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EMR HARDNESS DESIGN GUIDANCE

Georgia Institute of Technology

W. R. Free
D. E. Clark
J. K. Daher
E. E. Donaldson

ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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APPROVED: John H. Edwards Jr

JOHN H. EDWARDS, JR.
Project Engineer

APPROVED: David C. Luke

DAVID C. LUKE, Colonel, USAF
Chief, Reliability & Compatibility Division

FOR THE COMMANDER: John P. Huss

JOHN P. HUSS
Acting Chief, Plans Office

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This program was conducted to develop the overall methodology, guidelines, procedures, and guidance documentation required to establish an Air Force EMR hardness program for air launched ordnance systems. (The handbook title is "Management and Design Guidance Electromagnetic Radiation Hardness for Air Launched Ordnance System", MIL-HDBK-335(USAF).)

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EVALUATION

This final report summarizes a handbook on the design guidance for the hardening of airborne weapon systems to electromagnetic energy. Even though the handbook is written for airborne weapon systems, the application of the philosophy and management practices as outlined will apply to all electronic systems exposed to an electromagnetic environment. As the handbook will not have wide distribution, this report describes the handbook with enough detail that those in the DOD who have interest can obtain the complete handbook. The handbook is well written and organized to provide complete program guidance for acquisition of all electronic weapon system. The handbook title is "Management and Design Guidance Electromagnetic Radiation Hardness for Air Launched Ordnance System," MIL-HDBK-335 (USAF), dated 15 January 1981.

JOHN H. EDWARDS, JR.
Project Engineer

PREFACE

This report was prepared by the Electronics Technology Laboratory of the Engineering Experiment Station of the Georgia Institute of Technology on Contract No. F30602-79-C-0132. The work covered by this report was conducted under the general supervision of Mr. D. W. Robertson, Director, Electronics Technology Laboratory, Mr. H. W. Denny, Head of the Electromagnetic Compatibility Branch, and Mr. W. R. Free, Project Director. The report describes the objectives, activities, and results of a program to develop an Air Force EMR hardness program for air launched ordnance systems.

TABLE OF CONTENTS

		Page
1.	INTRODUCTION.	1
	1.1 Background	1
	1.2 Program Objective and Scope.	1
	1.3 Report Organization.	2
2.	TASK 1 -- DEVELOPMENT OF CONCEPTS AND PROCEDURES FOR ESTABLISHING A CAPABILITY FOR GENERATING EMR ENVIRONMENT FORECASTS	3
	2.1 Task 1 -- Objectives and Scope	3
	2.2 The EMR Environment	3
	2.2.1 Life Cycle Phases and Mission Scenarios . . .	4
	2.2.2 Forecasting Requirements	5
	2.2.3 Preparation of EMR Environment Forecasts . . .	5
	2.3 Requirements for EMR Environment Forecasts During the Acquisition Cycle	6
	2.3.1 Conceptual Phase	6
	2.3.2 Full-scale Development Phase	7
	2.3.3 Susceptibility/Vulnerability Evaluation Phase	7
	2.4 Organization and Procedures for Generating EMR Environment Forecasts	8
	2.4.1 Method of Approach	8
	2.4.2 Preparing Organization	8
	2.4.3 Types of EMR Environment Forecasts	8
	2.4.3.1 Type I EMR Environment Forecast . . .	8
	2.4.3.2 Type II EMR Environment Forecast. . .	9
	2.4.3.3 Type III EMR Enviroment Forecast. . .	10
	2.5 Current Status of the EMR Environment Forecasting Capability	11
	2.6 Task 1 Summary	12

TABLE OF CONTENTS (Concluded)

		Page
3.	TASK 2 -- DEVELOPMENT OF GUIDELINES AND PROCEDURES FOR ESTABLISHING, IMPLEMENTING, AND MANAGING AN EMR HARDNESS PROGRAM	13
	3.1 Task 2 Objective and Scope	13
	3.2 Study to Supplement EMR Susceptibility Data	13
	3.3 Study to Develop EMR Measurement Techniques	14
	3.4 Study to Develop EMR Prediction and Analysis Techniques	15
	3.5 Study to Develop Guidelines for Tailoring Specifications and Standards for EMR Hardness Programs	16
	3.6 Study to Develop a Recommended Outline for EMR Hardness Program Plans	17
4.	TASK 3 -- DEVELOPMENT EMR HARDNESS MANAGEMENT AND DESIGN HANDBOOKS	20
	4.1 Task 3 -- Objective and Scope	20
	4.2 Final EMR Hardness Management and Design Handbook	20
5.	SUMMARY AND RECOMMENDATIONS	23

1. INTRODUCTION

The purpose of this report is to describe the activities, accomplishments, and results of a program to develop an Air Force EMR hardness program for air launched ordnance systems.

1.1 Background. Air launched ordnance systems are exposed to a wide variety of high intensity electromagnetic environments in the performance of their missions. These environments result from electromagnetic radiation (EMR) from a large number of sources including friendly and hostile radars, radio transmitters, hostile jammers, etc. The potential vulnerability to these environments cannot be ignored in the design and development of new air launched ordnance systems.

To ensure that adequate consideration is given to EMR hardness in the design and development stages of a new system, it is necessary that an EMR hardness program for the system be established early in the acquisition cycle and implemented throughout the acquisition cycle.

1.2 Program Objective and Scope. The objective of this program was to develop the overall methodology, guidelines, procedures, and guidance documentation required to establish an Air Force EMR hardness program for air launched ordnance systems. The program was divided into three major tasks. The objective of Task 1 was to develop concepts and recommendations for establishing an organization to provide the capability for generating EMR environment forecasts and to work with RADC and Electromagnetic Compatibility Analysis Center (ECAC) personnel in establishing such a capability. In addition, this task included the development of specific information on how to request EMR environment forecasts, what input information is required for requests, and how the forecasts are to be used in establishing EMR hardness requirements for a specific system.

The objective of Task 2 was to develop detailed guidelines and procedures for implementing specific portions of the EMR hardness program. The results from this task were used to prepare sections of text and appendices for inclusion in the final EMR hardness management

and design handbook describing in detail how to implement critical portions of an EMR hardness program.

The objective of Task 3 was the development of EMR hardness management and design handbooks to provide program managers, system designers, and test personnel with detailed guidance for implementing an EMR hardness program throughout the life cycle of a system. This task included two distinct efforts. The initial effort was directed to the development of an interim handbook to provide interim guidance information in a short time frame for use until more comprehensive documentation was available. This interim handbook was completed four months after the initiation of the program and was submitted as Interim Technical Report No. 1 in August 1979. The second effort under this task was the development of a final EMR hardness management and design handbook which includes the information, procedures and guidelines developed under Task 1 and Task 2. This handbook is intended to serve as a complete information source on EMR hardening and addresses all of the requirements that may be encountered in establishing and implementing an EMR hardness program. The final handbook is being submitted concurrently with this report under separate cover.

1.3 Report Organization. The material in the remainder of this report is divided into four major sections. Section 2 describes the Task 1 effort of the program in establishing a capability for generating EMR environment forecasts. Section 3 describes the Task 2 effort of the progam in developing guidelines and procedures for implementing and managing an EMR hardness program. Section 4 describes the Task 3 effort of the program in developing EMR hardness management and Design Handbooks. Section 5 summarizes the current status of the Air Force EMR Hardness Program and recommends areas in which additional work is needed.

2. TASK 1 -- DEVELOPMENT OF CONCEPTS AND PROCEDURES FOR ESTABLISHING A CAPABILITY FOR GENERATING EMR ENVIRONMENT FORECASTS.

2.1 Task 1 -- Objectives and Scope. The objectives of Task 1 were to define the requirements for EMR environment forecasts, to assist RADC and ECAC in establishing a capability for generating EMR environment forecasts, and to develop guidelines and procedures for utilizing EMR environment forecasts in establishing the EMR hardness requirements for air launched ordnance systems. The task included the following efforts:

(1) Identify the points in the acquisition cycle at which EMR environment forecasts are required;

(2) Provide recommendations to ECAC as to the type, scope, level of detail, and the format for each environmental forecast;

(3) Assist ECAC in devloping guidelines and procedures for requesting EMR environment forecasts; and

(4) Develop guidelines and procedures for utilizing EMR environment forecasts to establish EMR hardness requirements.

2.2 The EMR Environment. The initial objective of this task was to define the electromagnetic environments that air launched ordnance systems will be exposed to during the accomplishment of their intended missions. The electromagnetic environment incident on an air launched ordnance system results from the electromagnetic radiation (EMR) from a number of radiating sources in the vicinity of the system. The radiating sources may include friendly and/or hostile radars, radio transmitters, jammers, and other relatively high power radiating systems. These radiating sources may be located on the ground, on ground vehicles, on ships, or on aircraft. The spectral distribution of the radiated energy in the electromagnetic environment (EME) is determined by the operating frequencies of the radiating sources. The levels of the EME are determined by the amount of power being radiated by the individual sources, the distance between the weapon system and the individual radiating sources, and the orientation of the weapon system relative to the radiation pattern of the individual sources.

While the system is mounted on a delivery aircraft, the radiation from electronic systems (such as radars, jammer pods, and communications transmitters) on board the delivery aircraft will be a primary source of the EME incident on the weapon system. If the delivery aircraft is flying in a formation, the radiation from escort aircraft may be a primary source of the EME incident on the weapon system. While the system is in free flight between the delivery aircraft and a target, the radiation from the ground environment may be a primary source of the EME. As the system approaches a target, the radiation from the target itself and emitters in the vicinity of the target will probably be the major source of the EME.

2.2.1 Life Cycle Phases and Mission Scenarios. An air launched ordnance system will be exposed to several different EMR environments during its life cycle. Thus, to define the EMR environment a system is to be hardened to, it is necessary to define each of the independent environments to which the system will be exposed. These individual environments include the ground environment, the cosite environment, the intersite environment, and the approach-to-target environment. The ground environment includes the radiation from all emitters (friendly and hostile) on the ground (and on water) over which the system will travel (both on the delivery aircraft and in free flight) in the performance of its missions. The cosite environment includes the radiation from emitters on-board the delivery aircraft. The intersite environment includes the radiation from emitters on escort aircraft, other friendly aircraft, and hostile aircraft. The approach-to-target environment includes the radiation from the target and emitters in the vicinity of the target. After the individual environments have been defined, each of the environments must be projected into the future by forecasting techniques to be representative of the environments the system will be exposed to at the end of its service life.

In order to establish the overall EMR hardness requirements for a system, it is necessary to integrate the forecasted individual environments into a composite EMR environment profile which indicates the maximum radiation levels that the system will be exposed to during its life cycle.

2.2.2 Forecasting Requirements. In defining the EMR environments a system will be exposed to during deployment, consideration must be given to the fact that the system will probably be in development for several years, and, in addition, the system will probably have an in-service life spanning several years. Hence, it is not sufficient to just define the EMR environments that exist at the present time; it is necessary to predict the EMR environments the system will be exposed to during deployment until the end of its in-service life. For EMR environment definitions used in the early stages of a system development, the environment definitions will have to be projected by forecasting techniques to a time frame which is the sum of the acquisition cycle and the in-service life cycle of the system in the future. As the development of the system progresses the projection time for the updated EMR environment definitions will be reduced. If it is assumed that the acquisition time of a typical system is 10 years and the average in-service life is 15 years, the initial EMR environment definitions would need to be projected by a 25-year forecast. Environment definitions used midway in the acquisition cycle would need to be projected by 20 years, while the environments used at the end of the acquisition cycle would need to be projected 15 years.

2.2.3 Preparation of EMR Environment Forecasts. The generation of an EMR environment forecast for a proposed air launched ordnance system is a complex and difficult process requiring extensive information describing the operational characteristics and geographical locations of friendly and hostile emitters world wide. The generation of EMR forecasts also requires extensive culling and processing of the emitter data and the application of validated forecasting techniques.

While the operational EMR environment forecasts for each system must be tailored for that specific system, the procedures and forecasting techniques for generating the EMR forecasts will be essentially the same for all systems. In addition, the generation of an EMR forecast for a specific system will entail processing the same EMR data base to tailor an environment to the operational and tactical requirements of the specific system.

Under these conditions, it is not reasonable to require each program office to generate the EMR forecasts for the system for which it is responsible. This would require each program office to establish an extensive EMR data base and develop the organization, procedures, and forecasting techniques for generating EMR forecasts. A much more efficient approach is to assign a permanent organization the responsibility for satisfying the EMR environment forecast requirements for all program offices. With this approach, the basic EMR data base, the processing procedures, and the forecasting techniques are only developed one time, eliminating duplication of efforts. The Electromagnetic Compatibility Analysis Center at Annapolis, Maryland was designated as the organization responsible for providing EMR environment forecasts for Air Force programs.

2.3 Requirements for EMR Environment Forecasts During the Acquisition Cycle. Another objective of this task was to define the points in the acquisition cycles of air launched ordnance systems at which EMR envionment forecasts are required. It was concluded from a study of the acquisition process that a minimum of three EMR environment forecasts are required. The actual total number of forecasts required will depend on the complexity of the system being developed and the time duration of the acquisition cycle. For a large complex system requiring an unusually long acquisition time frame, several EMR forecasts may be necessary.

The three points in the acquisition cycle at which the requirements for EMR environment forecasts are most critical were identified as: (1) the initiation of the conceptual phase, (2) during the preparation of the RFP documentation for the full scale development phase, and (3) during the system susceptibility/vulnerability evaluation phase. For large complex systems with extended acquisition periods, additional EMR forecasts may be required at the initiation of the validation phase and at the initiation of the production phase.

2.3.1 Conceptual Phase. The first EMR environment forecast should be available for use during the selection and evaluation of alternate concepts for satisfying the Statement of Need (SON) document. This

EMR environment definition should be used in feasibility analyses, trade-off studies of alternate approaches and concepts, and the definition of risks.

This initial EMR forecast should also be used by the program manager and the EMCAB to establish budgets, schedules, and resources requirements for inclusion in the EMR Hardness Program Plan and the Test and Evaluation Master Plan.

2.3.2 Full-scale Development Phase. A second updated EMR environment forecast should be available for use during the preparation of the Request for Proposal (RFP) documentation for the full-scale development phase of a program. This EMR forecast should be incorporated into the RFP to convey to the bidders the amount of EMR hardness that will be required. The forecast should also be used to tailor the limits and test procedures of any EMC specifications and standards (such as MIL-E-6051, MIL-STD-461, and MIL-STD-462) which will be invoked by the contract.

This EMR environment forecast should also be used by the selected contractor to establish the EMR hardness criteria for the design of the full scale engineering development model of the system. In addition, the EMR forecast should serve as a basis for the contractor's EMR Hardness Control Plan and the EMR Hardness Test Plan.

2.3.3 Susceptibility/Vulnerability Evaluation Phase. A third EMR environment forecast should be available for use during the susceptibility/vulnerability evaluation phase of a program. This forecast should be used by the system EMR test organization as guidance in conducting the system EMR susceptibility tests and as the threat definition in vulnerability analyses. The information contained in this forecast and the format should be such that the critical frequency ranges and modulation characteristics can be identified for system susceptibility test purposes. In addition, the format should be such that EMR environment profiles for specific mission scenarios can be generated for vulnerability analyses.

2.4 Organization and Procedures for Generating EMR Environment Forecasts.

2.4.1 Method of Approach. As previously discussed in Section 2.2.3, it was concluded that the most efficient approach for generating EMR environment forecasts is to assign a permanent organization the responsibility for satisfying the EMR environment forecast requirements for all program offices developing air launched ordnance systems.

2.4.2 Preparing Organization. The Electromagnetic Compatibility Analysis Center (ECAC) located at Annapolis, Maryland has been designated as the organization responsible for satisfying the EMR environment forecast requirements for Air Force air launched ordnance systems. This center is a joint-service Department of Defense facility, established to provide rapid analysis of electromagnetic compatibility problems of the military services. ECAC has an extensive electromagnetic environmental data base which includes a comprehensive listing of existing electromagnetic emitters throughout the world. In addition, ECAC has access to the required intelligence information and has extensive experience as to which organizations are the best sources of particular types of information. ECAC also has considerable experience in generating electromagnetic environmental profiles, similar to those of current interest, in support of RADC's HAVE NOTE test programs.

2.4.3 Types of EMR Environment Forecasts. While the objective of all EMR forecasts is the same (i.e., to define the anticipated operational electromagnetic environment of the system), the manner in which each forecast will be used, the stage of development of the system when each forecast is generated, and the extended time periods between forecasts dictate that the EMR forecasts obtained at different points in the acquisition cycle of a system will be different. Since EMR forecasts are required at three different points in the acquisition process, three different types of forecasts are required.

2.4.3.1 Type I EMR Environment Forecast. The initial EMR forecast for use at the beginning of a program will be based on a Type I

analysis. It is anticipated that at this stage of the program the system will be largely or entirely conceptual and little, if any, operational and tactical information, as well as performance specifications, for the system will have been defined. Thus, the Type I analysis technique must be capable of providing an EMR environment forecast with a minimum amount of input data. For example, if the theater(s) of operation has not been defined, then a worldwide environment should be considered in the analysis. If the type(s) of delivery aircraft has not been defined, then the worst-case, on-board environment for the class of aircraft which could serve as a delivery platform should be considered in the analysis, etc.

The total life cycle of a typical system from the initiation of the conceptual phase to the final phasing out of the system from the inventory is estimated to be approximately 30 years. Thus, in the absence of specific information to the contrary, the Type I EMR environment should be forecasted for a 30 year period.

It is realized that the absolute accuracy of a Type I EMR environment forecast based on a minimum amount of operational input data and forecasted over a 30-year period is highly questionable. However, this type of data will be extremely useful at the beginning of a program in performing feasibility analyses and trade-off studies of alternate approaches and concepts. In addition, this coarse EMR environment data will serve as a useful basis for establishing budgets, schedules, and resources requirements for the EMR hardness program and the EMR test program.

2.4.3.2 Type II EMR Environment Forecast. It is anticipated that in the development of a typical air launched ordnance system, a second updated (Type II) EMR environment forecast will be obtained for use in preparing the RFP documentation for the full scale development phase of the program. At this phase of the acquisition cycle, it is assumed that a great deal of the operational and tactical information for the proposed system will have been defined, and the desired performance specifications will have been defined. Specifically, the theater(s) of operation will have been defined, the type(s) of delivery aircraft (and possibly the location of the weapon on the aircraft)

will have been determined, and the specific classes or types of targets the weapon will be used against will have been established. Also, a 20-year forecasting period is considered adequate for a system at this stage of development.

Under these conditions, the Type II EMR environment forecast should be a far more accurate description of the actual operational EMR environment of the proposed system. The ground environments will be restricted to the actual theaters of operation and the on-board environment will be restricted to the specific delivery aircraft.

The Type II analysis technique must be capable of providing an EMR environment forecast with sufficient information so that when the forecast is incorporated into the RFP for the full scale development program it conveys to the bidders realistic EMR hardness requirements for the proposed system. In addition, the format of the Type II EMR forecast should be designed so that the selected contractor can readily use the forecast in establishing his EMR hardness design criteria for the proposed system. The selected contractor also must be able to use the Type II EMR forecast as the basis for his EMR Hardness Control Plan and his EMR Hardness Test Plan.

2.4.3.3 Type III EMR Enviroment Forecast. It is anticipated that a third updated (Type III) EMR environment forecast will be obtained for use during the susceptibility/vulnerability testing of the full scale development model and the production model of the system. This EMR forecast will be obtained near the completion of the full scale development model of the system. At this stage of the acquisition cycle, it is assumed that all operational, tactical, and performance specifications for the system will have been completely defined. A 15-year forecasting period is considered adequate for a system at this stage of development. Under these conditions, the type III EMR environment forecast should be an accurate description of operational EMR environment the system will encounter until the end of its service life.

The format of the Type III EMR forecast should be designed to provide maximum support to both the development of system susceptibility tests and the development of system vulnerability analyses.

The format should be such that critical frequency ranges and modulation characteristics can be identified for system susceptibility tests and that EMR environment profiles for specific mission scenarios can be generated for vulnerability analyses.

2.5 Current Status of the EMR Environment Forecasting Capability. The Electromagnetic Compatibility Analysis Center (ECAC) has developed a capability to rapidly generate current (baseline) and future (forecasted) EMR environment profiles that are tailored to both the acquisition and deployment phases of air launched ordnance systems. The complete capability, designated the DoD/ECAC Environmental Definition System (EDS), was developed under a project entitled "Tailored EMR Hardness Criteria" sponsored by the Rome Air Development Center (RADC).

ECAC is currently publishing a 5-volume report describing the Environment Definition system and the procedures for requesting EMR enviornment forecasts. The report is entitled "Environmental Definition System (EDS)" and the report number is ESD-TR-80-100-(Vols 1-5).

The EDS consists of a series of manual and computerized models, software support packages, and administrative procedures which can be used to define the current or the future EMR environment an air launched ordnance system will be exposed to in accomplishing its missions. The EDS consists of two parts. The first part, called the Ground Environment Definition System (GEDS), was designed to generate current and future EMR environment profiles resulting from ground based emitters. The second part, called the Aircraft Environment Definition System (AEDS), was designed to generate current and future EMR environment profiles resulting from aircraft based emitters. The GEDS is used to generate the ground environment profiles; and the AEDS is used to generate the aircraft cosite, aircraft intersite, immediately after launch, and final approach to enemy aircraft environment profiles.

Volume 1 of ECAC's report describes the baseline portion of the GEDS which is used to generate EMR environment profiles that result from currently existing ground based emitters. Volume 2 of the report describes the forecasting techniques developed to predict the future ground environmental conditions that will exist at specified times in the future. Volume 3 of the report describes the baseline portion

of the AEDS which is used to generate EMR environment profiles that result from currently existing aircraft based emitters. Volume 4 of the report describes the forecasting techniques developed to predict the future aircraft environmental conditions that will exist at specified times in the future. Volume 5 of the report is a Customer's Application Manual. This volume is designed to aid system developers in requesting EMR environment forecasts. The volume contains specific information on the procedures for requesting EMR forecasts, the types of forecasts available, the input data requirements, time and manpower estimates for different types of forecasts, and a glossary of special terms.

2.6 Task 1 Summary. The following efforts were accomplished during this task:

(1) The critical points in the acquisition cycle at which EMR environment forecasts are required were identified.

(2) The different EMR environments encountered by air launched ordnance systems during their life cycles were identified.

(3) The types of EMR environment forecasts required at different points in the acquisition cycle were defined.

(4) ECAC was designated the organization responsible for generating EMR environment forecasts for air launched ordnance system developers.

(5) ECAC has developed the capability to generate the different types of EMR forecasts and defined the procedures for requesting forecasts.

The pertinent information from the results of this task and ECAC's report was extracted and processed for inclusion in the final EMR Hardness Design Handbook.

3. TASK 2 -- DEVELOPMENT OF GUIDELINES AND PROCEDURES FOR ESTABLISHING, IMPLEMENTING, AND MANAGING AN EMR HARDNESS PROGRAM

3.1 Task 2 Objective and Scope. The objective of Task 2 was to generate additional information in selected areas related to EMR hardness in which existing information was insufficient to develop recommended guidelines and procedures for implementing these areas in an EMR hardness program. The areas addressed in this task included the following:

(1) EMR Susceptibility Data on Semiconductors

(2) Measurement Techniques and Guidelines for EMR Hardness Test Programs

(3) EMR Hardness Prediction and Analysis

(4) Tailoring Specifications and Standards for EMR Hardness Programs

(5) Addressing EMR Hardness Requirements in Program Documents

(6) Recommended Outline for EMR Hardness Program Plan

(7) Recommended Outline for EMR Hardness Control Plan

(8) Recommended Outline for EMR Hardness Test Plan

Studies were conducted in each of these areas to generate and accumulate sufficient information to develop guidelines and procedures for implementing these areas into EMR hardness programs. In addition, two additional studies were conducted under this task, one to develop definitions of terms and acronyms used in the handbook and a second study to develop an EMR hardness bibliography.

3.2. Study to Supplement EMR Susceptibility Data. The objective of this study was to conduct the necessary research in order to provide additional EMR susceptibility data on discrete devices for inclusion in the final EMR hardness handbook.

The scope of the study was to review existing documents on discrete device data and select those judged appropriate for inclusion in the

final handbook. The data acquired from this search was then to be processed into an appropriate format for use by system designers.

An in-depth literature survey was conducted, and some twenty documents from nine different sources were reviewed for susceptibility data on discrete components which could be included in the final handbook. While the documents reviewed contained susceptibility data on a large number of solid-state devices, a great deal of the data was deemed inappropriate for the purposes of this investigation. This decision was influenced by the variety of test procedures and operating conditions used to obtain the data, as well as the limited number of data points obtained on some of the devices.

The results from this study were used to provide additional EMR susceptibility data on discrete components for inclusion in the final EMR hardness handbook. The appendix on Establishing Susceptibility Levels presented in the Interim Handbook was supplemented to include susceptibility data on bipolar transistors and X-band point-contact diodes. These data were processed and formatted for presentation in the most usable form for system designers and developers. The appendix also include sample calculations demonstrating the procedure for performing susceptibility calculations using the discrete component data.

3.3 Study to Develop EMR Measurement Techniques. The objective of the study was to identify and assimilate the information and data necessary to describe the elements of an EMR hardness measurement program for air launched ordnance systems.

The scope of the study involved a review of current EMC and EMC-related documents (standards, specifications, handbooks, and other technical literature) pertaining to EMR measurement philosophies, techniques, and instrumentation and the extraction of information and data for application to EMR hardness measurements.

The study was directed to a review and analysis of approximately thirty documents dealing with EMC-related measurements. The thrust of this review and analysis was directed to three major categories of information which were considered of primary interest to an EMR hardness measurement program. The first category was that information useful to a description of the basic elements and requirements of an

EMR hardness measurement program - test philosophies, test facilities, test criteria, test plans, etc. The second category was that information dealing with test facilities applicable to EMR hardness measurements. Specific facilities of interest included shielded enclosures (conventional shielded enclosures, TEM cells, and tuned-mode shielded enclosures), parallel-plate transmission lines, anechoic chambers, and test instrumentation (signal sources, antennas, EMI receivers and auxiliary devices). The third category was that information concerned with test approaches applicable to EMR testing. This information included methods of identifying critical components/circuits and subsystems, measurement techniques (radiated and injection testing) for performing EMR susceptibility testing on components/circuits and subsystems, and techniques for performing shielding effectiveness measurements.

The results from this study were used to prepare an appendix to the EMR hardness handbook which describes the basic elements and requirements of an EMR hardness measurement program, the test facilities required for performing EMR hardness measurements, and the recommended test approaches to be employed.

3.4 Study to Develop EMR Prediction and Analysis Techniques. The objective of the prediction and analysis study was to develop guidelines and procedures for designing EMR hardness or protection into air launched ordnance systems with emphasis on the early development stages.

The scope of the study was to review available mathematical models and techniques applicable to ordnance systems. In particular, the Intrasystem Analysis Program (IAP) components were reviewed and descriptions of IAP capabilities developed. Also the various levels-of-analyses possible during a typical acquisition cycle were investigated.

The study consisted of two efforts. The first effort was to interface directly via visits with weapon system engineers and analysts involved in developing or in applying prediction and analysis techniques. The second effort was to acquire and review pertinent reports and technical papers that deal with the various aspects of prediction and analysis. For the first effort, a visit was made to RADC to discuss the IAP and its use at different levels-of-analyses. During this visit,

an IAP briefing was given for contractors and other government personnel and this briefing was attended by Georgia Tech personnel. At later dates, other meetings were held with the EMC/IAP support center personnel who were involved in a "system-x" study of a guided weapon system for which measured data was available. In order to obtain a major contractor's viewpoints and implementation approach, a meeting was held with General Dynamics (San Diego) personnel. The second effort involved acquiring reports and technical papers through telephone contacts, a library search, and NTIS. All of the major IAP reports and related studies documentation were acquired including the IEMCAP, GEMACS and NCAP user's and engineering manuals. Other key documents from NSWC, Sandia Labs, AFWL, ARC, and the University of Kentucky were acquired. Georgia Tech EES has an extensive document data base which was also utilized in this study. A total of approximately one hundred reports and technical papers were acquired and reviewed.

The guidelines and procedures developed from the results of this study were incorporated in the EMR hardness handbook as two appendices. The first appendix is a comprehensive description of the IAP and its components. The second appendix describes the methodology in applying IAP and general prediction and analysis techniques as a function of the acquisition cycle. These two appendices provide system designers with the basic information necessary to plan and implement analysis and prediction programs.

3.5 Study to Develop Guidelines for Tailoring Specifications and Standards for EMR Hardness Programs. The objective of this study was to accumulate the necessary information to develop guidelines for tailoring specifications and standards for use in EMR hardness programs.

The scope of the study was to review current EMC and EMC-related specifications, standards, and handbooks and select those most appropriate for application in EMR hardness programs. After the most appropriate documents were selected, guidelines were developed to tailor the specific documents so they adequately addressed the EMR hardness requirements of air launched ordnance systems.

The study included a review and analysis of fifteen specifications and standards concerned with EMC, other electromagnetic effects (HERO,

EMP, etc.), and EMC support areas (bonding, grounding, wiring, etc.) to determine which of the documents were most appropriate for application to implement EMR hardness programs. On the basis of the results from this initial review, the nine specifications, standards, and handbooks listed below were selected as the most appropriate for application to EMR hardness programs.

MIL-E-6051	Electromagnetic Compatibility Requirements, Systems
MIL-HDBK-237	Electromagnetic Compatibility/Interference Program Requirements
MIL-STD-461	Electromagnetic Interference Characteristics, Requirements for Equipment
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-463	Definitions and Systems of Units, Electromagnetic Interference Technology
MIL-STD-1512	Electroexplosive Subsystems, Electrically Initiated, Design Requirements and Test Methods
AMCP 706-235	Hardening Weapon Systems Against RF Energy
MIL-STD-1377	Effectiveness of Cable, Connector, and Weapon Shielding and Filters in Precluding Hazards of Electromagnetic Radiation to Ordnance, Measurement of
MIL-B-5087	Bonding, Electrical, and Lightning Protection for Aerospace Systems

These nine documents were analyzed in greater detail to develop recommended guidelines for tailoring the documents to achieve the goals of EMR hardness programs.

The results from this study were used to prepare an appendix for inclusion in the EMR hardness handbook which describes the tailoring process for specifications and standards. The appendix also discusses the application and scope of each of the nine selected documents and describes recommended guidelines for tailoring the individual documents.

3.6 Study to Develop a Recommended Outline for EMR Hardness Program Plans. The objective of this study was to accumulate and generate

the necessary information to develop recommended outlines for EMR hardness program plans.

The scope of the study was to review program management and acquisition documents and regulations as well as typical system acquisition cycles to determine the types of information which should be included in an EMR hardness program plan, an EMR Hardness control plan, and an EMR hardness test plan.

This study included a review of a number of documents concerned with program management, system acquisition, and system test and evaluation to determine the types of information required to develop a program plan that will ensure that the necessary EMR hardness functions are performed throughout a system life cycle. The documentation study included a review of the documents listed below:

AFR 800-2	Acquisition Program Management
AFSC P800-3	A Guide for Program Management
AFR 80-7	Electromagnetic Compatibility Program
AFR 80-14	Test and Evaluation
AFR 80-38	Management of the Air Force Survivability Program
MIL-HDBK-253	Guidance for the Design and Test of Systems Protected Against the Effects of Electromagnetic Energy
MIL-HDBK-237A (Proposed)	EMC Management Guide for Platforms, Systems, and Equipment
MIL-E-6051D	Electromagnetic Compatibility Requirements, Systems

In addition to the documentation review, discussions were conducted with system program office (SPO) personnel at Eglin AFB, FL to obtain additional information regarding the actual management functions and procedures during acquisition processes. Discussions were also conducted with system test personnel at RADC/RBCA to determine the functions and information requirements during system susceptibility tests and vulnerability assessments.

The results from this study were used to prepare a section of the EMR hardness handbook descibing the preparation of EMR hardness program plans, and EMR hardness test plans. In addition, the information was used to prepare three appendices to the handbook illustrating recommended outlines for the three types of EMR hardness plans.

4. TASK 3 -- DEVELOPMENT EMR HARDNESS MANAGEMENT AND DESIGN HANDBOOKS

4.1 Task 3 -- Objective and Scope. The objective of Task 3 was the development of EMR hardness management and design handbooks to provide program managers, system designers, and test personnel with detailed guidance for implementing an EMR hardness program throughout the life cycle of an air launched ordnance system.

This task included two distinct efforts. The initial effort was directed to the development of an interim handbook to provide interim guidance in a short time frame for use until more comprehensive documentation was available. This interim handbook was completed four months after the initiation of the program and was submitted as Interim Technical Report No. 1 on August 20, 1979.

The second effort under this task was the development of a comprehensive EMR hardness management and design handbook to serve as a complete information source for establishing, implementing, and managing an EMR hardness program for an air launched ordnance system. This handbook is being submitted concurrently with this report under separate cover.

4.2 Final EMR Hardness Management and Design Handbook. The final EMR hardness handbook entitled, "Management and Design Guidance Electromagnetic Radiation Hardness for Air Launched Ordnance Systems," is to be published as a Military Handbook to provide program managers, system designers, and test personnel with guidance for the design, development, and acquisition of air launched ordnance systems which are hardened against the detrimental effects of electromagnetic radiation.

The handbook consists of six major sections and fifteen appendices. Section 1 (Introduction) states the purpose and scope of the handbook and describes the format of the handbook.

Section 2 (Referenced Documents) lists military documents which may be tailored to invoke EMR hardness requirements and control into the acquisition process. While there are currently no government specifications or standards which specifically address EMR susceptibility or vulnerability of air launched ordnance systems, the more general electromagnetic compatibility (EMC) documents listed in this section

can be tailored to address the EMR hardness problem in contractual documentation. The information in this section is intended for government management and procurement personnel who are responsible for ensuring that EMR hardness is adequately addressed in contract documents. (Information on tailoring specifications and standards is presented in Appendix J.)

Section 3 (The EMR Vulnerability Problem) describes the nature, causes, and effects of EMR vulnerability. The information in this section is intended for management, design, and engineering personnel. It seeks to convey an understanding of the overall EMR vulnerability problem and to provide general descriptions of the EMR environment, the environment-to-system coupling mechanisms, and the degradation effects of EMR vulnerability.

Section 4 (EMR Hardness Control and Management) describes an overall management approach for implementing an EMR hardness program over the entire life cycle of an air launched ordnance system. The material in this section is intended primarily for program managers and EMCAB personnel who are responsible for the development, implementation, and control of EMR hardness programs for air launched ordnance systems.

Section 5 (EMR Hardening Design) describes an overall approach and the specific procedures that contractor personnel may utilize to ensure that the EMR hardness requirements are satisfied during the development and fabrication of a system. The information in this section is intended primarily for contractors' management, design, and engineering personnel who are responsible for incorporating adequate EMR hardness into the design and fabrication of air launched ordnance systems. The material in this section will also be of interest to government program managers and EMCAB personnel who are responsible for monitoring and evaluating contractors' EMR hardness efforts.

Section 6 (EMR Hardness Measurement Program) describes an overall test and evaluation plan to verify the EMR hardness of a system. The information in this section is intended for both the program office personnel who are responsible for establishing and evaluating an overall measurement plan and the contractor personnel who are responsible for developing an EMR hardness test plan and performing EMR hardness tests.

The appendices describe in greater detail major areas which must be addressed in an EMR hardness program and provide additional guidance for addressing these areas. The appendices include the following:

A. EMR Environment
B. EMR Environment Forecasting Capabilities at ECAC
C. Analysis and Prediction
D. The Intrasystem Analysis Program (IAP)
E. Establishing Susceptibility Levels
F. Establishing EMR Hardness Criteria
G. EMR Hardness Design Practices
H. EMR Hardness Measurement Techniques
I. EMR Hardness Considerations in Program Documents
J. Tailoring of Specifications and Standards
K. Outline for EMR Hardness Program Plan
L. Outline for EMR Hardness Control Plan
M. Outline for EMR Hardness Test Plan
N. EMR Hardness Bibliography
O. Definitions and Acronyms

5. SUMMARY AND RECOMMENDATIONS

An overall methodology for an EMR Hardness program for air launched ordnance systems has been developed. The guidelines and procedures necessary to implement and manage the methodology have been developed. The methodology, guidelines, and procedures have been incorporated into a Military Handbook to serve as a complete information source for implementing and managing EMR hardness programs.

To institutionalize the EMR Hardness Program within the Air Force, the following additional action is recommended:

(1) Address EMR hardness requirements in appropriate Air Force Regulations and acquisition documentation.

To improve the efficiency in implementing EMR hardness programs in the future, the following actions are recommended:

(1) The development of guidance documentation describing in detail how currently available analysis programs, mathematical models, and computer software codes can be used to satisfy the analysis and prediction requirements at specific points in an EMR hardness program.

(2) The establishment of a system to ensure that the EMR hardness handbook is revised and updated as required.

(3) The establishment of a continuous program to update and supplement the EMR environment forecasting capability.

(4) The establishment of an information and technology transfer system to ensure the transfer of "lessons learned" and "techniques developed" between program offices.

(5) The performance of a study to determine the feasibility of and procedures for integrating the requirements of the various electromagnetic effects specialty areas (EMC, EMP, EMV, etc.).

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