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Electromagnetic Pulse (EMP) Handbook Development for the Defense Nuclear Agency (DNA)

Annual Report for the Period October 1, 1980 - September 30, 1981

J. M. PIERRE

Plasma Radiation Group
Plasma Physics Division

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During FY 81, the Defense Nuclear Agency (DNA) initiated a program with the Naval Research Laboratory to provide technical and management support in the development of an electromagnetic pulse (EMP) handbook for ground based facilities. The focus of the handbook program during the first year was on the assessment of the data needs of the EMP user community and the adequacy of the existing data base. This report provides a summary of the activities, findings, and accomplishments during the past year in the EMP handbook development area.

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ELECTROMAGNETIC PULSE (EMP) HANDBOOK DEVELOPMENT FOR THE DEFENSE NUCLEAR AGENCY (DNA)
Annual Report for the Period October 1, 1980 — September 30, 1981

I. INTRODUCTION

Electromagnetic pulse (EMP) technology has evolved over the past twenty years in response to the need to provide EMP protection - or hardening - to materials, devices, equipment, or systems as specific needs arose. Although methodologies and procedures have been developed to meet the nuclear survivability requirements of particular systems, relatively little effort has been directed toward the unification of what has been learned concerning the effectiveness of various approaches to achieving an acceptable degree of nuclear hardness. This is particularly true in the case of providing protection to ground based facilities against nuclear induced EMP. Even though "hardened" facilities have been built in the past, for example, those associated with the Safeguard system, there is no clear understanding of how to plan, design, construct, test, and maintain a hardened site.

With the increased complexity and sophistication of current and proposed defense systems, particularly communication networks and missile systems, and the many types of ground facilities which are required to support such systems, there exists a continuing critical need to find cost effective, efficient, and workable approaches to facility hardening. Recognizing this need and the necessity for improving the organization of the existing data base, the Defense Nuclear Agency initiated a program during FY 81 to identify the needs of the EMP community in terms of what data is required by various segments of the federal, the defense, and the private sectors which would enable them to make sound decisions which pertain to the hardening of ground based facilities. While there does exist a large amount of experience and data on the hardening of facilities, this expertise and data are not readily available in a form which is of practical use to any except those who are already well versed in the technology. The existing body of knowledge is, at present, spread out amongst numerous data sources. The DNA EMP Handbook Development Program is an attempt to find a means of collecting and making available the appropriate, state-of-the-art data on nuclear hardness to various levels of personnel involved in EMP protection.

Manuscript submitted November 23, 1981.

During FY 81, the Naval Research Laboratory (NRL) has provided technical and management support to the Defense Nuclear Agency (DNA) in the development of an EMP handbook for ground based facilities. This report provides a summary of the activities, findings, and accomplishments during the past year in the handbook development area. Section II presents the background conditions under which the handbook development program was initiated. In Section III the rationale for the formation of a handbook development committee is discussed. The recommendations and the actions of this committee during the past year are summarized in Section IV. Section V gives a statement of the general philosophy behind the handbook program, while Section VI touches briefly upon the long term maintenance aspects of the data base. The highlights of the handbook development program during FY 81 are synopsized in Section VII.

A number of appendices are included in this report for the purpose of documentation. Of particular note are the Executive Summary (Appendix A) and the detailed outlines for each of the proposed volumes of the handbook as it is presently envisioned (Appendices B-D).

II. HANDBOOK DEVELOPMENT BACKGROUND

In October of 1980, a meeting sponsored by DNA/RAEE was held in conjunction with the DNA EMP Simulation and Hardening Symposium at the Naval Post Graduate School in Monterey, California. This meeting served as an excellent opportunity to bring together experts from a large cross section of the EMP community to discuss the need for an applications oriented EMP handbook for ground based facilities. The general concensus of both government and industrial representatives who attended the meeting may be summarized as follows:

1. Although EMP technology is far from complete, it is sufficiently mature to meet many of the facilities EMP protection requirements which exist today.
2. A critical need exists in both government and industry to have access to the best available data on the plan, design, verification, and maintenance of an EMP hardened facility.

3. Experience gained from the development of site protection for ABM, Minuteman, Defense Support Program, and NATO Wing Command Posts, as well as improved and new data from current and planned DNA experiments (eg. the Life Cycle Cost and the Verification Protocol programs), should be unified and organized into handbook form.

From the inception of the program, a concerted effort has been made to encourage communication between the EMP community, especially between potential handbook contributors and users, in order to maximize the effectiveness of the handbook to meet the community needs. Thus, a survey of the participants in the informal October meeting was conducted to solicit ideas on a) the need for a handbook, b) approaches to handbook development, c) potential data sources/voids, and d) topics appropriate for inclusion in the handbook. Many of the suggestions concerning handbook content and organization, which were obtained in response to the survey, have been incorporated into the preliminary draft outlines for the handbook, which will be discussed in Section IV. Copies of the draft outlines generated by the committee have been circulated to interested government organizations for comment. In addition to the survey, periodic progress letters on the handbook development program and on committee activities have been sent to organizations who have indicated active interest in EMP protection and in the handbook effort. The distribution list for progress letters is given in Appendix 1. (Anyone who wishes to be included on the distribution list should contact the author.)

III. HANDBOOK COMMITTEE COMPOSITION AND FUNCTION

Because the focus of the handbook program during the first year was on the assessment of the community needs and the adequacy of the existing data base, it was highly desirable to establish a format which allowed for broad based community participation. Thus, a committee approach to handbook development was adopted. A particularly attractive feature of the committee format was that it allowed for the direct involvement of persons whose corporate backgrounds cover a wide spectrum of past and present EMP protection experience. This approach had the added advantage that the data base assessment would be conducted by persons who had ready access to and applications experience with the existing data.

A nine member Handbook Development Committee was formed in November, 1980. The members served on a voluntary basis and were charged with providing technical guidance on data assessment. They acted as a peer review group which examined the existing data base on the hardening of facilities to determine where the data resides, the integrity of the data, and whether the data is in a form suitable for inclusion into a handbook. The approach which has been adopted toward handbook development, as well as its proposed content and format, have evolved as a result of committee recommendations made during the past year. It is planned that approximately one third of the committee members will be rotated each year so that community participation may be further broadened as the program matures. The membership of the committee during the past year is shown in Appendix ii.

IV. COMMITTEE RECOMMENDATIONS AND ACTIONS

The handbook committee met formally on three occasions during FY 81. The schedule of these meetings and the major milestones reached are given in the following chart.

MEETINGS OF THE HANDBOOK DEVELOPMENT COMMITTEE - FY 81

DATE(s)	HOST	MILESTONE(s)
December 12, 1980	Naval Research Laboratory Washington, D.C.	Basic structure of handbook identified. Subcommittees formed for each handbook volume.
March 24-25,1981	Mission Research Corporation Albuquerque, New Mexico	Draft outlines for volumes reviewed.
July 16-17, 1981	SRI International Menlo Park, California	Draft executive summary reviewed. Draft outlines for volumes finalized.

During the initial meeting at NRL, the committee concentrated on three major issues. These were, first, the identification of the objective of the handbook program, second, the definition of the technical scope of the handbook, and third, the identification of the audience to which the handbook is directed. The committee consensus on each of these issues and the supporting rationale for some of the decisions regarding these issues are summarized as follows.

1. Objective The basic objective of the handbook program is to identify, collect, and maintain the best available EMP protection data on ground based facilities and to transfer the requisite technology to various levels of personnel who have EMP protection responsibility.

This objective is dictated by the urgent need within the military services, government agencies, and industry to understand which hardness options may be exercised now to minimize mistakes which will prove costly to rectify in the future. In many instances, this need is time critical because hardness implementation has become a commonplace requirement in many military systems. In addition, while the need for EMP protection expertise is increasing, the number of available EMP experts is insufficient to meet the demand on a timely basis. Consequently, data and issues which can be clearly identified should be cast into handbook form to facilitate the technology transfer between the technology developers and the user community.

2. Scope The committee recognized that not all EMP issues which pertain to ground facilities can be adequately addressed by any single handbook. It therefore elected to restrict the scope of the technical content so that a reasonably usable document could be written and made available to users within three years time. Thus, the primary emphasis of the handbook is on the EMP protection of new facilities as opposed to the retrofit of existing ones. However, much of the information in the handbook will be equally applicable to retrofit situations as well. Similarly, it is intended to be applicable to ground facilities in general, although it is expected that the handbook will be particularly useful in the communications, command, and control (C^3) area because much of the recent EMP data base and interest is focused on C^3 systems.

It was also decided that only high altitude EMP would be addressed. Source region EMP was deliberately not included at this time because the issues are complex and the technology is not sufficiently mature. In addition, the handbook is intended to be applications rather than environment and phenomenology oriented. The long range plan for the development and maintenance of the handbook does, however, allow for the potential expansion of the technical scope to include other forms of EMP in the future. The long range plan for the handbook will be discussed later in Section VI.

3. Audience It is generally recognized within the EMP community that EMP protection of any system is a life cycle consideration. As such, it is important to consider EMP protection as part of other protection requirements. The life cycle requirements of a facility are specified in the planning phase of a system and must be carried out through the design, construction, and maintenance phases. Three distinct levels of personnel have been identified who have different types of EMP protection responsibility at various stages of facility development and evolution. The first gorup consists of persons who have the task of formulating and executing programs which are to result in a hardened facility, namely, program managers. The second group is comprised of engineers and designers who specify and construct the facility. The last group includes the personnel who are responsible for the day-to-day operation and maintenance of the facility. Each group must understand the EMP problem in a different context and each has different data requirements. In order to meet the needs of each group, the DNA EMP Engineering Handbook for Ground Based Facilities has been organized into three volumes. Each volume is directed to a different audience--Volume I for the program manager, Volume II for the engineer/designer, and Volume III for the operations and maintenance personnel.

As Appendix ii shows, subcommittees of three members each were formed to lead each of the volumes. In the months that followed, the subcommittees conducted interviews, assembled data, and developed preliminary outlines for the three volumes. These outlines were reviewed by the full committee at the March meeting which was held at Mission

Research Corporation in Albuquerque, New Mexico. During the following quarter, changes and revisions of the outlines were made and a draft executive summary for the handbook was developed. These were presented to the full committee for review during the July meeting which was hosted by SRI International, Menlo Park, California. It should also be noted that the handbook program and the volume outlines were reviewed by DNA/DDST during the C^3 Technical Review in June of 1981. The draft versions of the executive summary and the outlines for each volume are included in this report as Appendices A, B, C, and D respectively.

V. HANDBOOK PHILOSOPHY

The underlying philosophy behind the handbook development program is that even though there does not presently nor will there ever exist a universally applicable panacea for the EMP problem, the technology on facilities hardening is sufficiently advanced to provide limited, and in some cases adequate, salvation from the dilemma. To a large extent, the growth in EMP awareness over the past twenty years can be directly attributable to the "missionary" activities of DNA and its support contractors since the FISHBOWL experiments in the early 1960s. There is now widespread awareness of the existence and acceptance of the potential acuteness of the EMP threat. It is encumbent upon the EMP community to identify the critical technical EMP issues, to present in a usable form the quality data obtained through its research and technology programs, and to provide the user community with an understanding of the various protection options which are available. The handbook is not a "cookbook" with recipes for the production of hardened facilities, but rather will offer aids and choices which will allow the user to decide which options are most appropriate for his particular requirements. Particular attention will be given to providing the user of the handbook with a clear understanding of the limitations and caveats which apply to the data.

VI. THE HANDBOOK - A DYNAMIC DOCUMENT

Since the understanding of EMP protection is likely to change with time as the technology advances, it has been suggested that the handbook be maintained as a computerized data base. This concept will be discussed in a separate report.

At present, it is envisioned that the handbook will be a dynamic compendium of EMP protection methods, techniques and data which will provide an accurate and timely, applications oriented view of available EMP protection options. As the technology itself matures, changes, updates, and revisions of the handbook will be required. In some instances, it is expected that the handbook will point to data deficiencies or voids which will be rectified by present or planned programs. Thus, the handbook development program has application as a management tool. By providing the best available data to the user community through the handbook, the quality of EMP protection decisions which impact EMP programs will be improved by decreasing the need to rely on engineering judgment alone and by promoting the usage of quality data. The long term, dynamic evolution of the handbook is represented schematically in Figure 1 .

VII. SUMMARY

During the past year, NRL has assisted DNA in laying the ground work for the development of an EMP Engineering Handbook for ground based facilities. A committee composed of both government and industry experts on EMP protection of ground facilities was formed in November of 1980. This committee was charged with the development of a community consensus on a number of questions which included:

1. Is there a need for an applications oriented handbook for ground based facilities?
2. What type of approach to handbook development will best serve the community needs?
3. What is the adequacy of the existing data base and where are the data voids?
4. What topics are appropriate for inclusion in the handbook?

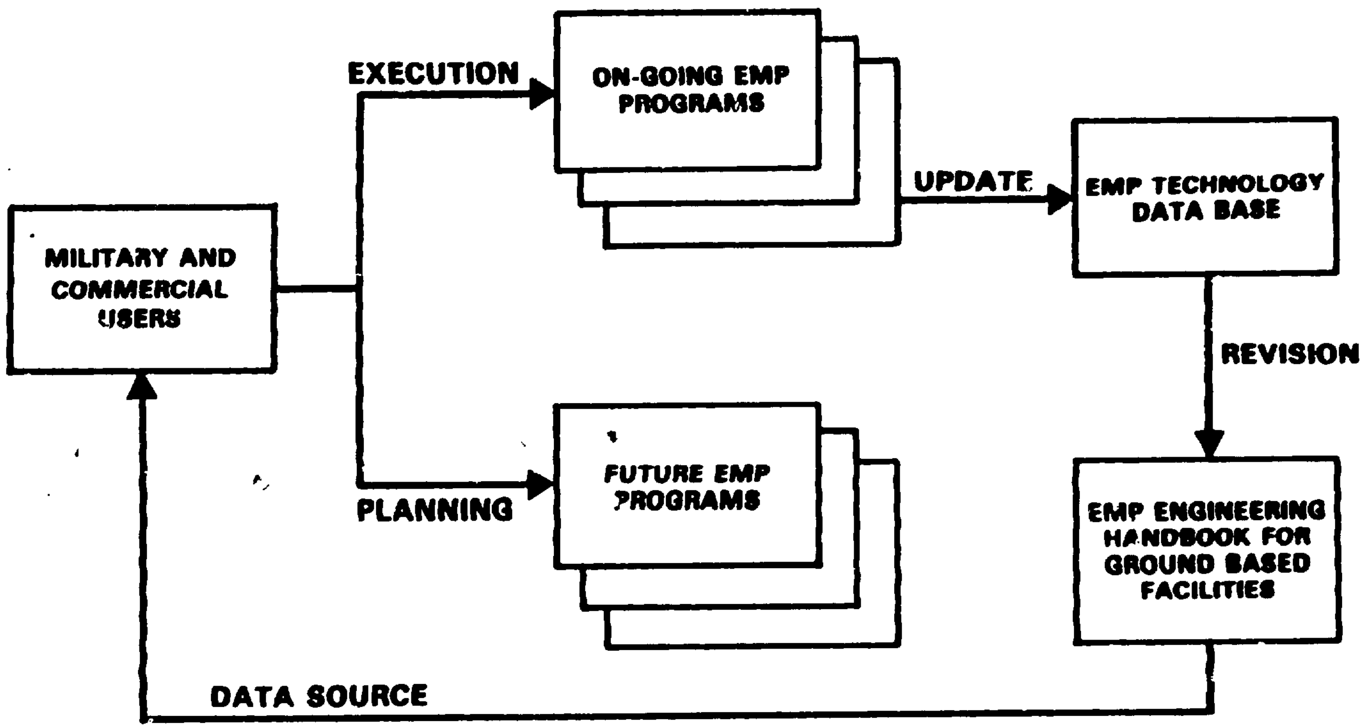
MILITARY AND COMMERCIAL USERS
EXECUTION
PLANNING
ON-GOING EMP PROGRAMS
FUTURE EMP PROGRAMS
UPDATE
EMP TECHNOLOGY DATA BASE
REVISION
EMP ENGINEERING HANDBOOK FOR GROUND BASED FACILITIES
DATA SOURCE

FIGURE 1

4. What topics are appropriate for inclusion in the handbook?

The committee concluded that there is a time critical need in the EMP community to identify the critical technical EMP issues, to present in a usable form the quality data obtained through its research and technology programs, and to provide the user community with an understanding of the various protection options which are available. Another major conclusion of the committee is that EMP protection of any facility must be a life cycle consideration. Thus, it is necessary that the handbook provide EMP protection guidance to all levels of personnel who are engaged in EMP protection activities. The proposed handbook will, therefore, consist of three volumes, each targeted to a specific audience--the program manager, the engineer/designer, and the operations and maintenance personnel. During FY 81, an Executive Summary and detailed volume outlines have been developed by the handbook committee. These documents should serve as an excellent basis for the orderly development of a draft handbook during the following year.

A crucial element of the handbook development program during FY 82 will be the establishment of an appropriate review process. It is expected that the tradition of open communication between the handbook developers and the user community which has been established during the past year will continue to be a hallmark of the program.

ACKNOWLEDGMENT

The accomplishments of the handbook development program are a tribute to nine individuals who during the past year offered their work, time, and cooperation through their participation on the handbook development committee. The author thanks each member of the committee - Alan Chodorow (Mission Research Corporation), Sam Colombo (Boeing Aerospace Corporation), Ernest Donaldson (Georgia Institute of Technology), David Durgin (Booz Allen Hamilton, Inc.), Manfred Espig (DASIAC, Kaman Tempo), Theodore Martin (IIT Research Institute), Ray McCormack (U. S. Army Construction Engineering Research Laboratory), Gene Morgan (Rockwell International), and Ed Vance (SRI International). Without their contributions, there would be little to report. Finally, the author gratefully acknowledges the encouragement and support provided by the Defense Nuclear Agency, especially Maj. R. B. Williams, the Project Officer, and Paul Fleming, RAEE Division Head.

Appendix i

Government

U.S. Army Engineer Division
ATTN: A. Thomas Bolt
Box 1600
Huntsville, Alabama 35807

Commander
Ballistic Missile Defense Systems Command
P. O. Box 1500
ATTN: Richard W. DeKalb/BMDSC-HW
Huntsville, Alabama 35807

Harry Diamond Laboratories
ATTN: Mr. Bill Petty
2800 Powder Mill Road
Adelphi, Maryland 20783

Air Force Weapons Laboratory
ATTN: Bill Page
Kirtland Air Force Base
Albuquerque, New Mexico 87117

Air Force Weapons Laboratory
ATTN: Dick Hayes
Kirtland Air Force Base
Albuquerque, New Mexico 87117

Commander
U. S. Army Construction Engineering
Research Laboratory
ATTN: Paul Nielsen
P. O. Box 4005
Champaign, Illinois 61820

C. William Bergman
D.C.E.C. Code R302
1860 Wiehle Avenue
Reston, Virginia 22091

Alexander Bartko
Defense Communications Agency
Code 213
Vulnerability Branch
S. Courthouse Road
Arlington, Virginia 22204

Don O'Bryhim
NAVELEX PME 110-241
Washington, D.C. 20360

Joseph Miletta
Harry Diamond Laboratories
(U.S. Army)
2800 Powder Mill Road
Adelphi, Md. 20783
ATTN: DELHD-NW-EA

NON-GOVERNMENT

SRI International
ATTN: Dr. Werner Graf
333 Ravenwood Avenue
Menlo Park, California 94025

Mission Research Corporation
P. O. Drawer 719
ATTN: Bill Crevier
Santa Barbara, Calif. 93102

Mission Research Corporation
ATTN: John W. Williams
1400 San Mateo Blvd, SE,
Suite A
Albuquerque, New Mexico 87108

IIT Research Institute
ATTN: Irving N. Mindel
10 West 35th Street
Chicago, Illinois 60616

IRT Corporation
ATTN: Brian Williams
P. O. Box 80817
San Diego, California 92103

Teledyne Brown Engineering
ATTN: Melvin L. Price
Cummings Research Park
Huntsville, Alabama 35807

Teledyne Brown Engineering
ATTN: James H. Whitt
Cummings Research Park
Huntsville, Alabama 35807

Boeing Aerospace Company
P.O. Box 3999
ATTN: I. James Carney
Seattle, Washington 98124

Georgia Institute of Technology
Engineering Experiment Station
ATTN: Hugh Denny
Atlanta, Georgia 30332

Sylvania Systems Group
Electronic Systems and Services Org.
GTE Products Corporation
ATTN: Arthur Murphy
189 B Street
Needham, Massachusetts 02192

Mission Research Corporation
ATTN: Dr. Werner J. Stark
P. O. Box 7816
Colorado Springs, Colorado 80933

DNA EMP Engineering (Facilities) Handbook Development Committee

Managerial Vol. Subcommittee	Design/Engineering/Construction Volume Subcommittee	Operation & Maintenance Vol. Subcommittee
Mission Research Corporation ATTN: Alan Chodorow 1400 San Mateo Blvd., SE, Suite A Albuquerque, New Mexico 87108 (505) 265-8306	DASIAC KAMAN - TEMPO ATTN: Manfred Espig 816 State Street Santa Barbara, Calif. 93102 (805) 965-0551	Boeing Aerospace Company P. O. Box 3999 ATTN: Sam J. Colombo Seattle, Washington 98124 (206) 251-4677
Georgia Institute of Technology Engineering Experiment Station ATTN: Ernest E. Donaldson Atlanta, Georgia 30332 (404) 894-3535	Rockwell International Autonetics Strategic Systems Division ATTN: Gene Morgan P.O. Box 4192 Anaheim, California 92803 (714) 632-1903	Booz Allen & Hamilton, Inc. ATTN: David L. Durgin 4330 East West Highway Bethesda, Maryland 20014 (301) 951-2602
Commander U.S. Army Construction Engineering Research Laboratory ATTN: Ray McCormack Champaign, Illinois 61820 (217) 352-6511	SRI International ATTN: Ed Vance 333 Ravenwood Avenue Menlo Park, California 94025 (817) 478-5653	IIT Research Institute ATTN: Theodore A. Martin 10 West 35th Street Chicago, Illinois 60616 (312) 567-4486

* Indicates subcommittee chairman

Maj. Robert B. Williams, RAEE
Defense Nuclear Agency
Washington, D.C. 20305
(202) 325-7016

Joan Ma Pierre, Code 4720
Naval Research Laboratory
Washington, D.C. 20375
(202) 767-3278

APPENDIX A

DEFENSE NUCLEAR AGENCY
EMP ENGINEERING HANDBOOK
FOR
GROUND BASED FACILITIES

EXECUTIVE SUMMARY

David Durgin (Booz · Allen & Hamilton, Inc.)

EMP Engineering Handbook
for
Ground Based Folstsnskw

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

1-0 OVERVIEW.

1-1 INTRODUCTION.

This summary provides an overview of the program management, technical practices, and operational considerations essential to the successful design, implementation and operation of facilities required to survive a nuclear electromagnetic pulse (EMP). The focus of the DNA EMP Engineering Handbook is on a life cycle protection method for new ground based facilities. In general, the techniques and data presented are also applicable to the EMP protection of existing facilities, but the methods and system engineering options differ. This handbook is not intended to be a cookbook for EMP protection, but rather a dynamic compendium of EMP protection methods, techniques and data that will provide an accurate, application oriented view of the EMP protection technology. This summary will also serve as a guide to the contents of the DNA EMP Engineering Handbook for Ground Based Facilities. Since EMP survivability is a relatively new requirement, an introduction to the subject of nuclear EMP generation and protection is included in this volume. This overview of EMP generation and effects is intended for persons who desire a basic understanding of the problem in order to manage facility EMP protection programs. A more detailed discussion of EMP effects and protection measures is included in the Handbook volumes that discuss facility design and construction, and operation and maintenance.

The DNA EMP Engineering Handbook for Groundbased Facilities is composed of three volumes:

Volume I - Program Management

Volume II - Design and Engineering

Volume III - Operation and Maintenance

Each volume is structured to provide information for a specific group of users. Volume I is directed at persons who have the task of formulating and executing programs which are to result in an EMP protected facility. Volume II is for engineers and technicians who must design, specify and construct EMP hardened facilities. Volume III has been prepared for personnel who have the responsibility for operating and maintaining a facility to retain its built-in EMP protection. This summary provides a brief discussion of the EMP problem, followed by a presentation of the content of each volume of the handbook.

1-2 THE EMP PROBLEM.

1-2.1 EMP Phenomenology.

As a result of nuclear weapon tests, it has been observed that one of the effects of a nuclear weapon detonation is the production of a strong pulse of electromagnetic energy. This electromagnetic pulse of energy can propagate great distances from the point of weapon detonation. The actual field strength produced by the nuclear burst depends upon the yield of the nuclear weapon and the altitude at which the detonation takes place. It has been observed, for instance, that the EMP energy from a one megaton weapon detonated at an altitude of several hundred thousand feet produces electric field strengths on the order of 50,000 volts per meter at the surface of the earth. These field strengths can be generated over a wide area of the earth's surface facing the detonation.

The physical processes which contribute to the production of nuclear EMP are quite dependent upon the altitude of detonation. As a result, the characteristics of the EMP wave vary with burst altitude. Presently, two classes of EMP are of primary interest to C^3 facility designers and managers. These are High Altitude EMP (HEMP) and Surface Burst EMP (SBEMP).

Exhibit 1 is a pictorial summary of the processes that occur as a result of a high altitude burst. When a nuclear weapon explosion

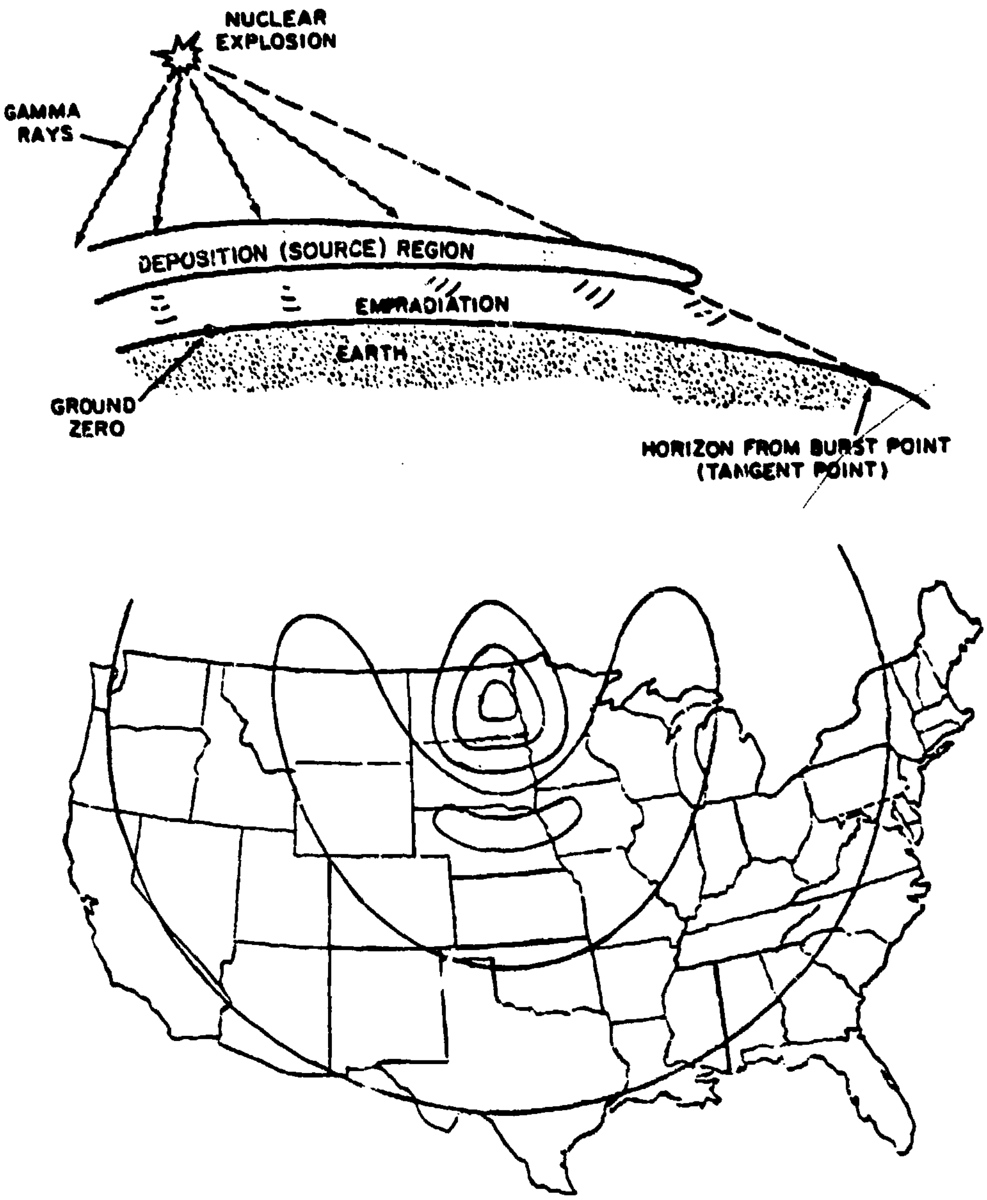

Exhibit 1. Generation and extent of EMP effects.

occurs gamma rays are produced in the nuclear reaction and in the neutron interactions with the surrounding media. The gamma rays interact with air molecules and produce high energy compton electrons traveling away from the point of weapon detonation. For nuclear explosions higher than about 30km above the surface of the earth, the gamma rays that travel downward, into increasingly dense air, produce an ionized layer of air called the deposition region in Exhibit 1. The high energy electrons leave positive ions behind so that a charge separation exists. In addition the trajectories of these electrons is curved by the earth's magnetic field, to produce a radiated EMP wave that propagates toward the earth. As shown in Exhibit 1, a single high altitude detonation can cover most of the continental United States with an intense electromagnetic field.

1-2.2 EMP Coupling.

By virtue of its intense electromagnetic fields (50 kV/m) and wide area of coverage, the high altitude EMP can induce large voltages and currents in power lines, communication cables, radio towers, and other long conductors serving a facility such as shown in Exhibit 2. Open-circuit voltages of up to 3 MV and short-circuit currents of up to 10 kA have been calculated for overhead power lines under maximum-coupling conditions. Buried cables are somewhat more protected by the earth; maximum currents of about 1 kA are calculated for these.

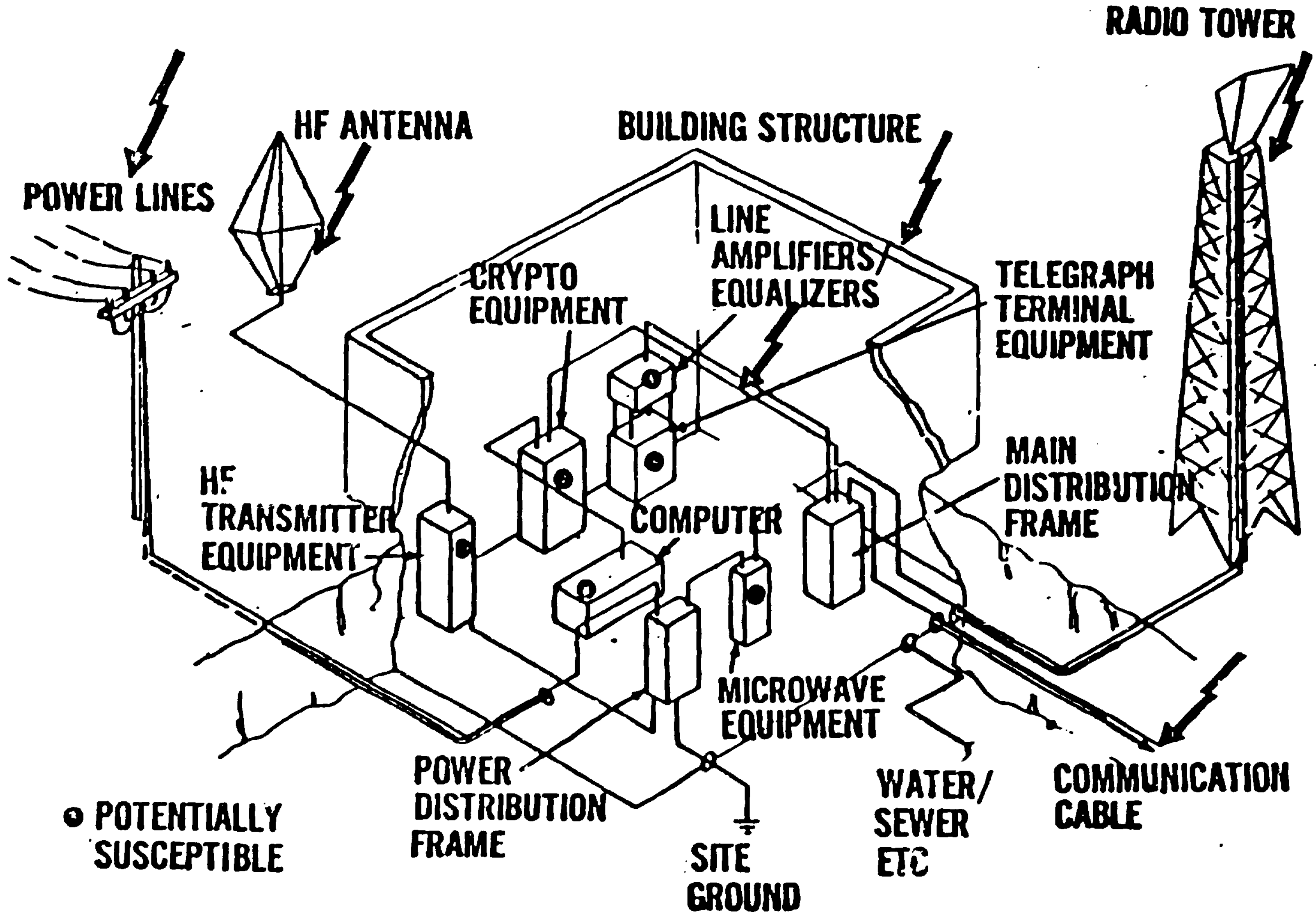

Exhibit 2. EMP coupling to C^3 facility.

While non-linear effects may limit their amplitude, large induced currents and voltages propagate along the conductors as guided electromagnetic waves in the usual transmission-line modes.

In addition, the 50 kV/m EMP wave propagates directly to the facility as a plane space-wave. This space-wave can interact directly with any interconnecting cables and circuits that are not provided with shields or other barriers to electromagnetic waves. Since the 50 kV/m wave can induce open circuit voltages of 25 kV in a 1 meter long wire (monopole antenna), control of the space-wave is usually as important as controlling the guided waves (often called "conducted" interference) on cables, power lines, and waveguides.

Secondary coupling to system electronic circuits can occur because of their proximity, because of imperfections in equipment shields, and in some cases because of uncontrolled arcing in terminals (e.g., in cable vaults or distribution frames). Such coupling depends on mutual capacitances and inductances, natural resonances of the circuits, and other properties of the circuits and intervening structure throughout the EMP spectrum (dc to 100 MHz).

1-2.3 EMP Effects.

The electromagnetic waves induced on power lines, cables, waveguides, etc., and the waves propagating through space directly to the facility produce electromagnetic stresses throughout the facility. If the EMP-induced stress at any point in the system exceeds the threshold for unacceptable performance, the system will be susceptible to the EMP. The threshold may be the damage level, the circuit upset level, or perhaps some other level.

Exhibit 3 shows the energies required to damage various components. Semiconductor devices, particularly integrated circuits in which small energy-per-function is a design objective, and microwave diodes, in which a small active region is an objective, are very sensitive to damage by transients; less than 1μ joule is sufficient to damage some of these devices. Since several hundred joules are available from EMP-induced power line transients, reasonable concern over the isolation of these sensitive circuits from the power lines is warranted.

Logic upsets or errors may be induced by smaller transients. Typical logic levels are a few volts, while raw EMP-induced power line voltages are few MV (open-circuit). Again the need for protection of these sensitive components is apparent.

In addition to electronic circuit upset and semiconductor damage, the EMP-induced transients can cause unusual and often unexpected actions in inadequately protected parts of the facility. Because of the large open-circuit voltages induced in wiring and cabling, insulation breakdown and terminal arcing can occur. Such discharges are

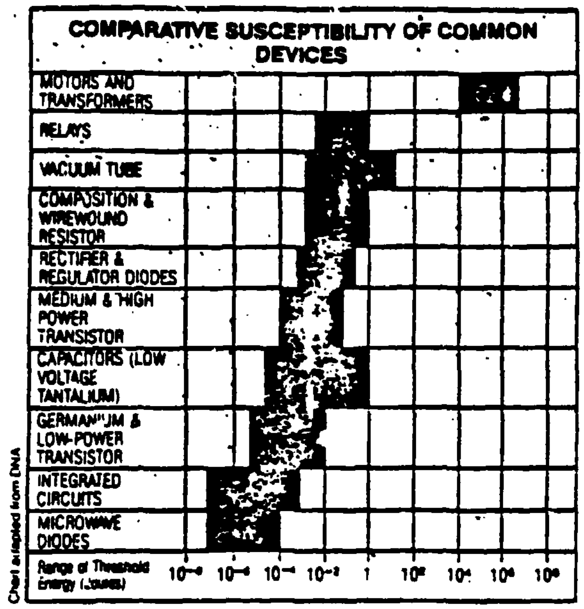

Exhibit 3. Energies required to damage electrical and electronic components.

particularly bothersome because neither the location nor the arc path is controlled. Thus, unless precluded by design, the arc can provide a transient connection between a circuit with large EMP-induced stress and a circuit containing low-threshold components.

1-2.4 EMP Protection.

Primary EMP protection is achieved by placing one or more electromagnetic barriers around susceptible parts of the system. The electromagnetic barrier must be sufficiently impervious to electromagnetic waves that the EMP-induced stress at any point in the system is below the threshold for unacceptable performance at that point.

Because the electromagnetic waves associated with the EMP may propagate through space, as well as along power lines and cables entering the facility, the barrier must be impervious to both space waves and conductor currents and voltages. Thus the barrier must contain a shield to limit interaction with space waves, and filters, surge limiters, etc., to control voltages and currents on conductors entering the facility. Topologically the barrier is a closed surface, made up of penetrating conductor treatments, a shield, and aperture treatments, that completely surrounds the protected volume. The shape of the barrier is usually chosen so that system structure, such as equipment racks and cases and cable trays and ducts, can be used as elements of the barrier.

If the barriers are sufficiently impervious to at least prevent component damage, secondary techniques such as circuit design and software innovations can be used to make digital circuits resistant to upset by spurious transients.

In command, control and communications, (C^3) facilities, there are almost always either deliberate or accidental electrical and electromagnetic coupling paths between the facility physical plant and the C^3 operating systems. This coupling occurs because of common grounding systems, distributed heating and cooling systems, interconnected commercial and auxiliary power systems, or signal cables that penetrate the facility. Therefore EMP energy reaches the sensitive equipment by either coupling directly through the structure or by coupling via conductive penetrations of the structure. As a result, definitive protection measures, called hardening measures, must be applied to a complete facility to assure the EMP induced damage or upset does not occur and interfere with the C^3 facility's operation.

2-0 MANAGING AN EMP PROTECTION PROGRAM--VOLUME I.

2-1 PROGRAM MANAGEMENT RESPONSIBILITIES.

Experience in the design and implementation of EMP protection measures has shown that the most cost-effective results are obtained when the EMP hardening activity is made an integral part of the overall facility design and construction. The cost of redesign and retrofit of existing installations could lead to compromises in the selection of hardening measures resulting in high cost protection design and construction and in operation and maintenance procedures which interfere with economic performance of the facility.

To assure that EMP protection is considered early in a facility design phase, and to assure that the construction and implementation phase contributes to achieving the EMP protection goal, it is necessary to introduce EMP considerations into the program at the beginning. Volume I of the Handbook describes the program management aspects of designing and building EMP hardened facilities. The purpose of Volume I is to provide facility program managers and the EMP hardening program managers with the management information required to successfully build a hardened C^3 facility.

Volume I provides a comprehensive description of the organization and structure of an EMP hardening program. It identifies appropriate assignment of responsibilities and authorities to execute a hardening program, and delineates the design interfaces which must be established to accomplish a cost-effective hardening program. Volume I also addresses the life cycle issues of operation, maintenance and testing that are necessary parts of an effective and enduring EMP hardening effort.

2-2 EMP PROTECTION PROGRAM STRUCTURE.

An EMP protection program involves the following phases:

Planning

Protection Design

Protection Implementation

Hardness Verification Testing

Hardness Maintenance

Exhibit 4 shows the flow of these activities over a facility life cycle. Each of these phases is described in more detail in the following sections.

2-2.1 Planning Phase.

The planning phase is first concerned with identifying the threat to ascertain the EMP levels to which the facility will be exposed. The threat will vary depending upon the type and location of nuclear explosions. For instance C^3 facilities located near missile launch sites may experience the EMP levels associated with low altitude nuclear detonations, while other C^3 facilities may be exposed only to high altitude EMP. This threat specification activity is described in Volume I.

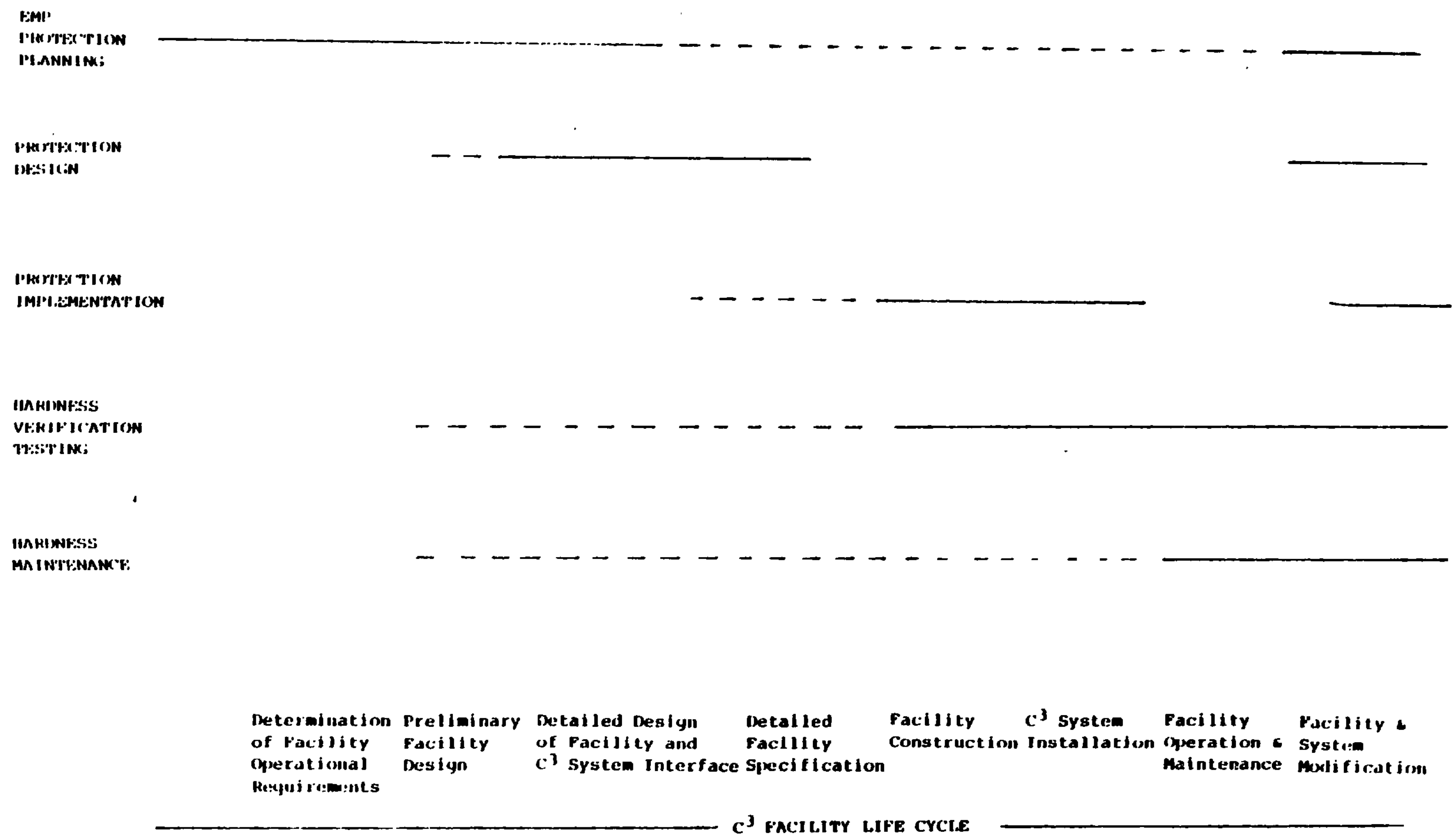

Exhibit 4. Facility hardening life cycle.

Having identified the nature of the EMP threat, the next step in the planning phase is to determine the survivability criteria or protection specifications that the C^3 facility must meet. Since there may be tradeoffs between the specifications, time, resources, and technology, the relative priority of program factors must be established. Also to be included in the planning phase is an identification of how EMP hardness will be maintained through the life of the facility. Particularly important is the determination of resources required for hardness maintenance and the development of a plan to integrate this requirement with other maintenance activities. Finally in the planning phase, a determination must be made as to how EMP protection will be integrated with the requirements associated with other electromagnetic environments such as EMC and lightning protection efforts. The focus in the planning phase is not only on how such integration will be accomplished technologically, but how it will be accomplished organizationally through the assignment of responsibilities and priorities.

2-2.2 EMP Protection Design Phase.

The protection design phase of an EMP protection program is directed at establishing the overall EMP protection architecture. It is during the design phase that protection requirements are established at the facility, system, subsystem and component levels. Through EMP coupling analysis, and utilization of data on hardening measure effectiveness, an identification is made of the various combinations of hardening measures which will result in a facility that meets the protection requirements. Having identified the various feasible hardening approaches, the next step in the design phase is the performance of trade studies to evaluate each of the hardening measure options in terms of effectiveness, schedule, cost, and maintenance considerations. Upon the basis of such tradeoffs a specific hardening approach is chosen.

The next step in the protection design phase is the preparation of a hardening plan which delineates the overall hardening architecture, the assignment of responsibilities throughout the life cycle of the hardening program, and of the facility itself. It defines the interfaces between technological disciplines, and identifies the type and level of testing to be accomplished during the implementation phase and operational life of the facility.

The final step in the design plan is the preparation of the engineering drawings, specifications, and process descriptions to guide construction of the hardened facility.

2-2.3 EMP Protection Implementation Phase.

The protection implementation phase includes all the component, subsystem and system acquisition and installation activity required during the construction of hardened C^3 facility. Components and subsystems must be purchased which meet the hardness requirements specified in the hardening plan. These components and subsystems must meet not only the EMP protection requirements but also the other operational and EM requirements.

During the implementation phase the adequacy of process controls and the quality of mechanical, electromechanical, and electronic fabrication workmanship are significant factors in the effectiveness of EMP hardening measures. Examples of protection measures that may be executed according to an EMP plan are the welding of reinforcement bars in walls or footings, grounding of water lines outside a building, and utilizing specified ground points for electrical fixtures and lights. Because much of the building construction and system installation work impacts the EMP hardness of a facility, it is necessary to consider such activities during the planning of EMP testing and inspection.

2-2.4 EMP Hardness Testing.

Testing the effectiveness of EMP protection measures occurs throughout the life of a facility. Testing is required during construction to verify that a given measure is installed correctly and meets the desired performance levels. If the protection measures fail to meet anticipated levels of performance the work must be repeated; or allowance for the performance shortfall must be made in other portions of the hardening architecture. Testing is required during the implementation phase to allow remedial action to be taken in a timely and cost conscious way. In Volume I, the management aspects of testing are discussed. In particular there is a detailed discussion of the plans and reports required to guide adequate testing to demonstrate compliance with the EMP hardness specification.

Upon completion of the facility construction and system installation, testing is required to verify the EMP hardness of the total facility. During the design and implementation phases it is virtually impossible to foresee or control all of the interactions and processes that may affect the hardness posture of a complex facility. Therefore testing is required to determine the "as built" EMP hardness status of the facility and to determine if further remedial action is required. The "as built" testing activity also provides a baseline against which hardness maintenance testing can be compared.

Because testing is an integral and essential part of an EMP hardening program, EMP testing must be folded into the overall hardening plan. A specific section of the management plan will be directed at the EMP test methods and schedules.

3-0 EMP DESIGN AND ENGINEERING--VOLUME II.

3-1 OVERVIEW OF VOLUME II.

The protection measures used to guard against the damaging and disruptive effects of EMP induced voltages and currents have much in common with the techniques used to protect against lightning and other electromagnetic interference. There are significant differences however, in the nature of the events and the areas affected. Lightning effects tend to propagate along cables and power lines, but not very efficiently through space. Thus a single lightning strike rarely affects more than one facility, while the EMP may simultaneously affect all facilities on a continent. It is also postulated that the rate-of-rise of the voltage induced on power lines can be larger than that induced by lightning, so that fast-acting surge limiters may be needed in the EMP barrier. On the whole, however, the protection against EMP must also be effective against lightning, so that both electromagnetic threats can be handled with the same set of barriers. Since temporary loss of a single facility to lightning can easily be accommodated, lightning protection tends to be geared to limiting property damage. The consequence of a significant vulnerability to the EMP are far more severe; thus EMP protection is designed for high functional reliability.

Volume II of the Handbook addresses the engineering details associated with quantifying the EMP effects, developing specific hardening requirements, and preparing system and equipment specifications to achieve required EMP protection. Volume II is written for the engineers and technicians who have the responsibility of quantifying the stress, designing protection measures, and for developing and meeting design specifications. Thus Volume II contains considerable detail on the technical characteristics of the EMP interaction, on hardening techniques, on equipment EMP threshold data, and on hardening technique cost and effectiveness. In addition, Volume II presents details on EMP testing and analysis approaches, on logistic support considerations in an EMP hardening engineering program, and on the operations and maintenance implications of specific hardening measures.

3-2 EMP PROTECTION MEASURES.

The primary EMP protection is obtained from electromagnetic barriers that are sufficient in number and sufficiently impervious that the EMP-induced stress at any level in the system is smaller than the threshold of the system for malfunction. Typically, two or more such barrier surfaces are desired; usually one is at the system level and one is at the equipment level. In some systems, an intermediate barrier is established at the rack or cabinet level. By distributing the protection among several barriers, no single barrier is required to be of extremely high quality; thus minor degradation of one barrier is less likely to compromise system survivability. The design and application of electromagnetic barriers is detailed in Volume II.

Volume II also describes methods for allocating hardening resources to the various elements of the barrier, such as penetrating conductor treatments, aperture treatments, and shields. To obtain maximum protection with available resources, the designer must be able to quantify barrier weaknesses such as apertures, as well as the treatments prescribed for these weaknesses; data and procedures used in this allocation are described in Volume II.

The allocation of hardening among the barriers (rather than among the elements of a single barrier as described above) is also important because this allocation determines (or is affected by) the way equipment units are specified. If for example, the protection consists of a facility-level barrier and an equipment-level barrier, the facility-level barrier provides the environment that the equipment must tolerate. The equipment barrier, consisting of the equipment case, input/output buffers, and power filters, must therefore be specified to withstand the environment inside the facility barrier. Alternatively, the facility barrier must provide an environment the equipment is specified to tolerate.

The design of the barrier system also affects the number and sophistication of the individual barrier elements, such as filters and surge limiters, required, and therefore the ease and confidence with which the system immunity can be tested and maintained. These nuances are discussed in detail in Volume II.

The relation of EMP protection to other interference control requirements such as lightning, power system transients, and other external sources, and facility rectifiers, switching transients, and other internal sources, is also described in Volume II. Since electromagnetic interference control barriers apply to all such sources whose .ctrum falls within the EMP spectrum (dc to 100 MHz), control of EMP and these other sources can be integrated in to a single system of barriers as discussed in Volume II.

3-3 EMP PROTECTION SYSTEM ENGINEERING.

A systems engineering approach to constructing an EMP hardened facility requires that a variety of considerations be integrated into the overall design and implementation process. These considerations include the reliability of the protection measures, the evaluation (testing) of the hardened system, the life cycle costs of differing hardening architectures, the maintainability of the protection system and the integration of EMP with other electromagnetic requirements. These subjects are discussed in Volume II, where details are provided on the integration of EMP design requirements into the total facility design. This volume also includes a discussion of the systems engineering aspects of hardness surveillance and maintenance, training, and logistic support.

3-4 EMP PROTECTION MODELING AND DATA.

The specification of high performance hardening measures requires the utilization of proven analytic models, and of test data derived from experience. Volume II provides the design and test engineer with specific analytic models for predicting the response of a circuit, system or facility to an EMP. Included in these sections are data concerning components, and hardening techniques used in the protection of C^3 facilities. With the models and data provided in these sections, an engineer can predict the magnitude of EMP induced currents and voltages, and evaluate the performance of candidate hardening measures.

3-5 EMP HARDNESS VERIFICATION.

During and after the construction phase there must be means to confirm that the protection levels sought are achieved. Testing is required to assure that protection measures are installed correctly as construction proceeds. Otherwise faulty components or workmanship may not be discovered until construction is completed, necessitating a costly retrofit program. Testing is also required at the end of construction to verify that the total integrated design meets the facility hardness specification.

Volume II provides detailed information on techniques to assure that hardness measures are carefully implemented during construction, and on the various testing methods useful during and after facility construction. Information is included describing the kinds of EMP simulators that are currently available.

3-6 EMP HARDNESS SURVEILLANCE AND MAINTENANCE.

While hardness surveillance and maintenance is an activity which occurs during facility operation, and is thus an operations and maintenance activity, it must be considered during the design phase. Since the facility will not be exposed to the EMP threat during normal operations, special inspections and tests are required to monitor facility hardness. Volume II addresses such considerations as the use of built-in test points, monitoring of system failures, and repair versus replacement issues. This volume also describes the logistic support issues which must be addressed during the design phase. These sections round out the technical data base necessary for a total systems approach to the design and engineering of an EMP hardened facility.

3-7 EMP PROTECTION LIFE CYCLE COST.

An important design consideration in an EMP hardening program is the life cycle cost of various hardening architectures. To perform life cycle cost trade-off studies, both life cycle cost models and data are required. Such models and data are provided in Volume II. Here the engineer will find a discussion of the existing life cycle cost models, and data required to project total life cycle costs of alternative EMP protection concepts.

4-0 OPERATIONS AND MAINTENANCE OF EMP HARDENED FACILITIES-VOLUME III.

4-1 OVERVIEW OF VOLUME III.

During the operational life of an EMP protected facility, day-to-day operational procedures, routine maintenance practices, and facility modificatins will affect the hardness of the facility. Hardness maintenance and hardness surveillance are performed to ensure that the facility's hardness features remain capable of protecting the facility should it be exposed to an EMP. Volume III of the handbook provides a compendium of reference material and guidelines for use by operations and maintenance managers, engineers and technicians for the planning and accomplishment of hardness maintenance and hardness surveillance.

4-2 GENERAL OPERATION AND MAINTENANCE CONSIDERATIONS.

Volume III provides a detailed examination of operation and maintenance requirements, including factors and constraints which are to be considered during the facility design and construction phases. It is important that HM/HS considerations be included early in a program so that its contribution to cost, risk and other elements impacting program decisions is included. In addition, early consideration is necessary so that the system's hardness can be maintained as of the time it goes operational. As such this section is of particular interest to program managers and system designers as well as to the operation and maintenance manager. Some of the topics presented in this section are O&M design factors, specifications and data packages necessary to support operations and maintenance, and the monitoring activity required during facility construction.

4-3 FMP HARDENING ELEMENT DEGRADATION.

Experience indicates that if activities aimed spacifically at maintaining hardness are not undertaken, hardness degradation will occur. One section of the O&M volume addresses the operational performance of EMP protection measures during the life of a facility. Included here are discussions of the types and causes of performance degradation of the various kinds of EMP protection measures, including deterioration of bonds and welds, distortion of gaskets, damage to cable assembles, and aging of components.

One of the methods used to help control hardness degradation is configuration management. Hardness integrity can be easily defeated by unauthorized configuration changes. The elements of a configuration management program aimed at precluding hardness degradation due to facility or equipment changes are also addressed in this volume.

4-4 O&M PLANNING.

Volume III also addresses the planning aspects of the operation and maintenance of a hardened facility. The basic tool for management control of resource acquisition, and on-site management of the maintenance and surveillance tasks is the O&M Plan. Volume III provides guidelines for the content of the O&M plan so that it is a useful tool for acquisition of resources, defining on-site tasks, and developing the maintenance capability required to preclude hardness degradation.

This section is keyed to the issues that must be addressed during the facility hardening design phase and the information that must be included is a Hardness Surveillance and Maintenance Plan. For example, technical data in the form of procedures to support maintenance and surveillance tasks, and data to support maintenance of support and test equipment will be needed. This section will discuss the kinds of information that should be included in the technical data to ensure standardization of tasks in hardness maintenance and surveillance.

4-5 EMP TESTING OF OPERATIONAL FACILITIES.

Volume III will also address the technical aspects of monitoring the EMP hardness of a facility once it has become operational. Since normal operational and maintenenace activities may not reveal EMP hardness degradation, procedures are defined for testing various protection features. This section also addresses hardness surveillance test equipment and facilities. It should be recognized that the normal facility support provisions may require augmentation to facilitate accomplishment of hardness maintenance and surveillance tasks. This section will include guidelines on the kinds of items that can impact facility design. Discussion of the characteristics, operations, and limitations of the various equipment/facilities used to test/inspect for hardness degradations are included.

4-6 EMP HARDNESS MAINTENANCE.

The unique aspects of maintaining EMP hardness are treated in this section. It addresses the configuration control and maintenance activities required for EMP hardness maintenance which are over and above that maintenance performed to meet the ground facility operational requirements. Hardness maintenance is performed to repair or replace protection features of the facility. It includes activities such as replacement of defective filters, suppressors and capacitors. It also includes correction of corrosion problems involving electrical grounds and repair of shields, finger stock and EMP gaskets. Maintenance concepts involving the location at which an item will undergo replacement/repair will also be addressed. Replacement/repair activities may be undertaken by on-site operating personnel, visiting maintenance teams, or at a depot.

Specific maintenance actions may be required following an EMP test. A plan needs to be developed addressing these actions. Volume III includes guidelines for the development of this plan.

4-7 TRAINING.

The last section of Volume III deals with the training aspects of an O&M program. The prime motivator of personnel is the training they receive. EMP hardness features are not always discernible as items of equipment; and educating personnel in what are the hardness features, how they function; and how they degrade will make personnel aware of how they can contribute to preserving the facility's hardness capability. This section of Volume III discusses issues that should be covered in awareness training for all personnel and in maintenance and surveillance training for those engaged in hardness maintenance and hardness surveillance. The topics to be included in a training program for O&M personnel and the identification of skills to be developed as a result of the training program are identified. The basic skills required for hardness maintenance and surveillance should build upon existing personnel qualifications. The final portion of this section is a sample training program.

APPENDIX B

Draft Outline for

DNA

EMP ENGINEERING HANDBOOK FOR GROUND BASED FACILITIES

VOLUME I

PROGRAM MANAGEMENT

Ernest Donaldson (Georgia Institute of Technology)

Ray McCormack (U.S. Army Construction Engineering Research Laboratory

Alan Chodorow (Mission Research Corporation)

VOLUME I

PROGRAM MANAGEMENT

PREFACE

The "EMP Engineering Handbook for Ground-Based Facilities" is intended to provide guidance for the acquisition of ground based facilities which are hardened against the detrimental effects of the electromagnetic pulse (EMP) generated by a nuclear burst. Without adequate protection against EMP, electronic systems and equipments which form a part of a facility are potentially susceptible to disruption or damage. To provide the required protection, it is extremely important that an EMP hardness program be instituted as an integral part of the facility acquisition process.

The Handbook is divided into three distinct but interelated volumes. Volume I, PROGRAM MANAGEMENT, is intended primarily for program managers who have the overall responsibility for the acquisition of a hardened facility. Volume II, DESIGN AND ENGINEERING, describes the principle and practices of EMP hardness design and contains detailed design information and data on EMP hardening techniques and devices. Volume III, OPERATION AND MAINTENANCE, addresses the O & M actions and requirements which are necessary to maintain the EMP hardness integrity of the facility throughout its operational lifetime. Within the state-of-the-art in EMP technology, the Handbook is intended to serve as a complete guide for the acquisition of EMP hardened facilities. The material contained within the three-volume series encompasses the total life cycle of the facility, and addresses the needs of management, design, and operational and maintenance personnel.

The material in Volume I, PROGRAM MANAGEMENT, is divided into seven major chapters. Following the introductory material in Chapter 1, Chapter 2 provides a listing and summary of documents which are to be used in conjunction with, or as a supplement to, Volume I. These documents include design guides, specifications, manuals, handbooks and other documents which contain information helpful to EMP hardness management and control.

Chapter 3 is intended to provide a basic awareness of the electrical threat of EMP and the need to circumvent this threat through appropriate facility design techniques. The generation and characteristics of EMP are introduced, followed by a summary of the mechanisms and paths by which the EMP environment is coupled into a facility and a description of the potentially adverse effects of the coupled energy on electrical/electronic systems.

The objective of Chapter 4 is to provide the Program Manager with guidance for the implementation, management, and control of an effective EMP Hardening Program for ground based facilities. The information presented in this chapter is intended to serve as a checklist of actions the Program Manager must take and issues he must address in conducting a hardening program. Particular emphasis is given to the EMP Hardness Program Plan - the management document which defines the elements and structure of the EMP Hardness Program. The major objectives, tasks, and milestones of the EMP

Hardness Program are defined, and the relationship between the tasks to be performed and the various life cycle phases of the facility acquisition process is described.

Chapters 4, 5, and 6 are included to provide an understanding of the basic concepts and elements of facility hardening. Chapter 5 describes the EMP hardness design process typically employed to harden a facility. The approach to establishing facility hardness requirements is described, and hardening approaches and techniques are summarized. Chapters 5 and 6, respectively, describe the types of hardness testing and hardness analyses which are usually performed in conjunction with the acquisition of a facility.

SUMMARY OUTLINE

VOLUME I

PROGRAM MANAGEMENT

1. INTRODUCTION

1.1 Purpose

- This section states the purpose of the Handbook (management guidance for the acquisition at C^3 facilities hardened against the detrimental effects of EMP).

1.2 Scope

- This section defines the scope of the Handbook material (EMP environments(s) to which Handbook is applicable, types of facilities considered, portion of acquisition cycle covered, etc).

1.3 Contents

- This section summarizes the Handbook organization and' contents.

2. REFERENCED DOCUMENTS

- This section identifies and summarizes the use of those documents which are to be used in conjunction with, or as a supplement to, this Handbook.

3. ELECTRICAL THREAT OF EMP

3.1 EMP Generation and Characteristics

- This section provides an introduction to EMP (what is EMP, how is EMP generated, and what are the general characteristics and potential threat of EMP).

3.2 Classification of EMP Environments

- This section identifies the types and basic characteristics of EMP environments (ground burst, high altitude, etc.)

3.3 Environment-to-Facility Coupling

- This section summarizes the mechanisms and paths by which the EMP environment is coupled into a facility.

3.4 Degradation Effects

- This section describes the potential effects of EMP energy which is coupled to electrical/electronic systems internal to a facility.

3.5 Need for EMP Hardening

- This section stresses the need for hardening to circumvent the EMP threat.

4. EMP HARDNESS CONTROL AND MANAGEMENT

4.1 Program Manager's Responsibilities

- This section delineates the overall responsibilities of the Program Manager for ensuring that appropriate EMP hardening measures are incorporated into the facility design.

4.2 EMP Advisory Group

- This section describes the concept of forming an EMP Advisory Group to assist the Program Manager in establishing, implementing, and controlling an EMP hardening program for facility design.

4.3 EMP Hardness and the Acquisition Process

- This section identifies the major life cycle phases of the facility acquisition process which the EMP Hardness Program must address.

4.4 EMP Hardness Specifications

4.4.1 General

- This section identifies the various methods for specifying EMP hardening for a ground based facility. For each method, government vs. contractor responsibility over facility life cycle is identified.

4.4.2 Specifications Based on Threat Definition and Survivability Criteria

- This section describes facility hardening specifications based on the threat definition and survivability criteria.

4.4.3 Specifications Based on Hardening Requirements

- This section describes facility hardening specifications based on hardening requirements (at facility level, equipment level, or both).

4.5 EMP Hardness Program Plan

4.5.1 Purpose of Plan

- This section describes the EMP Hardness Program Plan -- the top level management document for conducting the EMP Hardness Program.

4.5.2 Organization and Management

- This section addresses the organizational and management structure of an EMP Hardness Program.

4.5.3 Assignment of Responsibilities and Authority

- This section addresses the delegation of management responsibilities and authority to those organizational individuals involved in the facility acquisition process.

4.5.4 Hardening Program Implementation

- This section defines the objectives, tasks, and milestones of the EMP Hardening Program and identifies how and when these tasks are to be accomplished in relationship to the various phases of the facility acquisition process. Included is a detailed flow diagram which illustrates graphically specific actions to be taken by the program manager and contractor throughout the acquisition process.

4.6 Contractor Hardening Design Plan

- This section describes the purpose and nature of the hardening design plan -- a contractor prepared document which describes in detail his approach to ensuring facility hardness.

4.7 Interrelationships with Other EM Disciplines

- This section identifies the need for integrating EMP hardening requirements with the requirements of other electromagnetic areas (lighting protection, EMC, TEMPEST, etc.)

4.8 Role of Testing/Analysis

- This section identifies the role of testing and analysis in facility hardening.

4.9 Operation and Maintenance (O & M) considerations

- This section addresses the need for design features/ requirements which will facilitate the operation and maintenance of a hardened facility.

4.10 Data/Reporting Requirements

- This section identifies the EMP-related data/reporting requirements associated with the acquisition of a hardened facility.

4.11 Cost Considerations

- This section addesses fundamental tradeoffs which must be considered to realize the most cost-effective facility hardening design.

5. EMP HARDNESS DESIGN

5.1 General

- This section introduces Section 5, which describes to the Program Manager the EMP hardness design process typically employed to harden a facility to given specifications.

5.2 Contractor Hardening Plan

- This section describes the nature and requirements of the Contractor Hardening Plan, a contracturally required document which documents the contractors management and engineering plan for meeting the hardness specifications.

5.3 Hardening Methodology

- This section presents an overall methodology for facility hardening, from program initiation through the completion and testing of the facility. A flow diagram illustrating the methodology is included.

5.4 Establishing EMP Hardness Requirements

5.4.1 Overall Approach

- This section outlines the overall approach to establishing facility hardness requirements.

5.4.2 Definition of EMP Threat/Survivability Criteria

- This section identifies how the definition of the EMP threat/survivability criteria is used to initiate the facility hardening design.

5.4.3 Environment-to-Facility Coupling

- This section summarizes how coupling analyses are employed to establish the level of energy coupled into a facility.

5.4.4 Equipment/Component Vulnerability Thresholds

- This section describes how equipment/component vulnerability thresholds are used to define the adverse effects of coupled energy.

5.4.5 Required Hardening Level

- This section describes how a facility vulnerability assessment is performed to define hardening requirements.

5.5 Hardening Approaches

5.5.1 Hardening by Facility Shielding

- This section summarizes the concept of facility hardening by enclosing the facility within a shield.

5.5.2 Hardening at the Box Level

- This section summarizes the concept of facility hardening by the hardening of individual boxes within the facility.

5.5.3 Layered Hardening

- This section summarizes the concept of facility hardening by layered hardening (i.e., successive layers of hardening to achieve the overall hardening requirements)

5.6 Hardening Techniques/Devices

- This section summarizes the hardening techniques/devices available for facility hardening.

5.7 Design Tradeoffs

- This section addresses the course of action necessary to resolve tradeoffs between facility functional requirements and hardening requirements.

5.8 Hardening Verification

- This section addresses the need for, and approaches to, verifying that the hardness specifications have been met.

6. EMP HARDNESS TESTING

6.1 General

- This section outlines to the Program Manager the general types of tests performed to ensure that facility hardness requirements are met.

6.2 Program Test Plan

- This section describes the Program Test Plan to be prepared by the Program Manager which defines all testing to be performed in conjunction with the acquisition of a facility.

6.3 Contractor Hardness Test Plan

- This section describes the Contractor Hardness Test Plan, a document prepared by the contractor which describes the tests the contractor plans to perform to demonstrate compliance with the EMP hardness specifications.

6.4 Hardness Test Reports

- This section defines the hardness test reports to be submitted by the contractor in conjunction with facility design and construction.

6.5 Facility Acceptance Tests

- This section describes tests performed by the procuring agency in conjunction with the acceptance of a facility.

7. EMP HARDNESS ANALYSES

7.1 General

- This section outlines to the program manager the types of analyses applicable to facility hardening design.

7.2 Coupling Analysis Techniques

- This section contains a brief description of generic techniques by which coupling analyses can be performed.

7.3 Susceptibility Analysis Techniques

- This section contains a brief description of techniques by which susceptibility analyses are performed.

APPENDICES

1. Outline for EMP Hardness Program Plan
2. Outline for EMP Hardness Test Plan
3. Outline for Contractor EMP Hardness Design Plan
4. Outline for Contractor EMP Hardness Test Plan
5. Outlines for Hardness Test Reports

APPENDIX C

Draft Outline for

DNA

EMP ENGINEERING HANDBOOK FOR GROUND BASED FACILITIES

Volume II

EMP DESIGN AND ENGINEERING

E. G. MORGAN (Rockwell International)

E. F. VANCE (SRI International)

M. ESPIG (DASIAC, Kaman Sciences)

PREFACE

This handbook is intended as a guide to design personnel concerned with the hardening of ground facilities to nuclear electromagnetic pulse effects. It may also be of value to others who are involved in hardening of other types of systems.

The scope of the handbook is meant to be as broad and complete as possible at the time of preparation. It attempts to outline the principal alternatives, listing the pros and cons, without intending to bias the reader. The techniques described are those which are considered to have been "proven" by tests at some time in the past, and not just recent unverified concepts.

The purpose of the handbook is to provide detailed technical guidance to managers and designers needed to understand the principles and alternatives of EMP hardening. It also includes most of the data required to support the design task.

The users of the handbook are expected to be a diverse group including managers, electrical and mechanical engineers, system engineers, logistic support specialists, architects, facility engineers, construction contractors, and technicians. For this reason, the material organization begins with general principles, and progresses toward increasing levels of detail. Not all users are expected to need all the data presented.

The structure of the handbook addresses four major groupings of information as follows:

- Sections 1-5 — Principles and Understanding
- Sections 6-10 — Detailed Design Data
- Sections 11-15 — Hardness Verification and Support
- Section 16 — Life-Cycle Costs

Within these groups, individual sections are arranged somewhat in the chronological order in which they occur in a hardening program.

The major sections are generally arranged by task, or by technical specialty and are:

- Description of the EMP-hardening Problem
- Principles of EMP-hardening
- Facility-level Hardening Concepts
- Equipment Level Hardening Concepts
- Evaluation and Test Concepts
- System Engineering Requirements
- System Engineering Design
- Calculated Threat Level Transients
- Equipment Susceptibility Levels
- Detailed Design Data and Tradeoffs
- Hardness Assurance
- Hardness Verification and Tests
- Hardness Surveillance and Hardness Maintenance
- Developing Training Programs
- Logistic Support
- Estimating Life-Cycle Costs

This covers all the major areas of design activity in most facility EMP-hardening programs.

Two other volumes complete the series. They are:

- Volume I - Program Management, and
- Volume III - Operations and Maintenance

in which the focus and the emphasis are different, in line with different needs of Program Managers and O&M specialists.

No handbook can remain current indefinitely without periodic updates. This handbook has been prepared with that in mind. The structure of the document is somewhat modular for that reason. It is planned to keep the document current, by periodic updates, in the hope that it will grow, improve and continue to be useful.

DNA
EMP ENGINEERING HANDBOOK
OUTLINE
VOL. II. EMP DESIGN AND ENGINEERING

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13.9 Shield Repair Techniques

13.10 Hardness Surveillance/Hardness Maintenance Plan

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14.1 Need for EMP Awareness Training

14.2 Need for Maintenance Procedures

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14.4 Sources and References

15.0 LOGISTIC SUPPORT

15.1 Assuring Adequate Spare Parts

15.1.1 Problems with Procuring "Old" Parts Designs

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15.1.3 Estimating Spares Requirements

15.2 Integration of Logistic Support with Existing Logistics Organization/Current Programs

15.3 Logistic Support Plan

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15.4 Logistics EMP Reporting Requirements

16.0 ESTIMATING LIFE CYCLE COSTS

16.1 General Discussion

16.2 Existing Mathematical Models

16.2.1 Parametric Models

16.2.2 Detailed Calculation Models

16.2.2.1 Input Variables

16.2.2.2 Outputs

16.3 Typical LCC Tradeoffs

16.4 Typical LCC Results

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APPENDIX D

Draft Outline for

DNA

EMP ENGINEERING HANDBOOK FOR GROUND BASED FACILITIES

Volume III

OPERATIONS AND MAINTENANCE

T. A. MARTIN (IIT Research Institute)

S. J. COLOMBO (Boeing Aerospace Co.)

D. L. DURGIN (Booz Allen & Hamilton, Inc.)

Preface

Operations and Maintenance Handbook

During the operational lifetime or deployment phase of an EMP protected C^3 facility, the responsibilities of the Operations and Maintenance personnel are to continually maintain, validate, and assure the EMP hardness integrity of the facility throughout its operational lifetime. The purpose of this handbook is to provide a compendium of the reference material, information, and guidelines that are considered relevant to O.&M. managers, engineers, and technicians charged with the task of meeting these responsibilities.

The material content included in the handbook is organized around major subject and/or task areas identified as being of concern to the O.&M. specialists in meeting the EMP hardness assurance and maintenance objectives throughout the operational lifetime of the facility. These major topics of interest include:

- EMP Hardness Data Base for the facility
- General O.&M. Considerations
- Operations and Maintenance Planning
- Test/Inspection Procedures
- Test Equipment for Hardness Surveillance
- Maintenance techniques, procedures and control
- Personnel Training
- Documentation and record keeping

In presenting the material, information and data contained in the handbook in each of these subject areas, efforts have been made to avoid slanting it such as to bias the reader or making decisions for him. Hence the emphasis is put on identifying and presenting as many of the available and/or known approaches, options, and alternatives as possible together with sufficient supporting information to facilitate the selection of an approach or alternative method suitable to the reader's need. Also, the organizational structuring of the handbook in terms of these major subject areas facilitates the anticipated up-dating that will be required to include new material, new techniques, and new approaches as well as delete obsolete material.

It is important to note that some of the subject areas are not addressed solely to the O.&M. specialists. For instance, it is recognized that issues concerning the facility EMP Data Bases and Planning for O.&M. operations are of major concern to the developers and designers of the EMP hardening facility. They are the ones who will most likely be responsible for the development of both. However, since they are both a necessary input before commencing O.&M., it is felt that O.&M. specialists should be familiar with these data base and planning issues and be made aware of the factors considered in developing them.

Summary Outline (1st Revision)

OPERATIONS AND MAINTENANCE VOLUME

1.0 INTRODUCTION

1.1 Overview of Operations and Maintenance (O.&M.) Problems

1.1.1 Purpose of O.&M. (e.g. to continually validate, maintain and assure the "as-built" EMP hardness integrity of the facility throughout its operational lifetime).

1.1.2 Scope of Handbook Issues

- o Designing to O.&M. Requirements/Constraints
- o Protection Element Degradation
- o O.&M. Planning
- o Hardness Surveillance (test techniques, procedures, equipment)
- o Hardness Maintenance
- o Management/Training/Documentation

1.1.3 Intended Users

- o O.&M. Specialists
- o EMP Hardening Design Engineers
- o Managers

1.2 Background

1.2.1 Lessons Learned from Prior O.&M. Experiences

- o SAFEGUARD
- o Europe/NATO
- o Others

1.2.2 Reasons for O.&M.

1.3 Reference Documents

1.3.1 Reference Management and Design Handbooks

1.3.2 Vols I & II of this Planned DNA EMP Engineering Handbook Series

1.3.3 Other Reference Material

- o Facility EMP Hardening Design Description (assumed to be provided when facility is turned over to O.&M. personnel).
- o EMP Protection Element Performance Data Base (available at beginning of operations phase).

1.4 Definitions

1.4.1 Words

1.4.2 Terms

2.0 GENERAL O.&M. CONSIDERATIONS

(Addresses the O.&M. requirements, factors, and constraints to be considered during the EMP hardening design and construction phase.)

2.1 Hardening Design Factors from an O.&M. Point of View

2.1.1 Protective Element and/or Technique Degradation

2.1.2 Ease/Cost of Monitoring/Maintaining Performance Over Operational Lifetime

2.1.3 Initial vs. HS/HM Cost Trade-Offs

2.1.4 Operational Limitations/Constraints

2.1.5 Ease/Cost of In-Situ Test/Inspection

2.1.6 Requirements to Detect Faults, Degradation, etc.

2.2 Construction Monitoring and Acceptance

2.2.1 Conformance to Design

2.2.2 Construction/Implementation/Installation Monitoring, Testing and Control

2.2.3 Facility Hardness Verification Testing

2.3 Facility Specifications and Design Data Package

2.3.1 Preparation of a complete description of the design methodology utilized as well as the specific protective measures, devices and/or techniques employed to harden the facility against EMP.

2.3.2 A Data Base that characterizes the EMP hardness level of the facility in terms of acceptable performance for each of the specific EMP protective measures, devices and/or techniques employed.

2.3.3 Define/Identify expected problem areas during O.&M.

3.0 OPERATIONAL PERFORMANCE OF EMP PROTECTION ELEMENTS

3.1 EMP Hardened Facility Description

Describe the typical approaches used to EMP harden a facility, emphasizing the various design options, topological/configuration controls, construction techniques, components and techniques utilized to achieve a specified hardness level. (This section could be common to Volumes II and III).

3.2 EMP Protection Element Degradation (Identifies and discusses the types and causes of performance degradation in the various EMP protective measures/devices used in hardening a facility).

3.2.1 Building Shields and Apertures

3.2.2 Enclosure Shields (cabinets, racks, chassis, etc.)

3.2.3 Cable Assemblies (connectors, shields, splices, etc.)

3.2.4 Penetration Control Devices

- o Bonding Welds
- o Bonding Straps
- o Gasketing/Screening Elements
- o Doors, Windows, Ducts
- o Filters
- o TPD's

(Note: Detailed functional and performance descriptions should be in in Volume II and the above section focuses on degradation and failure related issues.)

3.3 Configuration Control Requirements

Describe the elements of a configuration control program to preclude hardness degradation due to facility or equipment changes, modification and re-design.

3.4 Reliability Considerations

3.4.1 Nominal MTBF

3.4.2 Impact of HS/HM on System/Equipment MTBF.

4.0 FACILITY OPERATIONS AND MAINTENANCE PLANNING

4.1 Review/Develop Awareness of Baseline Facility EMP Specifications and Qualification Data

4.1.1 Initial EMP Hardness Status of Facility

- o Hardening Design Methodology
- o Protective Measures/Techniques Employed

4.1.2 Facility Acceptance and Hardness Verification Reports

4.1.3 Protective Device Performance Specifications/Data Base

4.1.4 Annotated Hardening Design/Construction/Installation Drawings

4.1.5 Manuals (Operating, Service, Repair, etc.)

4.2 Configuration Control

4.2.1 Describe Purpose and Rationale for

4.2.2 Elements of Concern

- o Equipment Changes (re-location, part substitution, additions, deletions, etc.)
- o Changes in Cable Type, Length, Routing, etc.
- o Modification or Changes in Shielding Structures
- o Changes in EMP protective element types
- o Modification/Redesign at Facility, Intra-Facility and/or Equipment Level

4.2.3 Define Control Functions

- o Periodic Facility Surveillance/Inspection
- o Monitor/Control Changes
- o Update Documentation/Specifications to include Approved Changes, Modifications and Re-Designs
- o Monitor/Control Repair Activities

4.3 Integrated Hardness Surveillance/Hardness Maintenance Plan

4.3.1 Identify Facility Features to be Monitored and Maintained

- o Shields (envelop, cable, EMP vaults, cabinet shields, etc.)
- o EMP protective devices (TPD's)
- o Aperture Control Devices (doors, doorways, vents, gaskets, honeycomb structures, etc.)

- o Grounding/Bonding Configurations
- o Facility Configuration Control Activities
- o Equipment Susceptibility

4.3.2 Select Hardness Surveillance Procedures

- o Inspection and Monitoring
- o Test
- o Integrate with Standard Surveillance Practice
- o Periodic "Tiger Team" Surveillance/Testing

4.3.3 Define Facility Equipment, Personnel, and Training Requirements

4.3.4 Define Criteria for Acceptance and Decision to Repair

4.3.5 Define Repair/Maintenance Procedures

- o Preventative Maintenance
- o Relation to Standard Maintenance Procedures
- o Routine Repair
- o Major Repair, Modification or Re-Design

4.3.6 Post-Repair Verification Tests

- o Assure Hardness Quality
- o Establish Data Base for Subsequent HS/HM

4.4 O.&M. Management Plan

4.4.1 Resource Allocation

- o Staffing Assignments
- o Budget Appropriations
- o Test Equipment/Instrumentation Provisions

4.4.2 Data/Documentation/Record Keeping Requirements

- o EMP Protection Status Tracking
- o Modification/Repair Record
- o Feedback to Designers

4.4.3 Procurement/Re-Procurement Control Procedures

- o Spare Parts
- o Repair Parts
- o Instrumentation/Test Equipment

4.4.4 Facility Hardness Status Review

- Periodic Assessment of Surveillance Data/Reports
- Note Observed Performance Degradation
- Identify Pending Problems (i.e., trends indicating that repairs may be needed at some later date)
- Decision to Repair, Modify, Change, etc.

4.4.5 Scheduling of HS/HM Task Activities

- Establish Surveillance Inspection/Test Schedules
- Frequency and Type of Routine and/or Preventative Maintenance
- Approval Requirement to Repair/Modify/Design
- Training/Re-Training
- Test Equipment/Instrumentation Calibration

5.0 HARDNESS SURVEILLANCE TEST/INSPECTION TECHNIQUES AND PROCEDURES

Discuss hardness surveillance requirements and why normal facility surveillance may not reveal EMP hardness degradation.

5.1 Techniques for Detecting Compromises/Degradation in Bonding Integrity

5.1.1 Changes in Grounding Configuration (i.e. ground loops, etc.)

5.1.2 Operational Changes That Result in Improper Ties Between EMP, Signal and/or Safety Grounds

5.1.3 Changes in Bonding Impedance (ruptures, corrosion, frequent connect/disconnect, etc.)

5.1.4 Wear Between Contacting Metal Surfaces

5.2 Shield Surveillance Techniques (Discuss typical facility shielding schemes, types and causes of degradation in shield quality, and methods/techniques for detecting such degradation.)

5.2.1 Building Shields (include door, window and duct shields)

5.2.2 Enclosure Shields (cabinets, EMP vault, etc.)

5.2.3 Cable Shields (conduit, ducts, braid, etc.)

5.2.4 Gaskets, Fingerstock, Conductive Epoxies, etc.

5.3 Penetration Protection Device Surveillance Techniques

(Discuss typical penetration protection devices, types and causes of degradation in their performance, and methods/techniques for measuring and detecting such degradation)

5.3.1 Filters

- o Power Systems
- o Antenna Systems
- o Signal Lines
- o Mechanical Systems

5.3.2 Surge Arresters/Limiters

- o Power Systems
- o Antenna Systems
- o Signal/Communication Lines

5.3.3 Isolation Techniques/Devices (Transformers, relays, cable/wire routing, etc.)

- o Power Systems
- o Antenna Systems
- o Signal/Communication Lines

5.4 Susceptibility Measurement Techniques

6.0 <u>HARDNESS SURVEILLANCE TEST EQUIPMENT</u>

Discuss the characteristics, operations, and limitations of the various test/inspection equipment (electrical, physical, chemical etc.) for use in EMP hardness surveillance

6.1 Shield Performance/Quality Measurement Equipment

6.1.1 Shield Excitation Equipment

- o EMP Simulators
- o CW Simulators/Illuminators (discrete and/or pulsed RF)
- o Current Injection Devices (CW, transient, pulsed, etc.)
- o Magnaflux
- o Non-Electrical (dyes, etc.)
- o X-ray

6.1.2 Shield Excitation Response Measuring Equipment

- o Field Probes
- o Skin Current Sensors
- o B/D Probes
- o Others

6.2 Cable Shield and Shield Splice and Bonding Test Equipment

6.2.1 Bulk Core Current Injection Equipment

6.2.2 CW Shield-Current Excitors (i.e., in-situ coaxial test systems)

6.2.3 Continuity Measuring Equipment

6.2.4 Swept CW Excitation Equipment

6.2.5 Spectral Network Analyzers

6.3 Protective Device (TPD's) Test Equipment

6.3.1 Transient Voltage/Current Generators

6.3.2 CW Generators

6.3.3 Swept CW Generators

6.4 Other Applicable Test Equipment

6.4.1 Seam Sniffers

6.4.2 Telemetry Equipment

6.4.3 Signal Conditioners

7.0 HARDNESS MAINTENANCE

Discusses the requirements, approaches and procedures for maintaining facility EMP hardness. Also why normal functional maintenance may not be sufficient to maintain EMP protection.

7.1 Facility Maintenance Activities

7.1.1 Periodic Inspection

7.1.2 Operational Checkout

7.1.3 Testing

- o Regularly Scheduled Testing to Measure/Verify Performance of Specific Hardness Features
- o Troubleshooting/Fault Location
- o Post Repair/Modification Tests
- o Reference Standard Test Specifications and Procedures Whenever Applicable
- o Fault Detection
- o Fault Isolation

7.1.4 Preventive Maintenance

7.1.5 Documentation/Record Keeping

- o Performance Data
- o Cost Data
- o Feedback to Designers/Managers

7.1.6 Hardness Status Review

- o Periodic reviews to assess surveillance data, identify and/or anticipate failures, track performance degradation, etc.
- o Decision to Repair/Modify

7.1.7 Integration of Activities with Other Facility Inspection and Operational Checkouts

7.2 Repair/Modification Procedures, Control and Monitoring

7.2.1 Major Platform/Facility Repairs

- o Shields (envelop, EMP vault, entry-ways, etc.)
- o Penetration Control Devices/Techniques
- o Configuration Changes - Allowable/Unacceptable
- o Acceptable Repair/Modification Options
- o What Facility Repairs Can Impact EMP Protection Performance?

7.2.2 Intra-Facility Repairs

- o Intra-Facility Repairs That Can Have Impact on EMP Protection Performance
- o Cable/Cable Shield Repairs/Replacement

- Interior Room/Compartment Shield Repairs
- Ground System
- Cable Shield to Connector Bonds

7.2.3 Subsystem (Black Box) Repairs

- Effect of Subsystem/Black Box Repairs on EMP Protection
- Parts Selection, Substitution, Control, etc.
- Gasket Replacement
- Signal/Safety/EMP Ground System Changes
- Adherence to Established Grounding Philosophy

7.2.4 Post-Repair Hardness Verification Testing

- Assure Adequate Performance
- Provide Performance Measurement Data Base for Subsequent Surveillance

7.3 Operations

7.3.1 Standard Operational Procedures

- Reprogram/Restart Due to Upset of Power
- Communications Link Upset - options based on system configuration, alternate links, etc. (i.e., have plan available)
- Primary Power to Emergency Power Switchover Procedures
- Operational Do's/Don'ts (i.e., keep shield doors closed, don't circumvent protective systems, etc.)

7.3.2 Fault Isolation Procedures/Practices

- Is System Outage Due to Upset/Damage?
- On-Line Repair/Reset Practices
- Established On-Line Test Procedures and Equipments
- Do's/Don'ts - actions which would degrade hardness level (e.g., adding unprotected cable entry for test or non-critical function, etc.)

7.3.3 Outage/Maintenance Log Keeping

- o Outages
- o Preventive Maintenance/Tests
- o Repairs
- o History for Future Periodic Maintenance Scheduling, etc.
- o Feedback to hardening designers

8.0 PERSONNEL TRAINING

8.1 Overview of EMP Problem and the Need for Protection

8.2 Goals/Responsibilities of O.&M. Personnel in Maintaining "Built-In" EMP Protection

8.3 Review of EMP Hardening Design Approach, Techniques and Devices Incorporated to Harden the Facility

8.4 Discussion of Causes/Sources of Hardness Degradation

- o Natural (corrosion, wear, etc.)
- o Man-Made

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Marina Del Rey, California 90291
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