

ELECTROMAGNETIC PULSE TEST AIRCRAFT (EMPTAC) PROGRAM

Dean I. Lawry

Air Force Weapons Laboratory
Nuclear Technology Office
Kirtland Air Force Base, New Mexico 87117

ABSTRACT

Electromagnetic Pulse (EMP) efforts todate have primarily involved theoretical studies, laboratory experiments or tests of operational systems. Little has been accomplished at the system level concerning hardening design, improved test technology and hardness surveillance of aeronautical systems. This situation has existed due to the lack of a dedicated program and vehicle to support such efforts. This paper describes a new program designed to provide this support and help move EMP technology from an art to an engineering discipline.

EMP THREAT

EMP presents a unique threat to modern weapon systems such as aircraft. Other electromagnetic (EM) threats such as EMI and lightning are imposed on systems throughout their operational life and adverse effects are either corrected by redesign or maintenance actions or present only a limited threat such as occurs with lightning strikes. EMP is unique in that it will only occur in the event of nuclear war and presents a threat to systems not directly targeted. Therefore, it is essential that weapon systems critical to our strategic deterrence survive such a threat. Aircraft because of their distributed electronic subsystems, modification programs, daily maintenance, varying design approaches/vintage components and hostile operating environments present one of the most difficult challenges for EMP hardening and maintenance.

PAST EFFORTS

The majority of past EMP efforts have been confined to theoretical studies, laboratory experiments, verification tests of hardened systems or assessments of existing systems. These efforts have provided limited information needed to evaluate and determine possible hardening approaches or designs, or the trade-off data for determining the most effective approaches and those best suited for surveillance and maintenance. Tests of operational systems have made only limited contributions to improved or alternate test technologies since these tests are structured to minimize risks; thereby, depending on proven methodologies and procedures. Advancements have also been constrained by the lack of continuity associated with such system level tests. The lessons learned from one test are seldom passed on, or corrected on the next. Funding for the correction of problems is limited and new programs which

may have the necessary funds rarely have the lead time to accomplish these improvements. Because of the limited test time available when dealing with operational systems, the primary test objectives, the large data requirements and the constraints on modifying the configuration of such systems, it has been difficult to perform experiments aimed at providing design hardening trade-off data, improved test technology or the development of hardness surveillance technology and procedures.

IMPACTS

Because of the limited data and uncertainties associated with hardness design margins, excess design hardness has been built-in to most hardened weapon systems. This approach is not only costly during acquisition, but these costs continue throughout the lifetime of the system if this hardness level is maintained. Lack of test technology improvements have kept costs of system level EMP testing high, extended test periods and resulted in varied and nonstandardized test procedures for virtually every test. These problems coupled with the need to develop hardness surveillance technology for hardened aircraft systems now in the inventory or soon to enter operational status mandated that a new approach be tried.

EMPTAC

The EMPTAC program was initiated to solve many of the problems facing the EMP community by providing a dedicated aircraft to serve as a testbed for hardening design trade-off studies, development of hardness surveillance technology, development of standards and specifications to support the common EM specifications program and to improve test capabilities. This program provides a vehicle to demonstrate and correlate the theoretical studies and laboratory experiments in a system environment. The EMPTAC program allows efforts to be integrated and focused on realistic needs to begin to bridge the gap between the R&D and the operational communities.

TESTBED AIRCRAFT

The testbed aircraft consists of a cargo version Boeing 720B aircraft with a large cargo door for easy access. The aircraft is maintained in a fully functional, but nonflying status. This configuration supports the majority of experiments while keeping maintenance and operational costs down; thereby, allowing more of the program funds to be devoted to the technical aspects of the program. The aircraft will be modified to provide various EM

shielding topologies to emulate those found on hardened aircraft and to install modern electronic subsystems. All the exterior paint has been removed from the aircraft to allow good electrical contact between skin sensors, conductive tape, etc. These modifications will support experiments and technology development.

EMPERICALLY BASED

The EMPTAC program is structured to provide solutions based on experiments which closely approximate those configurations and constraints normally associated with operational aircraft and support organizations. The experiments selected for incorporation into the EMPTAC have first been evaluated either theoretically or experimentally in the laboratory before they are fielded on board the testbed. This approach insures that preliminary feasibilities and approaches have been worked out. The testbed is not only available for efforts initiated within the program, but it is also available to other programs wishing to utilize it for special studies of interest to them.

DESIGN HARDENING

Efforts are in progress to support the development of subsystem and system level hardening specifications and associated verification testing. These include the testing an inertial navigation system using a 1553 data bus to evaluate methods of testing subsystems for both permanent damage and upset both in the laboratory and on-board the aircraft in a free field environment and using direct drive testing. Laboratory direct drive tests have been completed and the system will be installed on the testbed for free field tests in the EMP simulators followed by on board direct drive tests. The results of these tests will be correlated to determine the differences in results between the different tests and to set specification and verification requirements. Zinc oxide varistors integrated into a multipin connector are currently undergoing laboratory testing and will be installed on the aircraft to evaluate their effectiveness in system applications. Various dielectric insertion devices for decoupling control cables and other hard penetrations will be evaluated following aircraft modifications later this year. The trade-offs between global shielding and zone shielding (bays and racks) will be evaluated as well as the need for high attenuation verses moderate attenuation shielding requirements when coupled with electronic subsystems which have a moderate baseline hardness level. Specific design approaches for shielding windows and door seals will be evaluated both in the laboratory and on the testbed.

HARDNESS SURVEILLANCE

Past efforts have concentrated on hardness design, assessment and verification with no concern regarding the maintenance

of the EMP hardening features. Therefore, no technology or procedures exist for hardness surveillance and the associated maintenance required to maintain the EMP hardness critical elements on an aircraft. This has not been of great concern in the past when there were no operational hardened systems. Now there is a pressing need for the technology to perform hardness surveillance for a variety of systems utilizing varied hardening approaches and design elements. The EMPTAC program has set a high priority on the development and demonstration of hardness surveillance technology including global shielding, local points of entry (POE) detectors, nonlinear terminal protection devices, cable shielding testors and correlation of these diagnostic tools to the threat criteria and system survivability. Tests have already begun on the development of local POE detectors and simplified means of inspection or measurement. Also in progress is the development of system level CW testing as a means of determining degradations of global shielding and the development of portable cable testers capable of determining cable shielding degradations. The most difficult challenge is not in the testing or measurements of global shielding responses, but in the analysis and interpretation of these responses and the differences between a normal baseline response and a degraded response and identification of the degradation. This area of development requires system level testing in both a CW and a high level pulsed environment under carefully controlled conditions so that actual variances may be introduced and evaluated one at a time and ultimately in a collective condition to evaluate and demonstrate a hardness surveillance capability. Once this basic surveillance capability has been demonstrated, the technology must then be transferred and tailored to each specific system to meet individual design approach requirements and available hardness margins.

TEST TECHNOLOGY

Improvements in test technologies are critically needed to support system level verification and assessment testing. Current instrumentation capabilities suffer from a limited dynamic range with excess noise and an insufficient time base to record the EMP induced responses without the use of multiple waveform digitizers. The use of multiple digitizers set on different sweep speeds results in a time response that must be "time tied" with software to create a continuous waveform. Unfortunately these "time tied" waveforms result in false results when transformed to the frequency domain. The degree of the errors is dependent upon the quality of the time tie and can create interpretation problems unless the analyst is familiar with the problem. This situation has been improved with the introduction of new time tying algorithms, but still leaves much to be desired from an engineering sense. New developments in waveform digitizers are underway which would not only allow the

time waveform to be recorded on one instrument as a single record, thereby eliminating the need for "time tieing", but will be adaptable to actual installation on board the aircraft. Installing these recorders on board will allow the use of hardwired instrumentation cables; thereby, improving the dynamic range and allowing the data to be transmitted off the aircraft by digital instead of analog fiber optics. To take advantage of these new instrumentation capabilities, new and standardized test procedures and data recording standards will be developed. This will reduce pretest planning efforts and lead times and will allow the development of success criteria for system level testing. Standardized baseline testing and reporting will not only benefit each individual test, but will generate a large data base to support generic studies for future improvements.

DATA ANALYSIS

Because of the R&D nature of the EMPTAC efforts and the need to develop new analysis capabilities, a dedicated computer analysis effort closely coupled with experimental requirements has been initiated. This effort will utilize proven algorithms and software when possible and augment these when necessary to support experimental needs. The computer analysis architecture will be structured to allow analysis flexibility, rather than a production type structure. This will be less efficient for the support of high data rate testing, but will be better suited to the lower data rates associated with the EMPTAC efforts while meeting the varied analysis needs. Once new algorithms or software modules have been developed which meet production requirements, these will be incorporated into the test facilities data processing capabilities. Critical to the success of the EMPTAC is the need to keep careful records of the various tests and test conditions for correlation of results not only within the program, but with the results of other programs. This will provide cross checks on results and improve confidence. However, this type of record keeping and correlation can be labor intensive if done manually. To meet these demands, an automated data base was initiated last year to be operational prior to the testing on EMPTAC. This data base is called "System Level Evaluation of Electromagnetic Tests" or SLEET. SLEET has been loaded with the results of the first EMPTAC data collected from tests in the Vertical Dipole facility and from other operational test programs.

TECHNOLOGY TRANSITION

Since any technology development program such as EMPTAC is only successful if it succeeds in transitioning these advances to the users, a concerted effort has been made to identify users needs and focal points for active participation in the program. This interactive participation includes preparations to support verification testing, development of stan-

dards and specifications and development of hardness surveillance technology. Cooperation with other organizations involved with EMP and EMI and lightning technology is being actively pursued to integrate results whenever possible and avoid duplication. The program is structured to allow elements of the technology to be made available for transition as soon as possible without waiting until the end of the program. These intermediate results may be incomplete and have limitations placed on their use, but still represent the best solutions available to a user faced with a time critical requirement.

CHALLENGE

The EMPTAC program was initiated in-house two years ago, with the aircraft acquisition occurring last year. The primary contract was awarded last Fall and the first test conducted in February of this year. This represents a good start, but the work has only just begun. It will challenge all those associated with the program to meet the technology development needs in a timely manner while maintaining a quality effort necessary to meet the user community requirements. A concerted effort must be made to keep the program on course and not to go down technically interesting, but nonessential paths.

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