems which distinguish it in some respects from other analytical techniques.

a. Sneak conditions are distinguished from other types of malfunctions primarily by their resistance to conventional forms of analysis. Thus, SCA can identify such problems as unintended current paths, false indications, misleading labels, sneak timing or signal race conditions, "glitch" conditions, and many "intermittent" problems which occur at only one portion of an operational cycle or are the result of procedural causes rather than faulty components. SCA is a "highlighting" technique which isolates particular areas of the system that are most likely to generate sneak conditions and applies intensive analysis of those areas to look for possible system malfunctions. Consequently, SCA is much more efficient in finding design flaws which would be classified as "sneak" conditions than other more conventional analyses.

b. SCA inherently results in a reasonably thorough design review by qualified analysts with experience and training in the type of system being analyzed. The analysts generally will possess a list of "clues" which are applied to isolate sneak conditions. Most of these clue lists also contain a variety of other common design oversights to consider when performing the SCA. While the SCA cannot be considered comprehensive in these other areas, it provides a "second check" of other more specific analyses, such as stress analysis, FMECA, etc. It has been found that the SCA frequently identifies problems in related areas such as:

   (1) Overstressed parts,

   (2) Single failure points,

   (3) Unnecessary or unused circuitry or components,

   (4) Lack of relay transient protection,

   (5) Excessive fan-out on microcircuits,

   (6) Component misapplication,

   (7) Drawing errors, etc.

c. SCA complements a number of other analyses commonly performed in a system development program, filling in for "blind spots" which exist in all analytical techniques. For example, it complements an FMECA by considering procedural errors rather than part failures. It complements the test program by concentrating on situations or conditions under which the system might not work rather than on proving that the system does work under particular controlled input condition. Section 5.3 discusses a number of other examples of this complementary nature of SCA when compared to more conventional analyses and test programs.

5.1.1 Benefits to system reliability. SCA benefits the system reliability program by identifying potential system malfunctions which are not the result of part failures. The more conventional methods of reliability prediction and control concentrate on the influence of inherent part failure rates on system reliability. More often than not, inherent or "random" part failures are not the most significant contributor to observed field failures of a system. Design oversights, procedural problems, and interface problems cause a significant number of field failures. By identifying these kinds of malfunctions, SCA attacks the persistent problem that exists of reconciling reliability predictions with observed field failure rates. In fact, SCA may be indicated when a large number of unexplained or non-verifiable field failures have been experienced on a program. By removing operational failures, glitches, intermittent failures etc., system uptime can be improved. The number of non-verifiable failures in the rework cycle should also be reduced, further increasing operational availability of the system.

5.1.2 Benefits to system safety. SCA is considered to be a System Hazard Analysis by MIL-STD-882, and it definitely performs this function, although the scope of SCA is considerably broader. Sneak circuits can be hazardous, and their removal would improve system safety in these cases. The performance of SCA can be very useful in performing a comprehensive Operating Hazard Analysis (OHA) or Operation and Support Hazard Analysis (O&SHA) because it identifies hazards which result from operational or procedural causes.

5.1.3. Benefits to life cycle cost. SCA can act to reduce life cycle cost of a system through early identification and control of system malfunctions. The removal of malfunctions which would occur during the Operation and Maintenance phase is particularly effective in reducing life cycle costs. Since SCA aims at a class of problems which are often overlooked by other analyses and test programs, the life cycle cost impact of SCA can be very real.

5.2 Applicability considerations. SCA must be considered for any Department of Defense (DoD) system procurement requiring conformance to MIL-STD-785. An SCA should be performed on a DoD system whenever operational requirements would make the consequences of a sneak circuit unusually severe. This decision can often be made by postulating the most severe consequences of possible unwanted operational modes and comparing the resultant cost with that of an SCA. Obviously some costs cannot be quantified in terms of dollars, such as the cost of human life, or a significant loss of defense preparedness, but in these cases, performance of an SCA is clearly indicated. SCA should be performed when one or more of the following conditions is present:

a. The system mission is critical, to the point that operational malfunctions cannot be tolerated.

b. Improper function of the system could endanger human life or substantially damage expensive equipment.

c. The system complexity is such that sneak circuits may go undetected in normal testing.

d. Correction of sneak conditions, if they occurred in operation, would be difficult or impossible.

e. The system involves interfaces of equipments designed or produced by a number of different contractors.

f. The unique features of an independent SCA would partially compensate for lack of thorough design evaluation by a supplier.

g. Sneak circuits are suspected in an existing system. Before a sneak circuit analysis is performed a failure analysis of the malfunction(s) should be performed to eliminate causes other than sneaks, such as electromagnetic interference, temperature sensitivity, etc.

5.2.1 Operational anomalies. Many operational systems develop problems which are intermittent or are not diagnostically repeatable. The application of SCA is a viable technique for identification of potential or actual causes for these anomalies. This is especially true when the system is inaccessible for testing and diagnostic checkout, as for example a spacecraft that has been launched. Large complex systems are difficult to analyze without the aid of an SCA type technique to determine the possible paths which could cause the observed problem.

5.2.2 Application to electrical and electronic systems. SCA is particularly applicable to electrical and electronic circuits of all types. When schedule, time and cost are the predominant factors, the analysis may be limited to specific critical subsystems or functions. The hardware and software directly related to specific hazards, safety, reliability, test anomalies and primary system functions are those most often selected for SCA.

5.2.2.1 Digital circuitry. SCA applies to digital circuits of varying complexity, including small scale integration (SSI), medium scale integration (MSI), large scale integration (LSI), and hybrids. Standard integrated circuits (ICs) allow simplification of clue lists and encoding procedures for data processing. Analysis of custom LSI and hybrid devices generally requires the IC to be treated in the same detailed manner as a circuit card. SCA of digital circuits can reveal unexpected cause and effect relationships, timing hazards, reliability concerns, and other related problems.

5.2.2.2 Analog circuitry. SCA of analog circuitry can reveal unexpected circuit configurations (modes), unexpected cause and effect relationships, error sources, timing (phase shift and stability) problems, reliability concerns and other related problems.

5.2.2.3 Embedded computer software. Many new systems are software driven or hybrid, that is, software controlled with hardware control backup. This situation has given rise to the development of software SCA techniques which were adapted from SCA of hardware. The SCA technique can be applied to the embedded software program as a separate entity (i.e., the "stand-alone" program), or to the integrated software/hardware as a system. There are definite advantages to applying SCA to the integrated software/hardware system, but this form of embedded code analysis is not widely available at present. The software SCA technique may also be applied to analyze stand-alone (i.e., nonembedded) software.

5.2.3 Limitations in application of SCA. SCA has been successfully applied to a variety of systems and has been responsible for removing many potentially costly sneak conditions from hardware. Nevertheless, there are several limitations of SCA which a government technical monitor or contracting officer must consider in applying SCA to a military system Some of these limitations are inherent to the SCA technique; others are a result of the present state of development and availability of SCA in the marketplace.

5.2.3.1 Lack of an approved SCA method. There is presently no defined government approved technique for performing SCA. As a result, techniques may vary among the agencies performing it. The thoroughness, the degree and quality of computer aids, the level of training of sneak circuit analysts, the validity and completeness of the "clues" used in looking for sneak conditions will differ and these factors must be resolved when selecting an SCA contractor.

5.2.3.2 Dependence on capabilities of the analyst. The techniques, even when highly automated and subjected to strict quality control, generally depend on an analyst who evaluates each path or network and considers the conditions under which that path may occur. This process is always subject to human error and may permit some sneak conditions to slip through.

5.2.3.3 Concentration on topological methods. In all its variations, SCA tends to concentrate on topological similarities of sneak circuits. While most sneaks can be found in this manner, not all possible anomalous conditions will be found because they are not part of the topology of the network as it is defined by the system drawings. For example, the commonly known "sneak circuit" which causes a transistor amplifier to oscillate because of stray capacitance between collector and base circuits would not normally be found in an SCA because the stray elements do not exist in the system drawing definition.

5.2.3.4 Component failure modes not considered. SCA considers that all system components are functioning normally, that is, they are failure free. In line with this assumption, the effect of varying environments on component failures is not considered. The analysis does consider the possible "failure" of the system operator to provide correct system inputs, but not component failures. Although the SCA often identifies single point failures, it cannot be considered comprehensive in this regard.

5.2.3.5 Lack of available cross-checks. The SCA technique has found numerous problems in mature systems that were overlooked in other analyses and test programs, but it is virtually impossible to determine whether an SCA has found all or nearly all sneak conditions in a system. In this respect, however, it is difficult to determine absolutely that any analysis technique has completely accomplished its purpose. Despite this, all analyses, including SCA, will identify problems that can be corrected, to the ultimate enhancement of operational availability.

5.2.3.6 Other analyses are still necessary. SCA provides a unique way of looking for potential problems in systems and may discover problems which would more properly be found by other analyses, such as single point failures which are also considered in a FMECA or excessive fan-out which is considered in a stress analysis. However, SCA must not be used as the sole reason for eliminating these other analyses. Other analyses are generally done to specific standards which define both methods and reporting requirements so that results properly support other activities in the systems acquisition cycle. For example, an FMECA will probably be used to support a maintenance analysis and to establish spares requirements. Although an SCA may consider single point failures, this is done more incidentally than as a primary objective of the analysis; SCA does not consider all or even most part failures. Similar arguments could be made for other analyses which have some overlap with SCA, such as stress analysis or hazards analysis. SCA necessarily concentrates most heavily on those areas in a system that are most likely to contain sneak circuits or conditions. This leads to differing levels of concentration on different subsystems or their interconnections. Accordingly, the SCA is not necessarily comprehensive in the aspects covered by other analysis techniques, nor is it intended to be.

5.2.3.7 Cost. The performance of SCA on a large system can be very costly. For this reason it may be impossible, within funding constraints, to perform a detailed SCA of a complete system. In such cases, the SCA may have to be limited to a system-level analysis or to the analysis of a few critical subsystems.

5.3 SCA compared to other analysis techniques. SCA is contrasted to other analyses commonly performed in a reliability and safety program in a number of important ways. SCA generally concentrates on the interconnections, interrelationships, and interactions of system components rather than on the components themselves. SCA concentrates more on what might go wrong in a system rather than on verifying that it works right under some set of test conditions. The SCA technique is based on a comparison with other systems which have "gone wrong", not because of part failures, but because of design oversight or because a human operator made a mistake. The consequence of this subtly different perspective may be very important, because it tends to concentrate on and find problems which may be hidden from the perspectives of other analytical techniques.

5.3.1 Failure modes, effects, and criticality analysis (FMECA). FMECA differs from SCA in that it predicts and quantifies the response of a system to failures of individual parts or subsystems. An FMECA is an analysis of all expected failure modes and their effect on system performance. FMECA results are often used in maintainability predictions, in the preparation of maintenance dependency charts, and to establish sparing requirements. On the other hand SCA considers possible human error in providing system inputs while FMECA does not. In this regard the two types of analysis tend to complement one another.

5.3.2 Hazard analysis. The general objective of hazard analysis is the identification of system features which could threaten the safety of personnel or other equipment. MIL-STD-882 defines several different types of hazard analyses depending on the state of development of the system design, the portion of the system analyzed, and the principal causative agents considered to create hazards.

5.3.2.1 Preliminary hazard analysis (PHA). This is the first analysis of the system and is designed to identify gross system hazards as the basis for more rigorous and detailed analysis later. There is little overlap between SCA and PHA. The detailed data base needed for SCA is normally unavailable at the time a PHA is performed.

5.3.2.2 Subsystem hazard analysis (SSHA). An analysis of hazards associated with some element of the total system is called a subsystem hazard analysis. MIL-STD-882 defines three types of SSHA: fault hazard analysis, fault tree analysis, and sneak circuit analysis.

5.3.2.2.1 Fault hazard analysis (FHA). The FHA is an inductive method of analysis in which potential hazard modes are postulated and their effects on the subsystem are determined. The method overlaps SCA in that hazard modes other than component failure are analyzed.

5.3.2.2.2 Fault tree analysis (FTA). The FTA is a deductive method in which a catastrophic hazardous end result is postulated and the possible events, faults, and occurrences which might lead to that end event are determined. FTA also overlaps SCA because the FTA is concerned with all possible faults, including component failures as well as operator errors.

5.3.2.2.3 Sneak circuit analysis (SCA). The SCA is also considered an SSHA by MIL-STD-882, although the technique applies equally to system hazard analysis (SHA) discussed below. There is clearly an overlap between the intent of SCA and that of both FHA and FTA; each is intended to discover undesirable system operating modes, and each considers possible causes; however, there are significant differences. There is a difference in emphasis; FTA and FHA include and emphasize component failures and combinations of failures with other events as causative agents, SCA does not comprehensively address failures. There is a difference in objective; FTA and FHA are concerned with hazardous end result; SCA is concerned with hazardous results but also with any other results which do not conform to design intent. There is a difference in perspective; FHA and FTA generally consider the possible; hazards are all considered even though their probability is remote. SCA, by its comparison to other systems with actual sneak circuits in them, and by its reduced concentration in areas unlikely to have sneak conditions, is concerned more with the probable. Under some conditions, FHA and FTA could be combined with SCA, especially if the analyses were done by the same contractor. The configuration data base is common to both analyses. The network trees generated by the SCA can be very valuable in evaluating the propagation of faults in a system. By considering non-single point failures and combinational effects at those points where hazards are noted in the SCA, the objectives of FHA could also be achieved. The preparation of fault trees for an FTA from SCA results would then be relatively straightforward and inexpensive.

5.3.2.3 System hazard analysis (SHA). System hazard analysis is performed on subsystem interfaces to investigate safety problem areas in the total system. The same techniques as SSHA are applied. Likewise, the comments regarding the similarities and differences with SCA also apply to system hazard analysis. With proper planning, a system hazard analysis could be cost effectively combined with the SCA for the system.

5.3.2.4 Operating and support hazard analysis (O&SHA). The scope of O&SHA is very broad, in that it is intended to identify any hazards which might occur during production, installation, maintenance, testing, modification, transportation, storage, operation, training and disposal of a system. Because of this, performance of SCA cannot obviate the need for O&SHA. SCA can be used in support of O&SHA to identify potential hazards and to analyze the interconnection of the system within a larger system and the interfaces with test and ground support equipment.

5.3.3 Stress analysis. Stress analysis is performed to assure that all components and piece parts in a system are operated within their maximum ratings or limited to some more conservative derating design value. An SCA analyst should consider part stress in specific instances where it appears to be a potential problem and should report his findings. However, the regimen and meticulous attention paid to the stresses on all piece parts during a stress analysis is not a part of SCA. Therefore performance of SCA should never be used to justify deletion of a stress analysis on a system.

5.3.4 Worst-case analysis. Some systems or subsystems are subjected to a worst-case analysis which considers build-up of component and input tolerances, worst-case temperature variations, aging effects, and a variety of other factors in determining that a design will function within design limits under all conditions. SCA generally has little overlap with worst-case analysis and the performance of SCA does not eliminate the need for worst-case analysis if it is otherwise needed. A possible overlap with digital SCA exists, however, in the reverse direction. If a thorough worst-case analysis were performed on a purely digital system and the analysis considered variations in all possible system inputs, worst-case signal timing, and worst-case loading, the performance of an SCA would probably not be justified.

5.3.5 Human factors analysis. The consideration of human factors in the design of military systems is covered in MIL-STD-1472. The standard defines detailed requirements for the proper design of components and systems so that they can be successfully operated by humans. The intent of SCA to find sneak labels, sneak indications, logical inconsistencies, etc., recognizes the possibility that humans can make errors when operating a complex system. SCA of all types should be performed with the standards of MIL-STD-1472 in mind. SCA cannot, however, be considered a replacement for a thorough human factors analysis; neither the emphasis nor the intensity is sufficient to ensure that all human factors have been considered. On the other hand, SCA results can be very useful in identifying possible human engineering problem situations which can then be subjected to more intensive human factors analysis.

5.3.6 The SCA and test programs. Testing can never obviate the need for SCA. Testing is intended to show that the system functions properly when the proper system inputs are made. SCA, on the other hand, looks for plausible situations and combinations of inputs which may cause the system to work incorrectly. Testing is almost always repetitive; if a problem exists when a certain combination of inputs occurs, repeating a set of tests that do not contain the combination will never detect the problem. In addition, connection to the tester can itself be the source of sneak circuits. Therefore, the tester connection to the unit under test (UUT) should be considered a likely candidate for an SCA, and should definitely be performed if there are possible hazardous conditions which could result from testing. An SCA which also considers failure modes of the UUT could be very useful in finding failure modes which might go undetected by normal test sequences.

5.3.6.1 Software test programs. Software SCA attacks the same problems as do the software quality assurance, QA testing, and verification and validation (V&V) functions, that is the achievement of software that meets performance requirements with no undesirable operating modes or sneak conditions such as unresolved code loops, inaccessible code, or unused subroutine entries or exits. The impact of MIL-STD-1679 in achieving widespread use of structured coding techniques, top-down design principles, and performance requirement traceability has yet to be assessed. The degree of sophistication of code compilers and code analyzers used in modern computers is also increasing rapidly. All of these factors will have an impact on the advisability of performing the SCA on a particular software program. If modern coding practices, compilers, a thorough and pervasive QA program, and independent V&V have been applied, the need for software SCA certainly diminishes. However, there is still much software being produced which has not had the benefit of these practices. Embedded software which interfaces directly with hardware on which SCA is being performed is another likely candidate for software SCA. In both of these cases, software SCA should be considered as a good means of augmenting a less than ideal test program.

5.4 Trade-offs. The potential benefits of an SCA will always be weighed against other program considerations. Factors such as cost, schedule, the existence of other analyses, the availability of data, the ease with which available system data can be interfaced with SCA programs, and the availability of a qualified SCA contractor, must all be considered. When it is considered that SCA can be tailored to fit the needs of most systems by applying it only to system-level interconnections or only to the more critical subsystems, an argument against SCA based strictly on cost is not really defensible. While there is some overlap between SCA and other analyses, performance of most other analyses and test programs cannot substitute for an SCA (and vice versa).

6.0 PERFORMING ACTIVITY AND OTHER PARTICIPANTS

6.1 General. One factor in assuring that an effective SCA is performed is the determination of the activity which is to actually conduct the analysis. This determination should include consideration of many facets, all of which are variable and will be different for each given situation. Similarly, it will be necessary to determine what activity can most effectively order and manage the effort, as well as to designate the other participants who are to be involved in establishing the scope or depth of the analysis, evaluating the results, devising corrective actions and the implementation thereof, and other related aspects.

6.2 Performing activity. In the designation of the activity to perform the SCA, in order to assure maximum effectiveness, the following considerations should be evaluated: (1) capability, (2) costs, (3) level of program involvement, and (4) merits of independent analysis versus "in-house" analysis. Additional considerations may also apply in a given situation.

6.2.1 Capability. All activities engaged in design and development will have some capability in SCA, whether or not they refer to it by that nomenclature. Only a limited number of activities, however, will have developed the sophisticated computer programs and structured SCA techniques that are essential to detailed analysis of the more complex systems. Accordingly, the selection of the performing activity will be substantially influenced by the scope of the analysis. Methods for assessment of prospective SCA contractors capabilities are discussed in Section 8 herein.

6.2.2 Costs. Potential costs for performance of the SCA will typically vary considerably between prospective activities. For example, the contractor who is to perform other analyses will have structured the system data base (such as flowcharts, logic timing, block diagrams, etc.) much of which is directly applicable to the SCA. Additionally, the development contractor will have ready access to all system documentation which should result in less cost than compilation and dissemination to a second party. On the other hand, a second party may have in place systemized techniques and qualified analysts, which will reduce costs associated with development of such capability. Some guidance for estimating and evaluating costs is provided in Section 9 herein.

6.2.3 Program Involvement. The level of involvement in the development of the system may influence the selection of the activity to perform the SCA. Because of the nature and purpose of the SCA, it would generally be inappropriate to task several subcontractors to perform the analysis on the subsystem under their cognizance. From this standpoint, the prime development or integrating contractor is best positioned to have the necessary total overview (the prime development or integrating contractor may be a government agency). However, depending on individual circumstances, the activity best positioned to command a total overview may not have in place the requisite capability.

6.2.4 Independent analysis. Traditionally, system effectiveness analyses are performed by other than the designers (reliability groups, safety groups, etc.). The effectiveness of this approach has been amply demonstrated. It is effective because it is more likely to be objective, plus it provides a "double check" which is always desirable. Those directly involved in the design process may be "too close to the trees to see the forest." This factor strongly suggests that an independent contractor should be considered for the performance of the SCA, but does not rule out performance by an independent group within the development contractor's organization. One aspect that must be given careful consideration is the feasibility of interchange of data, both the preliminary data base (including analysis tools such as flow charts, timing sequences, block diagrams, etc.), and the data outputs from the SCA. An independent contractor may consider the details of the analysis (which are essential to evaluation of the thoroughness and correctness) to be proprietary.

6.3 Ordering activity. Depending on circumstances, the activity to order and administer the SCA may be a government organization or a prime contractor. Consideration should be given to that activity best qualified to negotiate the effort, and to evaluate the results. As a minimum, the ordering activity must have personnel who are thoroughly conversant with the objectives of the SCA and have at least a rudimentary knowledge of the techniques involved. Further, the ordering activity must have technically qualified specialists who are familiar with the system(s) involved, and who are capable of assessment of the analysis results and their disposition (no action required, design change required, procedure change required, etc.).

6.4 Other participants Typically, the performance of the SCA will necessarily involve several organizations or groups within a given organization. Before initiating the SCA, such organizations, groups, and individuals should be identified, and their responsibilities clearly defined.

6.4.1 Establishment of criteria. At the offset it will be necessary to determine the extent and scope of the SCA, determine the activity to perform the analysis, determine the schedule, and negotiate all aspects. This will involve contract administrators, program management, and technical personnel from each activity participating.

6.4.2 Inputs to the analysis. Design disclosure documentation (drawings, schematics, specifications, etc.), as well as baseline data such as flowcharts, block diagrams, etc., will be required. This will involve configuration management as well as technical specialists. Negotiation with subcontractors may be necessary in order to gather all necessary detail.

6.4.3 Coordination with other efforts. Continuous coordination will be required to advise the performing activity of changes as they occur as well as to supply him with supplemental data he may require. If the effort is properly planned, interim reports will be provided, especially when any potential problems are identified.

6.4.4 Evaluation of the results. The results of the analysis must be evaluated, incrementally, and at the conclusion of the effort. This is necessary not only to assess the validity of the findings, but finally to determine if the performing activity has satisfactorily completed the effort.

6.4.5 Utilization of the results. Determinations must be made as to actions to be taken based on the results of the analysis, including implementation and validation of any changes required. This may involve negotiations with the performing activity to repeat certain portions of the analysis.

7.0 SCHEDULING THE SCA

7.1 General. Scheduling of the SCA for optimum effectiveness is paced by the design process. There will be an optimum point in time for every program, based almost exclusively on the degree of design maturity, but this point will typically be somewhat difficult to identify. Performance of the SCA too early in the development process may result in penalties because of insufficiently mature design data, and thus wasted effort in attempting to structure the data base and in analysis of an evolving design. Conversely, if the SCA is delayed too long, changes may be very costly in terms of dollars and schedules; this would be especially true where early commitment for long lead time items is necessary (and this is more often than not the case, especially for highly complex systems).

7.2 Multiple subcontractors. The more participants involved in the development program, the more difficult it becomes to optimize the SCA schedule. Inevitably, the different subcontractor's designs will be in different stages of maturity and the documentation will be in varying phases of completion. Early consideration of this aspect by program management will, however, permit establishment of a milestone at which all participants must have at least semifinal documentation available. Although the timing will never be as well coordinated as would be desired, early recognition of the need for such a milestone should serve to alleviate the problem, by improving the probability of having the necessary data to initiate the SCA at the appropriate time in the acquisition cycle.

7.3 Acquisition phases. The DoD acquisition phases are as depicted in Figure 2, which also shows the preferred scheduling of SCA activities as related to the acquisition milestones. This of course represents a somewhat idealized situation and can only be considered a general guide, if for no other reason than the fact that programs rarely track the acquisition milestones precisely. Generally, the SCA related activities are as follows:

a. Planning and scoping

b. Data base assimilation

c. Performance of the analysis

d. Corrective action and validation

e. Monitoring changes

f. Problem investigation

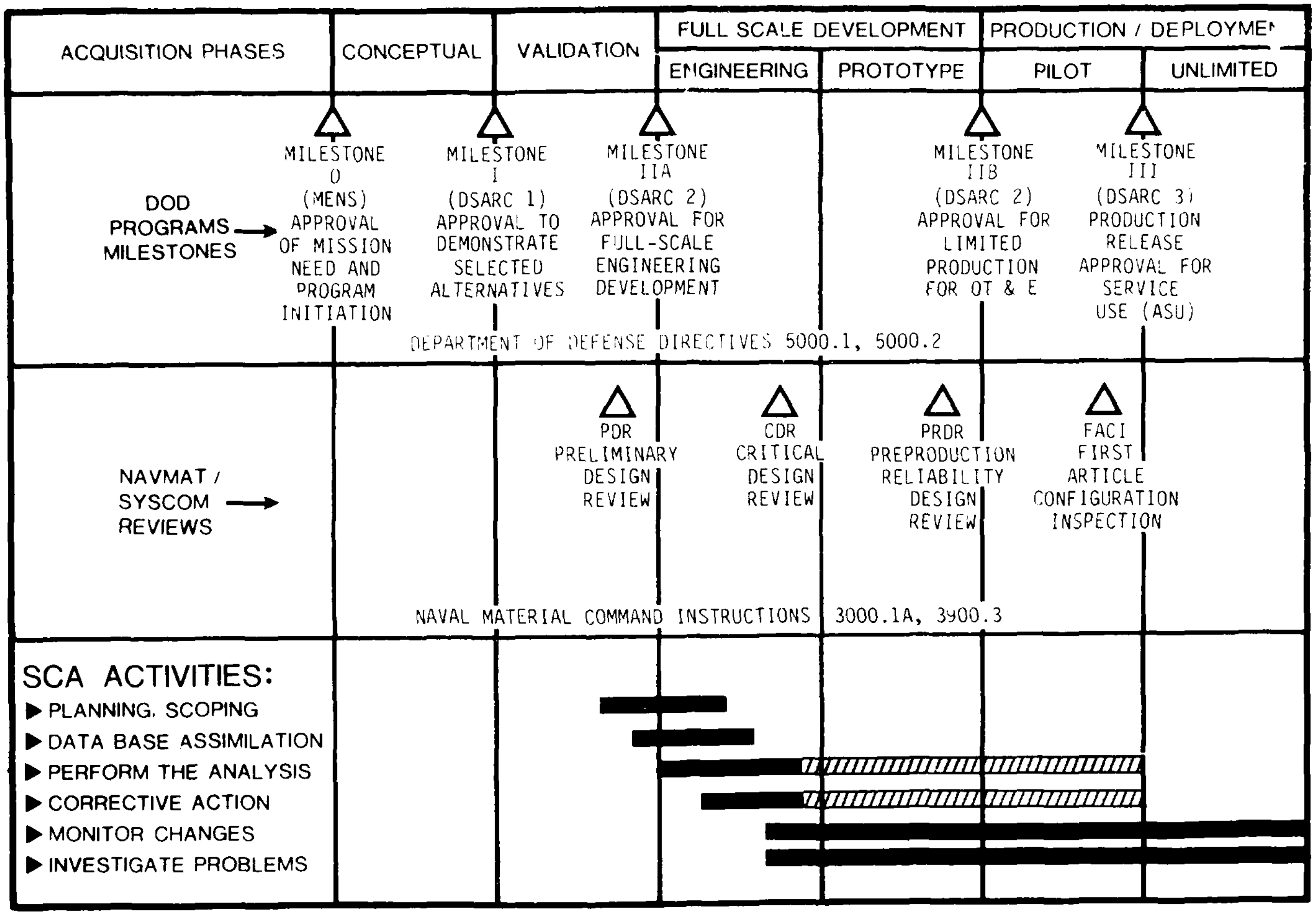


FIGURE 2. Phasing of the SCA within the DoD System Acquisition Process

7.3.1 Planning and scoping. These activities include the decision as to whether or not to require the SCA for the program of interest, and establishment of the level or scope of the analysis. Considerations as to the designation or selection of the activity to perform the SCA should also be initiated in this time frame.

7.3.2 Data base assimilation. During this period milestones should be established for delivery of requisite documentation and data by all applicable participants. A configuration management program will be required to ensure that all pertinent data will be available and under formal change control. As documentation becomes available, baseline data such as block diagrams, flowcharts, etc. (which define the system in a form amenable to the performance of the analysis) should be prepared. Generally, these baseline data will be fed back to the ordering activity for validation of the accuracy of the system description and any assumptions associated therewith, before the actual analysis is initiated.

7.3.3 Performance of the analysis. As indicated in Figure 2, the detailed analysis results should be available in time for the Critical Design Review (CDR), as an input to the decision for the transition to the production phase, and the associated hardware commitments. At the very latest, the results must be available at Milestone III, if they are to be useful.

7.3.4 Corrective action and validation. These activities should take place more or less in parallel with the analysis, given that the analysis results are reported incrementally, which should be mandatory, except for possibly the situation where the analysis is very limited in scope or is being performed on a relatively simple system. Generally, any corrective actions that are established should be fed back to the SCA analyst for incorporation in his model and revalidation.

7.3.5 Monitoring changes. Changes to the hardware or the software will occur throughout the development phases, and typically throughout the production/deployment phases. Those changes occurring during the conduct of the SCA should be fed back to the SCA performing activity immediately. Subsequent to completion of the SCA, evaluation of proposed changes should be relatively inexpensive if provision has been made to maintain the baseline data, system models, etc.

7.3.6 Problem investigation. Not infrequently, problems occur during both development and production/deployment of military systems for which the explanation might be forthcoming from a limited SCA. Problems of an intermittent nature are particularly good candidates for the SCA. As with change monitoring, this should be relatively inexpensive if the baseline data are intact.

7.4 Non-DSARC programs. Programs not under formal DSARC control (generally programs where the dollar commitment to development or production does not exceed certain thresholds) may also be candidates for SCA, if they meet some of the criteria set forth in Section 5 herein. In these instances, milestones generally equivalent to those of the DSARC should be available for guidance in planning and implementing the SCA. The same considerations of design/development status will apply.

7.5 Alternative scheduling considerations. These discussions and guidelines are not intended to cover every possible situation where the SCA techniques may be applicable, and tailoring to meet the needs of each individual situation is to be encouraged. Section 8 of this handbook discusses some alternatives that may be useful in contracting for and managing the SCA.

8.0 CONTRACT MANAGEMENT

8.1 General. Previously in this guide the SCA has been described, and the many factors influencing the decision as to whether or not it might be applicable or beneficial as applied to a given program have been discussed. Scheduling of the SCA within the systems-acquisition cycle and the selection of the performing activity have also been addressed. It is the intent of this section to present suggestions and guidelines with respect to contracting for and management of the effort. Because of the many variables, it would not be appropriate to specify exact methods of contracting for, nor performance of, the SCA; the intent rather is to identify those aspects that should be considered in making these determinations in a given specific situation.

8.1.1 Preliminary tasks. As discussed previously, particularly in Sections 6.0 and 7.0 herein, there are a number of matters to be resolved before selecting the type of contract that would be most suitable in a given situation. Some of these will have been addressed, at least in part, in the process of determining whether or not to require the SCA, but they will need to be investigated in more detail in order to establish contractual provisions, and a plan for the management of the effort. These matters include, but are not necessarily limited to, the following:

a. Determine scope or extent of analysis

b. Determine what data bases will be available

c. Determine schedules for design documentation availability

d. Determine prospective performing activities

e. Determine participants and responsibilities

8.1.2 Statement of requirements. Unlike most conventional analytical techniques, there exists no documented procedure generally accepted or recognized by the industry or the Government for the SCA. Thus, requirements must be stated in general terms. Because there are a number of methodologies in use, it would be inappropriate to be specific regarding the method, even if this were possible. The emphasis should accordingly be on the results expected. In this regard, it is of paramount importance that the performing activity be required to submit (or make available for inspection) sufficient data to illustrate that the analysis has been complete to the extent required, and to provide assurance that all potential sneak conditions have been identified.

8.2 Contracting for the SCA. The necessity for request for proposals (RFP), purchase orders, or contracts to be very explicit is particularly important in the case of the SCA. Because the SCA is not well defined, this will not be an easy objective to realize, but it is essential. In this context, RFPs should require that responses (proposals) clearly indicate the types and extent of analysis to be performed and that the methodology be fully defined so that the procuring activity may be assured that the contractor understands the intent of the procurement. In most cases, supplemental pre-award conferences between the procuring activity and the prospective contractor(s) will be required.

8.2.1 Types of contracts. A wide selection of types of contracts is available to the contracting parties. The respective contract types vary as to (1) the degree and timing of responsibility assumed by the contractor for the costs of performance, and (2) the amount and type of profit incentive offered the contractor to achieve or exceed specified standards or goals. With regard to degree of cost responsibility, the various types of contracts may be arranged in order of decreasing contractor responsibility for the costs of performance. At one end is the firm-fixed-price contract under which the parties agree that the contractor assumes full cost responsibility. At the other end of this range is the cost-plus-a-fixed-fee contract where profit, rather than the price, is fixed and the contractor's cost responsibility is therefore minimal. In between are the various incentive contracts which provide for a varying degree of contractor cost responsibility, depending upon the degree of uncertainty involved in contract performance. The specific type of contract should be determined by the degree of risk in contract performance. When the risk is minimal or can be predicted with an acceptable degree of certainty, a firm-fixed-price contract is preferred. However, as the uncertainties become more significant, other fixed price or cost type contracts should be employed to accommodate these uncertainties and to better match risk and cost by the SCA contractor.

8.2.2 Contracting in phases. Consideration should be given to the feasibility of contracting for the SCA in a progression of discrete phases, especially for larger or more complex situations. By this approach, it should be possible to manage the effort more effectively because of definitive milestones that will be inherent to the process. Accordingly, risks for both the ordering activity and the performing activity should be reduced. Such a plan could take the following form:

a. Phase 1: The initial phase would include refinement of and agree-ment on the system description (based on scoping the effort) and preliminary data base tools (such as flow and logic diagrams, etc.). The approach to be used in the actual analysis would be defined. For more complex or more critical systems, it would be desirable to have two or more contractors perform the Phase 1 effort independently but concurrently.

b. Phase 2: During this phase the SCA would be performed at system/ subsystem level by the contractor selected at the completion of Phase 1. The objective would be to identify top level problems and establish a plan for more lower level analysis in a selective manner.

c. Phase 3: This phase would include in-depth analysis to the extent established by Phase 2. Reevaluation of corrective actions resulting from potential problems identified in this and previous phases would be included as applicable.

d. Phase 4. During this phase monitoring and evaluation of changes and problem investigations would be performed on an as required basis.

8.2.3 Reports and other data items. The exact types and formats of reports and other data items should not be initially stipulated by the ordering activity but should be proposed by the prospective performing contractors subject to negotiation prior to contract award. Requiring the contractor to conform to arbitrary formats is counterproductive in terms of cost effectiveness, and serves no useful purpose, so long as sufficient information is presented to permit evaluation of the problems, and to assure that the analysis has been completed to the extent and depth prescribed. Requests for proposals (RFPs) must, however, be explicit in requiring prospective contractors to describe in detail their reporting plans and procedures, which then become contractual obligations upon award.

8.3 Evaluating and monitoring the SCA. This activity consists of three principal steps; (1) evaluation and selection of the performing activity; (2) monitoring the SCA effort during performance; and (3) evaluating the final results.

8.3.1 Selecting an SCA contractor. Prior to awarding an SCA contract, the technical monitor will be called upon to evaluate competing SCA techniques proposed by different activities, and select the most appropriate for the system under consideration. Under present conditions, the selection among candidate SCA techniques must be made via an evaluation of their effectiveness in detecting sneak conditions, rather than by a detailed specification of the steps to be taken in performing the analysis.

8.3.1.1 Evaluating SCA techniques In declaring his capability, or responding to an RFP, the contractor should be required to provide a detailed outline of the SCA procedure to be used, withholding any proprietary procedures but indicating in general what these entail. The bid or proposal should include a formal justification of the proposed techniques, consisting of a theoretical discussion of the validity of the technique, supposed advantages, any known limitations, and a formal report detailing the results of any tests run to establish its validity on either real or test cases. Reports demonstrating successful previous applications of the proposed SCA procedures should also form a part of the bid package if they are available. The technical monitor should evaluate the competing proposals based on their anticipated effectiveness on the system under consideration as well as any other factors which are pertinent to the procurement. It should be remembered in this regard that new or innovative SCA techniques will not have as strong a historical basis as more established techniques; however this should not be the sole reason for rejecting such procedures; innovation involves some risk. The evaluation of competing proposals may involve on-site inspection of supplier's facilities to review data processing capabilities, personnel, and quality assurance procedures.

8.3.1.2 Data to be provided. A critical aspect in the evaluation of proposals is the necessity to ensure that the proposed deliverable output data from the analysis will be sufficiently comprehensive to permit a determination as to whether or not the analysis was complete. Merely reporting discrepancies or problems is not sufficient for this purpose. Notwithstanding the possible proprietary nature of certain types of material, the prospective performing activity must declare his willingness to provide such material if this is necessary in order to permit an adequate evaluation of the results. Such material might include worksheets, network trees, topographs, or similar data that would illustrate the actual extent of the analysis (such as the circuits that were actually analyzed, specific components considered in the analysis, assumptions made regarding circuit states input/output conditions, etc.). There is little benefit to selecting the performing activity based on cost, assumed capability, or other factors, if it is not possible to conclusively determine (upon completion) that the objectives were realized.

8.3.2 Monitoring SCA performance. Monitoring SCA performance must begin by establishing provisions in the SCA contract which will facilitate monitoring throughout the effort. Results of any trade-offs (e.g., cost, schedule, etc.) incorporated as a result of scoping the SCA effort deserve special attention. Incidental features which are to be included in the analysis should definitely be specified contractually. For example, assurance that analysts look for single failure points, part overstress, lack of transient suppression on relays, etc., can only be obtained if specifically called for in the contract. Further assurance of proper contractor performance can be gained by (1) contractually requiring periodic technical and final progress reports, (2) by requiring government involvement in the final partitioning process, and (3) by separate funding of SCA phases with provisions for redirection between contract phases, if necessary. Periodic on-site surveys may also be desirable. The Government monitors should review technical progress against expenditures, evaluate interim results, and provide technical liaison with the design activity on any problems identified.

8.3.3 Evaluating SCA results. Every SCA contract must require a final report detailing SCA results, sneak circuit conditions found, and the recommended disposition for any problems identified. If the performing activity is to be involved in the resolution of problems, the report should include final disposition of any problems noted. The contract must also require that any computerized system data base used in the analysis be delivered to the Government or retained by the contractor for the duration of the program. In this way, the data base will be available to evaluate later modifications to the system. The Government monitors must assure that all contractual, contract data requirements list (CDRL), and data item description (DID) requirements have been met. Problem identification, recommended solutions and dispositions should be reviewed for appropriateness and adequacy. The monitors must assure that the configuration used in the SCA is adequately documented, including any engineering change notice (ECN) or marked-up drawings, and must assure that any computerized data base is retained. Any worksheets which have been delivered as part of DID requirements should be reviewed for completeness and depth of analysis.

8.4 Data Considerations. The SCA contract should include provisions for the control of system data during the course of the effort. Data considerations include (1) specifying the required input data, (2) special formatting requirements, (3) security, (4) scheduling (5) output data requirements, and (6) final disposition of system data.

8.4.1 Required input data. Input data requirements may vary somewhat with the scope of a particular SCA, differences in SCA technique, and peculiar formatting requirements for computer processing. Generally, the data package will include:

a. Schematics, wiring or interconnection diagrams, cable drawings, wiring harness definitions, etc.

b. Functional descriptions of system operation, theory of operation documents, and perhaps technical briefing by design personnel.

c. Software performance specifications, design specifications, source code, preferably on magnetic tape, and in an agreed format, data base information, and operator's manuals if available.

d. Operational procedures documentation, and electromechanical, pneumatic or hydraulic functional diagrams if these special features are to be involved in the SCA.

e. Integrated circuit, hybrid microcircuits, and special component schematics, procurement specifications, and description of operation documents.

Data requirements should be agreed upon prior to award of contract. The contract should specify the data to be supplied including special formatting, the schedule for data delivery, and a cutoff date for ECN inputs after which schedule and cost must be renegotiated.

8.4.2 Security. The contract monitor must assure that the performing activity's facilities, personnel, and computer processing facility are cleared to handle the highest classification of data required in the SCA effort.

8.4.3 Output data requirements. The contract must include CDRL items for all required deliverable documentation, including progress reports, final reports, worksheets, and magnetic tapes of the system data base. Each CDRL item must be defined by a DID. If the performing activity is to retain the data base, the contract must specify the data to be kept, and the duration. If the data are to be returned, the contract should specify the data, schedule, and conditions of the return.

8.4.4 Special data considerations. When proprietary data is involved in an SCA, it may be necessary to obtain a signed agreement from the performing activity not to release such data to a third party and to use such data only in the performance of the SCA. The SCA data base including input data, computer data base, output reports, worksheets, etc. should normally be retained by the performing activity for a specified period to ensure its availability should the need arise to perform SCA on system modifications. Maintenance by the performing activity will be more cost effective and the risk of loss is less. If the data are returned to the Government or the design activity, provision should be made for storing the data through the operation and support phase of the system life cycle.

8.5 Statement of work examples. Appendix C presents some examples of statements of work that could be applied, with appropriate tailoring, when ordering the SCA. Also presented is a DID that generally reflects the type of data to be ordered.

9.0 COST FACTORS

9.1 General cost considerations. Estimating the cost of an SCA program can be complicated because of a number of factors. There is a variation in SCA techniques among contractors which can lead to significant differences in their cost estimates for the analysis. The process of tailoring, i.e., of partitioning the system and using different techniques and different levels of scrutiny in the analysis of certain subsystems may also cause a wide variation in cost estimates for what is apparently the same job. Other factors, such as the degree of accessibility to the SCA data base, the level of government involvement, amount of liaison required, frequency of reports and specific CDRL requirements, will all have an effect on the price quoted for the SCA.

9.1.1 Assumptions. It is assumed in this section (and in the related Appendix) that the technical monitor can make a valid independent assessment of the technical differences among SCA methods proposed by different contractors. The technical monitor must further assure that the scope of the SCA under consideration, including system partitioning and special considerations, such as, system-level SCA only, detailed SCA of MSI or LSI circuits, etc., is clearly defined in the request for quotation (RFQ), and that the quotes received reflect the contractors' understanding of these specific tailoring requirements. It is further assumed that the technical monitor will include contract provisions for monitoring SCA performance sufficient to assure that the SCA is performed with the same techniques, partitioning, and levels of scrutiny as were quoted. Only after all of these preconditions have been met can the technical monitor be sure that the price quotes are truly comparable or, at least, that the price quote really do support a trade-off decision between cost and SCA effectiveness.

9.1.2 Cost effectiveness. The application of SCA on a program must always be done with a serious consideration for cost effectiveness. There are obvious situations in which SCA is clearly mandatory, such as a manned space flight, a nuclear power plant control system, or a nuclear missile system. In such cases the consequences of sneak conditions are potentially disastrous; the costs of a serious error are virtually incalculable. The decision in most other cases is not so clear-cut. The technical monitor must weigh the potential benefits of SCA against the cost and decide either to do it or not. The material in Section 5 provides some assistance in making this decision.

9.1.2.1 Tailoring to reduce costs. Tailoring the SCA to reduce costs while maintaining the essential benefits of the analysis is strongly encouraged. A top-level program office assessment of the areas in the design most likely to generate sneak conditions can do a great deal to improve the cost effectiveness of SCA on a given system. Thus, the built-in test equipment (BITE) circuitry, or the interconnection to a test set, or the control and indicator subsystems could be singled out as the primary focus for SCA. Experience has shown that power distribution circuits are especially susceptible to sneak conditions and are thus potential candidates for the SCA. Of course, this top-level tailoring of the effort should remain flexible until SCA contractor inputs regarding proper tailoring are heard and considered.

9.1.3 Relation to other activities and analysis. Another consideration in assuring that an SCA remains cost effective is the efficient use of the system data base. The configuration management costs for maintaining an accurate system data base can be substantial for a large system. An effort should be made to have the SCA performed by the same activity that performs other analyses if this is possible, or at least to minimize the number of activities at which the data base must be maintained. The benefits of having an SCA performed by an independent agency may outweigh the additional data base costs, but this factor should at least be considered. Some cost benefits can be derived by combining analyses, such as, SCA with FMECA or SCA with stress analysis, especially if computer-aided analysis is anticipated for these other analyses.

9.1.4 Separate funding of SCA phases. The cost of SCA on a large system is likely to be high. The cost of preparing accurate and detailed cost estimates for performing SCA can likewise be high. The most desirable partitioning of the system for cost effectiveness, or the relative effectiveness of several candidate SCA techniques, may not be obvious at the outset of a program. In such cases, the contract monitor should consider separate funding of the SCA phases discussed in Section 8.2.2.

9.2 Estimating SCA Costs. Appendix A presents some general guidelines for estimating the cost of an SCA. The guidelines were formulated in part from historical data on the NASA-developed sneak path analysis technique and its derivative software SCA procedure. It must be understood that none of these were competitive procurements. Consequently, the data on historical SCA cost may be a poor indicator of what future cost will be. One of the primary intentions of this handbook is to encourage the development of innovative and cost effective SCA procedures. The combined impact of price competition, innovation, and an effective means of tailoring SCA to fit the needs of particular systems should act to reduce SCA costs in the future. Appendix A also suggests a way to estimate SCA costs independent of historical data so that future SCA costs may be at least roughly estimated.

9.3 Evaluating costs. The best means of evaluating supplier quotes is to form an independent estimate of the expected cost for comparison. This independent estimate must be based on what the supplier proposes to do during the SCA, i.e. the proposed technique, and on independent estimates of the required skill levels, manhours, computer time, and materials, and on local labor rates, company overhead, G&A, and profit. Appendix A suggests a general outline for doing this, but the accuracy of any such estimate will be strongly dependent on the technical monitor's knowledge of the proposed SCA procedures, and his persistence in getting accurate data for the estimate.

9.3.1 Caveat. The very existence of cost guidelines in a handbook such as this will undoubtedly tend to precondition or "ballpark" some supplier's quotes. The technical and contract monitors should be watchful of this and use whatever means available to crosscheck supplier quotes.

APPENDIX A

ESTIMATING SCA COSTS

10.1 Scope. This appendix presents information to assist in developing rough order of magnitude cost estimates for the performance of Sneak Circuit Analysis (SCA).

10.2 Cost estimating procedures. The variation in SCA procedures among performing activities make the estimation of SCA costs quite tenuous (see Section This Appendix is presented in two sections. The first section presents a cost estimation process which is based on historical cost data for SCAs using the sneak path search technique developed for NASA and proprietary derivative techniques. The information could be used to budget for SCAs using these techniques. It should only be used as a reference point, however, on SCAs using other methods. The second section provides some general information for a government technical or cost monitor in budgeting for or evaluating quotes for SCAs using other procedures. Because of the potentially wide variation in techniques, this information can only be very general to help keep the monitors from overlooking major cost elements while working up an independent estimate of SCA cost.

10.2.1 Historical SCA costs. Cost data have been provided for SCA of both hardware and software. These data represent the historical costs for SCA using the NASA-developed path search technique and certain additional proprietary enhancements. These data are reasonably regular and support a linear cost relationship with parts count, except near the origin. Because of the differences in the amount of labor, computer time, materials, etc., required to analyze different part types, each part type has a different weighting factor in determining the cost of the SCA. The cost (in 1979 dollars) can be calculated by adding together the costs for each individual part type. Table A-1 presents the weighting factors for different part types and their approximate tolerances. Table A-2 presents a sample calculation for a system consisting of 1000 parts of the indicated mix ratio.

10.2.1.1 Software SCA estimates. The cost of a software SCA based on historical data is approximately $10 per assembly code instruction.

10.2.1.2 Cost estimating accuracy. Historically the accuracy of the parts-count technique presented in Table A-2 is ±10%. When the exact component mix is not known and the weighting factor for a generalized component mix in Table A-1 is used, the accuracy is ±20%. Both of these estimators produce larger errors for parts-counts below about 300 parts. In this region, the data are better represented by a constant dollar figure of $30,000 ±$20,000. The accuracy for estimating software SCA costs using the cost factor of 10.2.1.1 is ±10%.

Table A-1. Cost Factors for Different Part Types.

Part Type	Weighting Factor	Weighting Factor Tolerance
	$/Part	$/Part
Resistors, Capacitors, Coils	29	±8
Relays, Transistors, Switches	79	±11
Small-Scale Integrated Circuits (SSI)	164	±14
Medium-Scale Integrated Circuits (MSI)	284	±14
Large-Scale Integrated Circuits (LSI)	468	±25
Generalized Component Mix (Used when actual component mix is not known)	94	±19

Table A-2. Sample Calculations.

Part Type	Number of Parts	X	Weighting Factor	=	Component Cost
Resistors, Capacitors, Coils	400	X	29/Part	=	$ 11,600
Relays, Transistors, Switches	200	X	79/Part	=	15,800
SSI	150	X	164/Part	=	24,600
MSI	100	X	284/Part	=	28,400
LSI	50	X	468/Part	=	23,400
Totals	1,000				$103,800

10.2.1.3 Cost adjustments. Costs calculated using the methods of 10.2.1 are stated in 1979 dollars for work generally performed in the Houston, Texas, area. Cost adjustments for inflation in later years and for different geographical areas can be made using current statistics provided by the U.S. Department of Labor, Bureau of Labor Statistic s(BLS). Examples of the type of data available in these publications are shown in Figure A-1. These data are not necessarily current; the latest available issues of the BLS data should be consulted.

10.2.2 Cost estimates for other SCA procedures. Estimating the cost of an SCA when new or innovative procedures are to be performed or when the scope of the SCA has been limited by some tailoring process is more difficult. If the technical monitor is sufficiently knowledgeable of the SCA procedure which is to be used, he can construct an estimate which will at least be "in the right ballpark." An SCA cost estimate is developed by isolating each task to be performed. Preparing a Work Breakdown Structure (WBS) of the required tasks is a very useful first step. The WBS elements involved are Project Management, Data Management, Engineering Analysis, Quality Assurance, and Reporting. The technical/contract monitor would estimate the engineering and support time involved in each WBS element, any computer charges involved, special materials, equipment charges, and travel. It is not the intent herein to provide a "cookbook" for this estimating process, but rather to identify some of the factors that should be considered.

10.2.2.1 Engineering skill levels required. The performance of SCA requires an analyst possessing certain learned SCA skills if it is to be performed efficiently. It also requires a depth of experience in electrical equipment design (or in software coding practices) which is not generally available in entry-level personnel. Most detailed electrical SCA will be done by engineers in categories II, III, and IV as defined by the U.S. Department of Labor, Bureau of Labor Statistics. The exact mix will be dependent both on SCA job requirements and on the engineering mix that the contractor has available at a given time. The contractor may, for example, substitute a higher engineering category for a lower one if there is an insufficient number of personnel in the lower category on his staff. Equivalent statements can be made for software SCA analysts; personnel capable of doing software SCA normally have titles such as "Systems Analysts" or "Sr. Systems Analysts". The Department of Labor Statistics has not defined skill categories in this technical discipline.

10.2.2.2 Engineering time for an SCA. Although SCA techniques vary, they have certain common features:

a. Data assimilation and entry. This is normally done by engineering aides, keypunch operators, or computer assistants. It will also require some engineering time to organize and supervise the effort. A time estimate can generally be made by estimating the number of data entries involved including any verification time.

Table 1. Average Salaries: United States.

Occupation and Level	Monthly Salaries				Annual Salaries			
	Mean	Median	Middle Range		Mean	Median	Middle Range	
			First Quartile	Third Quartile			First Quartile	Third Quartile
Engineers								
Engineers I	1,327	1,316	1,225	1,425	15,928	15,794	14,700	17,097
Engineers II	1,464	1,450	1,348	1,580	17,567	17,400	16,170	18,960
Engineers III	1,683	1,665	1,515	1,835	20,194	19,980	18,183	22,020
Engineers IV	1,998	1,983	1,800	2,185	23,972	23,790	21,600	26,220
Engineers V	2,333	2,315	2,121	2,535	28,001	27,780	25,452	30,420
Engineers VI	2,689	2,657	2,433	2,911	32,264	31,887	29,198	34,934
Engineers VII	3,043	3,005	2,774	3,291	36,520	36,056	33,288	39,492
Engineers VIII	3,509	3,450	3,172	3,758	42,104	41,400	38,062	45,101
Technical Support								
Key Entry Operators I	712	666	585	784	8,546	7,994	7,020	9,411
Key Entry Operators II	842	810	709	937	10,099	9,720	8,509	11,241

Engineer I
General characteristics. This is the entry level of professional work requiring a bachelor's degree in engineering and no experience, or the equivalent of a degree in appropriate education and experience. Performs assignments designed to develop professional work knowledges and abilities. May also receive formal classroom training.

Engineer V
General characteristics. Applies intensive and diversified knowledge of engineering principles and practices in broad areas of assignments and related fields. Makes decisions independently on engineering problems and methods. Uses advanced techniques and modifications and extensions of theories, precepts, and practices of own field and related sciences and disciplines

Engineer III
General characteristics. Independently evaluates, selects, and applies standard engineering techniques, procedures, and criteria, using judgment in making minor adaptions and modifications. Assignments have clear and specified objectives and require the investigation of a limited number of variables.

Engineer VII
General characteristics. Makes decisions that are recognized as authoritative and have an important impact on extensive engineering activities. Will have demonstrated creativity, foresight, and mature engineering judgment in anticipating and solving unprecedented engineering problems, determining program objectives and requirements, organizing programs and projects and developing standards and guides.

Figure A-1. Excerpts from Bureau of Labor Statistics Publications.

b. Computer or manual data processing to produce usable working materials for the analyst, such as, manageable reduced network schematics, network "trees", assembly code flow diagrams, etc. This is likely to vary so much with different SCA techniques that no useful guidance can be given.

c. Detailed analysis by a trained SCA analyst who applies certain "clues" to isolate potential sneak circuits. This is generally done on a worksheet of some sort to aid in the "housekeeping" necessary to assure completeness. It may be done with the asssistance of computerized aids. The time required can normally be estimated from the expected number of hours per worksheet. It should be remembered that this is the step in the SCA process most affected by tailoring. Tailoring will result in the analyst reviewing fewer networks, worksheets, etc., thus reducing the amout of analysis time required. It would be expected that tailoring would result in a significant deviation from the linear parts-count relationship presented in 10.2.1.

d. Report preparation costs should include technical, typing, editing, and drafting labor, and any special equipment and materials cost required to meet specific CDRL requirements.

10.2.2.3. Taking advantage of available data. The process of cross-checking a supplier's estimate can become quite involved. The Government monitors should take advantage of all available data sources to make their estimates as accurate as possible. Depending on the situation, the technical or contract monitor may have available the supplier's labor rates, overhead, G&A, and fee structure. This information would be available, for instance, if they were evaluating a supplier's quote on any cost-reimbursable type contract. On fixed fee or incentive fee type contracts, they would also have the supplier's estimate of total manhours in each labor category, computer, and other direct costs (ODC). If the SCA effort were to be funded in phases, they would also have the supplier's estimates by phase. Lacking this specific information on supplier costs, the monitors can use average labor rates in the geographical area involved which are available from the Department of Labor Statistics. Approximate rates for overhead, G&A, and fee structures can be found in other contracts with the involved company or inferred from similar information from competitive companies.

10.2.2.4 Costs of subcontracting SCA. In addition to the costs involved in duplicating the SCA data base at a subcontractor's facility, standard industry practice is for the prime contractor to add G&A and profit charges on a subcontracted SCA. Subcontractor costs will already include the subcontractor's G&A and fee charges. This duplication in charges will increase costs and may dictate a direct contract between the government and the performing activity in some instances, but this consideration must be traded off against other factors, such as which activity is best positioned to manage and understand the technical aspects, and costs involved in incorporating design changes as a result of the analysis.

10.2.2.5 Including government costs. In addition to contractor costs for SCA, the costs for government coordination must also be included. These costs would include any special costs for travel, coordination, review, or independent technical consultant services associated with the SCA effort.

APPENDIX B

ANALYSIS TECHNIQUES

20.0 Mechanics of performance. The general procedures followed in performing SCA are outlined herein. Exact procedures cannot be defined at this time and no such definition is intended. Procedures are discussed generally so as to provide a knowledge of SCA fundamentals to help the technical monitor in establishing SCA requirements, reviewing proposed new SCA techniques and reviewing SCA work in progress at a supplier's facility. Since system partitioning is an essential feature of establishing the scope of an SCA this subject is discussed in more detail.

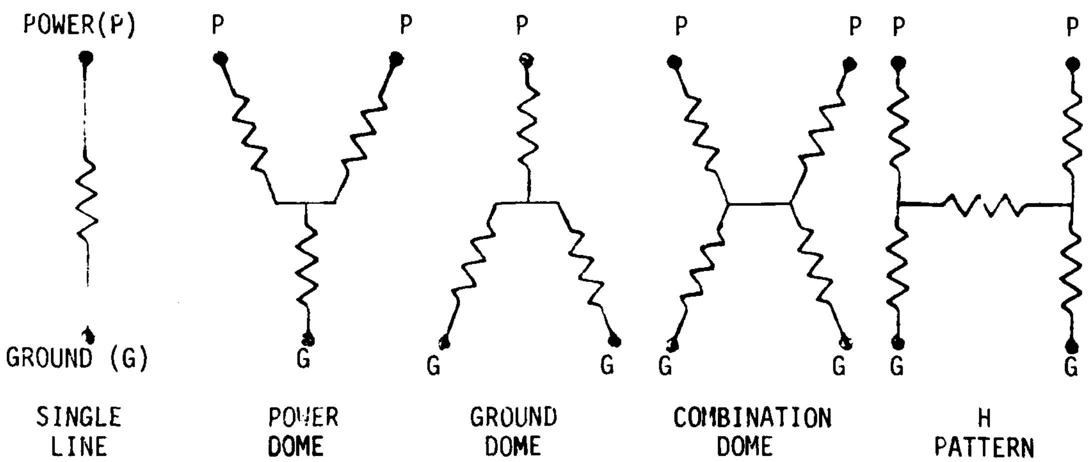
20.1 General procedures. Although SCA techniques may vary in detail, all of the established techniques have been based on the methods originally developed for the National Aeronautics and Space Administration (NASA) and successfully applied in the space programs. As electronic systems technology has evolved, some of these procedures have been found inadequate to analyze new systems, notably complex digital systems, and integrated hardware/software systems. New techniques have been developed to cope with these systems, but the developers have considered these (and all SCA) techniques proprietary, hence the difficulty in defining exact procedures. The general procedure followed in an SCA will consist of four fundamental steps, (a) assimilating the data, (b) organizing the data for analysis (generally using computer data processing), (c) review of the data by trained analysts, and (d) reporting of the results. Obviously this scenario fits SCA as well as many other procedures used to analyze systems, so some further definition of the process is required.

20.1.1 Assimilating the data. In SCA this will involve two kinds of assimilation of data. The first is the development of a thorough understanding of the system and how it works by the persons who will analyze it. This level of understanding progresses as the SCA program develops. The understanding of details of system operation may not be necessary to make a reasonably accurate estimate of cost and schedule but it is essential to the persons performing the detailed analysis. To clarify this somewhat, it should be stated that one of the principal advantages of SCA is to "highlight" sneak conditions, thus removing the dependence on the abilities of individual analysts to an extent. Nevertheless, an analyst must understand the operation of the system in detail in order to isolate real or likely sneak conditions from the many cases which are "highlighted" by the general SCA procedures. The second kind of data assimilation involved in SCA is the formatting, entry, and verification of all necessary system data for computer (or manual) data processing. Here again, SCA may differ from other procedures because the intent of SCA is to detect sneak conditions in the system as built, not as the system designers might think it is built. Consequently, the input data for an SCA should always be derived from the best available source, the production definition if possible, although to be performed on a timely basis, it will almost always be performed on some earlier definition and later updated with production data.

20.1.2 Organizing the data. Data processing procedures will vary both in the compatibility of data formats with a supplier's data base, and with the degree of cross-verification of input data provided by the data processing programs. The intent of the data processing programs is to verify the input data to remove errors and to generate the working materials, such as partial schematics, flowcharts. etc., that will be used in the next step in the analysis. The data processing programs may also automate some (but never all) of the sneak search procedures to be used by the sneak circuit analysts, providing certain preprocessed data to be used in the next phase of the analysis. The data processing may also be performed entirely with manual rather than computer data processing programs. This is probably best limited to small systems, no larger than perhaps 100 to 200 total parts count for switching and analog systems, 50 small-signal integrated circuit (SSI) digital systems, or 300-500 statement software programs.

20.1.3 Detailed sneak circuit analysis

20.1.3.1 Sneak path analysis. The procedures developed for NASA were based on the observation that certain similarities existed among sneak circuit conditions which had occurred in hardware systems. It was also observed that any (electrical) network could be reduced to one of five subnetworks called "network trees", and that each "tree" could be efficiently analyzed for sneak circuit conditions, using the accumulated knowledge gained from previous sneak circuit situations. A "network tree" is a portion of a network having common ties with other trees only at power or ground connections. The five basic types of trees are shown below:



Although some networks may appear more complex, they can always be represented as a combination of these five basic trees. The impedance elements in the trees may be combination of electrical impedances, wires, connector pins, switch contacts, etc. In the NASA procedure, detailed lists of "clues" were developed to analyze each type of network tree. The clues are based on both theoretical principles and on experience with other sneak conditions which have occurred historically. The clues for a particular type of network tree are used whenever that type tree is encountered in an SCA. The clue lists and computer data processing programs are the primary features of SCA considered proprietary by most companies. Because of this, a comprehensive list of SCA clues cannot be presented here. However, to indicate what kind of clues are involved several typical ones are presented. One clue which is nearly always applied is to consider the timing and direction of currents in the tree. The conditions of switches in the tree are analyzed to see if all switch conditions lead to intended currents in the network. The existence of currents in a reverse direction from the normally intended current is also a clue that a sneak circuit may be present. The generation of network trees is normally done with computer assistance. Further reduction of network trees down to essential elements is normally performed using either manual or computer-assisted methods. Essential elements are those which might possibly lead to a sneak condition, and will include control elements such as relay coils, transistors, switches, pull-out connector pins, etc. Certain non-essential elements may be eliminated, e.g. fixed impedances, hardwired connections, pins of connectors that are not removed during operation, etc., in order to simplify later analysis. This step becomes the controlling consideration in deciding whether computer data processing is required to perform sneak path analysis. Because of the difficulty in visualizing network trees (or some equivalent subnetwork in a different SCA process), manual sneak path analysis should only be done on systems below about 100-200 component parts. Once the system circuitry has been reduced for analysis, sneak circuit clues are applied by the analysts to each reduced network. This process is normally the most time consuming in the SCA. The analysts may be assisted in this process by numerous computer data processing outputs which tend to reduce the amount of time required to apply clues.

20.1.3.2. Digital SCA procedures. The process just described has been defined as "sneak path analysis". The derived technique of digital sneak circuit analysis arose primarily because of the difficulty in analyzing the multiplicity of possible states of a digital system by considering each state independently in a manual (really a thought process) analysis. Consequently, some digital SCA procedures have been modified to take advantage of available logic analyzer or logic simulator computer programs in addition to the more conventional sneak path analysis procedures. Digital logic systems are more easily analyzed by tracing functional signal paths through the network rather than power-to-ground network trees. This type of analysis can be done manually up to about 50-75 SSI circuits or about 20-25 MSI circuits. Beyond this, computer-assisted techniques should be used.

20.1.3.3 Software SCA procedures. Software SCA was derived from the application of the principles of sneak path analysis for hardware to computer program flow diagrams. Here again, clues are applied that are specific to particular flow diagram topographs. The procedure may utilize computer aids to analyze the multiplicity of input conditions for a given flow diagram, and it may involve an adaptation of hardware path search software to generate the suspect flow diagram topographs. It is also quite likely that new software code analyzer programs will be developed with many of the same features as software SCA and will be used as substitute analytical procedures. Software SCA can also be performed manually on small programs. The limits is probably in the range of 300-500 code statements for relatively well structured code. If the code is poorly structured, the limit could be much lower. There are also derived SCA techniques for handling both hardware elements and software code statements in the same topographs, i.e., hardware/software integration analysis. This is a relatively new procedure and little guidance beyond that provided herein for evaluating new SCA methodologies can be given.

20.1.3.4 Supplementary considerations. All of the defined types of SCA involve the application of certain formalized clues to isolate sneak circuit conditions. Since the entire system will be scruntinized by a group of trained analysts, the SCA offers an excellent opportunity to review other features of the design which might cause it to malfunction, although they are not considered as sneak conditions, per se. Consequently, the clue lists used in SCA have generally been expanded to include additional features which the analysts look for in addition to sneak conditions. Thus, overstressed parts, single point failures, excessive fan-out, documentation errors, and unused circuitry may also be identified during an SCA. The SCA is not comprehensive in these areas, but can be very useful as a "second check". The SCA contract should be explicit in specifying which of these supplementary features are to be considered in the SCA; otherwise they may be omitted from the analysis by the performing activity to reduce costs.

20.1.4 Reporting SCA results. SCA results are reported in the conventional manner, although supplier's formats may vary. Section 8.4 provides guidance on specifying reporting requirements.

20.2 System partitioning. An SCA can be performed at any one of several levels, depending on a variety of factors which have been considered in this handbook. Within certain constraints, the levels of SCA may be mixed to provide increased scrutiny on selected portions of the system. There are two primary reasons for partitioning a system. The first is to assist in defining the scope of the SCA. The SCA may be performed at system level, subsystem level, or device level. Certain more or less independent functions can also be isolated for intensive analysis, e.g. the Built-in-Test (BIT) features, the power distribution or ground distribution networks, or the specific circuits involved in the arming and firing of explosives. The trade-offs involved in determining the most cost effective scope for an SCA are discussed in Section 9. The second reason for partitioning is to isolate certain portions of the system to simplify subsequent analysis. For example, an obvious partitioning might be to break a system at a hardware/software interface, or between power distribution circuits and digital subsystems. This type of partitioning would be used to adapt the system to a supplier's specific SCA procedures.

20.2.1 System level SCA. A system level SCA concentrates on the system interconnections between subassemblies, considering subassembly inputs and output as loads or sources respectively, and considering subsystem functions as correctly generated, without considering possible sneak conditions within subsystems or at any lower level. Power distribution and ground distribution circuits would also be included. Signal flow would be considered; however signal generation would not. All system level switching functions and all system level discrete components would normally be included. System level SCA is most appropriate where subassemblies are well understood, either because they are standard assemblies in wide usage or there is some other background of good historical data on the subassemblies. It must be pointed out that any tailoring process reduces the effectiveness of SCA to an extent, and performing system level SCA alone may permit some sneak conditions at subsystem level or below to slip through. Abiding by these suggested constraints should minimize the "leakage" for the dollars spent.

20.2.2 Subsystem level SCA A subsystem (or "black-box") level SCA provides an additional level of discrimination beyond that of system level SCA. In the subsystem level SCA, each of the subassemblies is also considered for possible generation of sneak conditions. Subsystems would normally be represented by the discrete components making up the subsystem, except that integrated devices would be represented by their logical functions or by their analog function e.g. by an operational amplifier rather than by the integrated components making up the operational amplifier. Performance of subsystem level SCA normally presupposes the performance of system level SCA although exceptions are possible. Subsystem level SCA provides additional assurance that most sneak conditions will be found, normally at a relatively large increase in cost. It is appropriate for newly-designed subsystems or subsystems which have no background of trouble-free historical data, which might justify their exclusion from the SCA. Subsystem SCA can be performed on all subsystems or on selected subsystems, e.g. BIT circuitry within a system level SCA.

20.2.3 Device level SCA. The device level SCA considers all parts in a given subsystem, even integrated circuits at their fundamental component level, e.g. a digital logic integrated circuit would be represented as an assemblage of resistors, capacitors, transistors, diodes, etc. The device level SCA might be used to analyze a particular integrated circuit or selected integrated circuits within a subsystem level SCA. It might also be used totally independently to analyze a new integrated circuit. Device level SCA can be expected to be relatively more expensive than "subsystem level SCA." It would normally not be cost effective to do device level SCA on a complete system consisting of many integrated circuits.

APPENDIX C

STATEMENT OF WORK

30.1 General. This appendix presents some examples of contract statements of work that may be applicable when ordering an SCA, and a typical Data Item Description (DID). Statements of work, Contract Data Requirements Lists (CDRL), and DIDs must be appropriately tailored for each individual situation.

30.2 Examples. Examples of general statements of work and options which may be selected, depending on the individual circumstances, are presented in exhibits C-1 through C-12.

30.3 Data item description (DID). Representative DIDs describing typically required data items to be delivered in conjunction with the SCA are included at the end of this appendix.

Perform a (software) sneak circuit analysis of the __________ system. The analysis shall be performed using established contractor-developed procedures and shall identify latent electrical paths (or software logic control paths) which can cause an undesired function to occur or can inhibit a desired function. Analysis results shall be reported in accordance with item A001 of the attached Contract Data Requirements List (CDRL). Periodic status reports shall be submitted during the course of the analysis in accordance with item A002 of the attached CDRL.

Exhibit C-1. General Statement of Work

The sneak circuit analysis shall be limited to the system level. As such it shall include the interconnections of all subassemblies defined in the attached drawing list, all power distribution and control circuits, all ground circuits, all relay and panel switching, and all system level discrete components.

Exhibit C-2. System Level Option

The sneak circuit analysis shall be limited to the (name(s)) subsystem(s) defined in the attached drawing list and to its (their) interconnections within the systems. Within the subsystem, the SCA shall be taken to the device function level for subsystem components. All power distribution and control circuits, all ground circuits, all relay and panel switching and all system-level discrete components involved in the interconnections of the specified subsystem(s) into the ____________ system shall be also included in the analysis.

Exhibit C-3. Subsystem Level Option

The sneak circuit analysis shall be limited to the (name(s)) subsystems defined in the attached drawing list, and for the specified subassembly(s), shall be taken to the device level. All power distribution and control circuits, all ground circuits, all relay and panel switching, and all system level discrete components involved in the interconnections of the specified subsystem(s) into the ______ system shall also be included in the analysis.

Exhibit C-4. Discrete Part Level Option

The sneak circuit analysis shall be performed using contractor developed procedures for SCA of digital systems. The SCA shall also identify:

a. Logical errors and inconsistencies
b. Sneak timing
c. Excessive fan-out
d. Power supply cross-ties, grounding or other misconnection of signal pins

Exhibit C-5. Digital Hardware Option

The sneak circuit analysis shall be performed using contractor-developed procedures for SCA of software (or the integration of software and hardware).

Exhibit C-6. Software SCA Option

In addition to latent paths, the SCA shall identify, to the extent of the limitations in scope defined above, all instances of the following conditions noted during the analysis:

a. Single point failures
b. Lack of relay transient protection
c. Drawing and documentation errors
d. Unnecessary or unused circuitry

Exhibit C-7. Additional Reporting Options

The analysis shall be performed in phases as defined below. Each phase shall be funded separately. Prior to the end of each phase, the Government shall release funds for the subsequent phase provided that the delivered items provided to that point are acceptable. In the event that the delivered items are unacceptable or that a change or limitation in scope is necessary, the contract shall be renegotiated prior to initiation of the next phase.

Exhibit C-8. General Phasing Statement

Phase 1 During the initial phase, the contractor shall define the system which is to be subjected to SCA, including the drawings issues, computer program, configuration items, and level of analysis to be applied in each area of the system. Methods to be used in each system area shall be defined. Results and recommendations for system partitioning, lists showing required drawings, data items, documents and identifying any missing documentation shall form a part of the periodic status report immediately preceding the completion of Phase 1.

Exhibit C-9. Phase 1 Option

Phase 2 The SCA shall be performed at the system-level and to the subsystem level to the extent defined in the contract. Preliminary results and recommendations during this phase shall form a part of periodic status reporting. The contractor shall make recommendations during this phase relative to any subassemblies or integrated circuits which should be analyzed at the device level, and shall include this in the periodic status report immediately preceding the completion of Phase 2. Any computer program configuration items requiring detailed analysis shall also be identified and similarly reported.

Exhibit C-10. Phase 2 Option

Phase 3 The SCA shall be completed to the device-level to the extent defined in the contract. The contractor shall update the complete SCA to include any system changes made to correct problems identified during previous phases. Summary results and recommendations, including current status of disposition of recommended changes shall be included in the final report.

Exhibit C-11. Phase 3 Option

Phase 4 The contractor shall provide monitoring and evaluation of system changes and shall update the SCA to the extent required. Results, recommendations, and current status of all problem dispositions shall be included in the periodic status reports during this phase. If directed, the contractor shall update the final report to reflect the final dispositions of all identified problems at the conclusion of Phase 4.

Exhibit C-12. Phase 4 Option

DATA ITEM DESCRIPTION

1. TITLE Sneak Circuit Analysis Plan	2. IDENTIFICATION NO(S) AGENCY: NAVY-SE NUMBER:
3. DESCRIPTION/PURPOSE This plan presents the contractor's concept of the sneak circuit annalysis.	4. APPROVAL DATE 5. OFFICE OF PRIMARY RESPONSIBILITY 6. DDC REQUIRED 8. APPROVAL LIMITATION
7. APPLICATION/INTERRELATIONSHIP This Data Item Description is applicable to any phase when complete documentation is available. The following DID's are interrelated: DI-R-22594 Analysis, Sneak Circuit DI-R-XXXXX Status Report, Sneak Circuit Analysis	9. REFERENCES (Mandatory as cited in block 10) MIL-STD-785A Notice 1 (EC) MCSL NUMBER(S)

10. PREPARATION INSTRUCTIONS

10.1 The Sneak Circuit Analysis Plan shall include, but is not limited to, the following:

a. Scope of analysis including hardware and software to be analyzed

b. Data required to perform the analysis

c. Reports to be submitted

d. Metholodgy to be used

e. Schedule for performing analysis

f. Corrective action procedure

10.2 The plan shall be in contractor's format.

DATA ITEM DESCRIPTION

2. IDENTIFICATION NO(S). AGENCY	NUMBER
NAVY-SE	

1. TITLE
Sneak Circuit Analysis Status Report

3. DESCRIPTION/PURPOSE

This report presents the progress that has been made to date on the sneak circuit analysis.

4. APPROVAL DATE

5. OFFICE OF PRIMARY RESPONSIBILITY

6. DDC REQUIRED

8. APPROVAL LIMITATION

7. APPLICATION/INTERRELATIONSHIP

The following DID's are interrelated:
DI-R-22594 Analysis, Sneak Circuit
DI-R-XXXXX Plan, Sneak Circuit Analysis

9. REFERENCES (Mandatory as cited in block 10)

MIL-STD-785A
Notice 1 (EC)

MCSL NUMBER(S)

10. PREPARATION INSTRUCTIONS

10.1 The status report will provide an accounting of work accomplished to date and planned tasks for the next reporting period.

10.2 The report shall be in contractor's format.

DATA ITEM DESCRIPTION	2. IDENTIFICATION NO(S)	
	AGENCY	NUMBER
1. TITLE REPORT, SNEAK CIRCUIT ANALYSIS (SCA)	NAVY	

3. DESCRIPTION/PURPOSE

3.1 Description. The SCA report describes all sneak circuit conditions identified during the formal SCA and provides recommendations for their correction. The report also describes and recommends solutions for other design problems discovered during the SCA. In addition, provision is made for retention of critical SCA data.

3.2 Purpose. The SCA report is used to document the results and to ensure the thoroughness and completeness of the sneak circuit analysis.

4. APPROVAL DATE

5. OFFICE OF PRIMARY RESPONSIBILITY

6. DDC REQUIRED

8. APPROVAL LIMITATION

7. APPLICATION/INTERRELATIONSHIP

7.1 Application. Sneak circuit analysis is applicable to mission critical hardware and software systems and equipment. The SCA is applicable to system, subsystem, or equipment levels.

7.2 Interrelationship. The SCA may be implemented independently or as one of the specific tasks in accordance with a reliability program in accordance with MIL-STD-785. SCA results may also be useful in performing hazard analysis in accordance with MIL-STD-882.

9. REFERENCES (Mandatory as cited in block 10)

MIL-STD-785
MIL-STD-882

MCSL NUMBER(S)

10. PREPARATION INSTRUCTIONS

10.1 General. Unless otherwise specified by the contracts, the documents cited in this block, of the issue in effect on the date of award form a part of this Data Item Description to the extent specified herein.

10.2 Content. The SCA report shall detail the results of the SCA performed, and shall include the following items:

a. Discussion of the SCA methodology used and any assumptions made in performing the analysis.

b. Tabulation of all actual or suspected sneak circuit conditions including:

(1) Identification of the circuit, computer program, situation or condition creating the sneak circuit.

(2) Discussion of the conditions causing or suspected of causing the sneak circuit condition.

(3) Recommendations for the correction of all sneak circuit conditions.

c. Reports of any and all drawing or design errors, suspected design oversights, inconsistencies, or incompatibilities noted during the analysis. Situations to be reported shall include overstressed or overloaded components, single point failures, unused or inaccessible circuitry or computer code, and lack

(Continued on attached pages)

DATA ITEM DESCRIPTION	2 IDENTIFICATION NO(S)	
	AGENCY	NUMBER
1 TITLE REPORT, SNEAK CIRCUIT ANALYSIS (SCA)	NAVY	

3. DESCRIPTION PURPOSE	4 APPROVAL DATE
	5 OFFICE OF PRIMARY RESPONSIBILITY
	6 DDC REQUIRED
7 APPLICATION INTERRELATIONSHIP	8 APPROVAL LIMITATION
	9 REFERENCES *(Mandatory as cited in block 10)*
	MCSL NUMBER(S)

10 PREPARATION INSTRUCTIONS

of transient suppression devices, to the extent these were identified in the SCA.

d. A complete record of drawings used in the analysis, including drawing revision, engineering change notices, and any exceptions taken during the SCA.

e. A complete record of the computer data base used in the analysis, including input, intermediate, and output data adequate to duplicate or update the SCA. Upon contractual agreement, this data base may be retained by the contractor for a specified period.

f. Analyst worksheets used in the SCA to the extent specified in the contract.

10.3 Format SCA reports may be supplied in contractor's format.

SNEAK CIRCUIT ANALYSIS

BIBLIOGRAPHY

1. NAVORD OD44942, Paragraph 7.5.4, "Sneak Circuit Analysis," pp. 7-42 through 7-47.

2. AS5503, Reliability Program Requirements for Weapons Systems Developments, General Specification for" (Naval Weapons Center, China Lake).

3. Proceedings Document, "Sneak Circuit Analysis of Military Systems," E. J. Hill and L. J. Bose, Boeing, Aerospace Co., Houston, Texas, (Proceedings of the Second International System Safety Conference, July 1975, pp 351-372).

4. Boeing Aerospace Company Document, "Sneak Circuit Analysis Workshop Handbook", presented 20 January 1978 and 4 April 1978.

5. Air Force Technical Note, AFNL-TR-75-254, "Software Sneak Circuit Analysis", J. P. Rankin, G. J. Engles, and S. G. Godoy, Boeing Aerospace Company, Houston Texas, 1976, (NTIS AD/A-024718).

6. IEEE Conference Paper, "Sneak Circuit Analysis Development and Applications", Robert C. Clardy, Boeing Aerospace Co., Region V IEEE Conference Digest, April 14, 1976, (IEEE catalog no. 76CH1068-6, REGE, pp. 112-116.)

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