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REPORT
OF THE
DEFENSE SCIENCE BOARD TASK FORCE
ON
EMP HARDENING OF AIRCRAFT (U)

NOVEMBER 1980

OFFICE OF THE UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

WASHINGTON D.C. 20301

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REPORT

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DEFENSE SCIENCE BOARD

TASK FORCE

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November 1980

Office of the Under Secretary of Defense for Research and Engineering
Washington, D.C. 20301

[redacted]

[redacted]

[redacted]

OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE BOARD

OSO
5 U.S.C. § 552 (b)(6)

10 April 1981

MEMORANDUM FOR SECRETARY OF DEFENSE

THROUGH THE UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

SUBJECT: Report of the DSB Task Force on EMP Hardening of Aircraft - INFORMATION MEMORANDUM

(U) I am transmitting to you the report of the Defense Science Board's Task Force on EMP Hardening of Aircraft, chaired by Dr. [redacted] The B-1, E4B and the B-52 aircraft are specifically discussed in this report. This report provides a background introduction to the EMP phenomena, a discussion of the various approaches to hardening and a set of recommendations.

(U) The issue of aircraft EMP hardening is important, timely and replete with controversy; especially within the scientific community. The community appears to agree that (a) EMP is a significant problem to be dealt with if aircraft are to operate in a nuclear weapons environment; and (b) designing EMP hardness into a new strategic aircraft is relatively easy, inexpensive (less than 2% of total cost for B-1) and the advisable thing to do. The community controversy revolves around the verification of system hardness and the approach to hardening an existing aircraft, given cost, schedule and technical constraints.

(U) The illusive nature of EMP/aircraft system interaction and lack of test procedures and standards for evaluating an aircraft's EMP hardness contribute to the problem. In addition, the TRESTLE test system has just come on line and sufficient aircraft tests have not been completed nor has an adequate threat spectrum been generated to completely validate the facility's capabilities. A Joint Service, aircraft hardening verification testing protocol, which the entire EMP community can endorse, needs to be obtained as soon as possible. The Defense Nuclear Agency is planning such a protocol.

([redacted]) The salient points of the study, by aircraft type, are summarized below: (U)

[redacted] B-1: The B-1 is cited as the classic example of a "designed hard" aircraft. However, the B-1 must be system tested to assure that it is indeed as hard as the specifications indicate.

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[redacted] E-4B: The E4B should be subjected to proof of principle system tests on the TRESTLE, and TRESTLE should be augmented with a trailing wire antenna (TWA) pulser to adequately test the TWA.

[redacted] B-52: A major series of B-52 EMP tests were conducted over the past year. [redacted] The two approaches differ considerably in cost and mission impact, as well as complexity. The availability of funds to continue any B-52 EMP work in fiscal year 1981 is of immediate concern. As much as $60M may be necessary.

(U) Dr. Seymour Zeiberg, Deputy Under Secretary of Defense for Research and Engineering (Space & Strategic Systems), is currently addressing the B-52 EMP problem. EMP is of critical importance in its potential impact on the mission capability of such systems as the B-52 which is, of course, the mainstay platform for the multi-billion dollar cruise missile program.

(U) A dissenting opinion has been written by one of the Task Force members and is included as an appendix. The primary concern expressed is that the report should have more thoroughly addressed the areas concerned with vulnerability of mission non-essential equipment, functional upset, offensive avionics hardness and cost/effectiveness comparisons.

(U) I plan to distribute this report to the persons and organizatons on the attached list within two weeks, unless you express a preference for more restricted distribution.

[redacted]
Chairman

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OFFICE OF THE SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

DEFENSE SCIENCE BOARD

14 January 1981

MEMORANDUM FOR CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Report of the Task Force on Hardening of Strategic Aircraft to EMP

Submitted herewith is the report of the Task Force on Hardening of Strategic Aircraft to EMP.

The report is based on review of the available technology and the actual hardening programs of various strategic aircraft. We conclude that a shielding approach similar to that developed for the B-1 is applicable at reasonable cost for all aircraft -- even those, such as the B-52, that have been in operation for many years.

In accordance with the charter of the Task Force, the report documents the work reported to the Defense Science Board on 5 October 1979. At that time, the B-52 Special Project Office (SPO) was in close agreement with the (so-called Team A+) approach recommended by the Task Force. Since then, however, the SPO, in accordance with direction from Headquarters, U.S. Air Force, has embarked on a test and analysis program with the hope that a hardening design could be found that would not be as costly and would not delay the deployment of hardened B-52Gs as cruise-missile carriers.

At the request of the DSB, the Task Force reconvened and met on 30 September and 1 October 1980 to review progress on the "test/fix" approach directed by Headquarters, U.S. Air Force. Although a day and a half is insufficient to critique the year's effort, it is our judgment that neither the testing nor the analysis provided a convincing basis to shift from an approach based on shielding to one based on hardened or protected critical components, the impressive (estimated) reduction in total cost notwithstanding.

One further observation seems in order. If the central conclusion of the Task Force is correct: viz., that EMP hardening can be provided by the recommended shielding approach, then it is time to develop a protocol for such hardening so that program offices can harden their aircraft in a broadly accepted manner and can anticipate in reasonable detail the acceptance and certification conditions that they must meet.

Although this effort has not been an easy one, we appreciated the opportunity to contribute to this aspect of national security and for the excellent support and courtesy so often extended to the Task Force by the many members of the defense community with whom we worked. Not the least of these, with respect to courtesy and guidance, was the Board itself.

[redacted]
Chairman
Task Force on Hardening
of Strategic Aircraft

Copy to:
Vice Chairman, DSB

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GLOSSARY OF ACRONYMS

AFWL	Air Force Weapons Laboratory
ALCM	Air Launched Cruise Missiles
ASD	Aeronautical System Division
BIT	Built In Test
CITS	Central Integrated Test System
CMC	Cruise Missile Carrier
CMCC	Common Mode Core Current
dB	decibel
DNA	Defense Nuclear Agency
DOD	Department of Defense
DSB	Defense Science Board
ECM	Electromagnetic Countermeasure
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMP	Electromagnetic Pulse
FFF	Form, Fit, and Function
HPD	Horizontally Polarized Dipole
JCS	Joint Chiefs of Staff
LRU	Line Replaceable Unit
MEE	Mission Essential Equipment
OAS/CMI	Offensive Avionics Suite/Cruise Missile Interface
PDF	Probability Density Function

RF	Radio Frequency
SPO	Special Project Office
TEM	Transverse Electromagnetic
TWA	Trailing Wire Antenna
USDRE	Under Secretary of Defense for Research and Engineering
VLF	Very Low Frequency
VPD	Vertically Polarized Dipole

(U) 1. INTRODUCTION

(U) The importance of insuring that military aircraft can survive and function in the electromagnetic (EM) environment created by nuclear explosions above the sensible atmosphere (the so-called electromagnetic pulse or EMP) was emphasized during the Defense Science Board (DSB) Summer Study of 1978, and accurately set forth in an 8 Jan 79 memorandum from Dr. William Perry, Under Secretary of Defense Research and Engineering (USDRE), to Dr. Eugene Fubini, Chairman of the DSB. In that memorandum, presented in this report as Appendix A, Dr. Perry identified "electromagnetic pulse susceptibility as one of the dominant problems facing bombers", and noted the "essential role of aircraft in assuring communications with the SLBMs and ICBMs".* He concluded that "the ability of U.S. aircraft to survive EMP is crucial to the successful application of the entire Triad".

(U) Dr. Perry recognized the difficulty in achieving this goal; his memorandum specifically cited the complications induced "by the diversity of models within a single aircraft designation, and by the tendency to create military aircraft systems from aircraft which were designed for other purposes". Other complications could have been noted: our inability to predict the impact of EMP on sensitive electronics is not a result of a lack of fundamental understanding of the phenomena, but rather of the sheer electrical complexity of military aircraft. Further, one would think that

(U) * Throughout the report each acronym is defined when it is first presented. All acronyms are collected and defined in a glossary. The only (known) exception to this format is made with regard to "SLBMs and ICBMs," U.S. and USSR.

such difficulties in analysis could be circumvented by testing, but the absence of an adequate physical simulator of EMP, the difficulties and expense of instrumenting aircraft in such a simulator, and the ambiguities and contentiousness in interpreting the results have all contributed to the present malaise. But the greatest contributor of all has been postponement, induced by the hope that the old aircraft, that are difficult to harden, would soon be replaced by new aircraft designed to withstand EMP from the moment of conception.

(U) The role of the B-52G as a Cruise Missile Carrier (CMC) offers an excellent, but by no means only, example. The basic design of the B-52 preceded an appreciation of EMP, and programs to provide hardening of the later models were easily postponed by anticipation of the (EMP hardened) B-1. Today, as a result of cancellation of the B-1, the country faces a difficult decision on the B-52 CMC: should the period of time, during which confidence in the EMP survivability is low, be minimized by a fast-paced, parallel, and thereby expensive hardening program, or should an extended period of potential vulnerability be accepted in return for a less expensive, serial program of design, prototype installation, test, modification, redesign, and eventual installation of hardening kits? <u>This report cannot and does not address the question of acceptance of an extended period of strategic vulnerability, but it does attempt to provide the technical background that is necessary for such a decision, and if the decision is to proceed rapidly, the report recommends a program that attempts to provide the balanced approach that Dr. Perry requested in his memorandum to the DSB.</u>*

* It should be noted that [redacted] of R&D Associates is in disagreement with this report. His comments are in Appendix C of this report.

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(U) In accordance with this approach, the report is tutorial in style; it deals first with the state of the art of EMP analysis, hardening, and test (or simulation). Then, with unaccustomed modesty, worrisome points are presented that undermine our confidence in mastering the complexities of EMP hardening and diminish our ability to recommend unequivocal programs. Although USDRE cited nine aircraft for consideration, and although we reviewed all but two and added the EC-135, we have, with his approval, reported on only three: B-1, E-4B (airborne command post), and B-52 CMC.*

(U) The composition of the Task Force deserves special attention. Probably because the data are sparse, the field complex, and the payoff obscure (except in the event of nuclear war), the EMP community is small and highly critical of the much larger community that builds strategic aircraft. In order to insure full debate and reasoned decisions in the face of large uncertainty, the membership of the Task Force was leavened with men of proven judgment from the aircraft industry. (See Table 1.) This proved to be a felicitious choice: the need for a balanced view of the conflicting and often confusing aspects of EMP hardening of aircraft was evident in meeting after meeting. It certainly must be the judgment of all, that the members of the Task Force devoted unstintingly many hours to this complicated undertaking.

(U) * It should be noted that a briefing was provided to the DSB on 5 Oct 79 and to Dr. Perry in accordance with his request for "a final report by September 1979". The delay in providing a written report was dictated by USDRE's request that the (slightly revised) Task Force first examine the structural vulnerability of the B-52G to the blast, shock, and thermal radiation of nearby nuclear explosions.

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Table 1. MEMBERS OF THE TASK FORCE

[redacted] Chairman
Palmer-Smith Corporation

[redacted]
R&D Associates

[redacted]
R&D Associates

[redacted]
Defense Nuclear Agency

[redacted]
Rockwell International

RAdm. George Jesson, USN
Naval Air Systems Command

[redacted]
Intell Corporation

[redacted]
Office, Under Secretary of Defense
for Research and Engineering

[redacted]
Defense Nuclear Agency

[redacted]
Lawrence Livermore Laboratory

MGen. Jasper A. Welch, Jr., USAF
National Security Council

USAF 5 U.S.C. § 552(b)(6)

(U) There are many who deserve the thanks of the Task Force. Primary among these are the directors and staffs of the specific program offices -- particularly [redacted] To these, to their hard working and loyal staffs, and to the many others who have assisted (and educated) the Task Force, we extend our thanks and the sincere hope that they will be successful in producing a survivable fleet of strategic aircraft -- whether or not they implement all the recommendations contained herein.

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[redacted] 2. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS (U)

[redacted] 2.1 Uncertainty as the Major Factor (U)

(U) The effect of EMP on strategic aircraft is a field marred by uncertainty. The phenomenon itself was subjected to only rudimentary testing immediately prior to the Atmospheric Test Ban of 1963, and controversy still reigns regarding the free-field EM environment created by a high altitude nuclear explosion. Nonetheless, the Task Force accepted the preponderant view of the technologists in the field and proceeded on the basis that the free-field was predictable.

[redacted] The primary uncertainty is caused by (1) the complexity of coupling of the EM field to the maze of wires, cables, hydraulic lines, and antennae that mark any strategic aircraft and (2) the complexity of predicting the damage to key electronic equipment even if the voltage and current inputs to these equipments are fully known. On the other hand, electronic upset is not a prime consideration. Unlike missiles, which fly only once, release large amounts of energy under highly automated conditions in short periods of time, and where any unanticipated electronic upset often aborts the mission, manned aircraft can react more slowly and be flown routinely in the face of heavy electromagnetic interference and lightning. Hence, it is our judgment that uncertainty in the generation of the EM field and electronic upset are secondary considerations; the primary uncertainties are the coupling of the EM energy to the aircraft system and subsequent damage of key electronic equipments. Furthermore, we conclude that the predictability is not likely to improve at anything other than a slow but steady rate.

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[redacted]

(U) Overlying these phenomenological uncertainties is a hierarchy of ensembles. For example, no one B-52 is the electrical twin of any other B-52, there are many conditions that describe the state of any particular B-52 (flaps up, gear down, etc.), and the Line-Replaceable Units (LRU) (including the components within the LRUs) have been purchased from a variety of vendors and maintained in a variety of ways. In short, no one analysis or test of a strategic aircraft is (electromagnetically) representative of a fleet of such aircraft.

[redacted] The uncertainties have not been reduced by less than threat-level simulation which usually produced no damage, a limited number of "anomalies," and a goodly amount of contentiousness between the associated Special Project Office (SPO) and the so-called EMP community. Nor has a review of the Soviet approach shed much light. The USSR conducted a more extensive set of high altitude nuclear explosions, but has not built any large scale simulators. [redacted] reasonable and sensible.

USAF 3.3(b)(4) 1.4(a),(g)

[redacted] In the world of engineering, uncertainty does not preclude construction; it simply requires a margin of safety greater than the uncertainty. [redacted]

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USAF 3.3(b)(4) 1.4(a),(g)

[redacted]

OSD 3.3(b)(8)

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

(S) 2.2 The Preferred Approach: Shield and Test (U) OSD 3.3(b)(8)

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

(U) 2.3 The B-1

(U) The B-1 was designed and built to be hard to EMP. It appears to us that it has achieved its goal at an incremental cost of less than two percent, but it must be tested. Therefore, we recommend that the B-1 be subjected to a Trestle test in the near future. [redacted]

USAF 3.3(b)(4)
1.4(a),(g)

(The information on this page is [redacted].)

[redacted]

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

[redacted]

[redacted] 2.4 <u>The E-4B</u> (U)

USAF 3.3(b)(4), 1.4(a),(g)

[redacted]

[redacted] 2.5 <u>The B-52G CMC</u> (U)

[redacted] The essense of the decision regarding EMP hardening of the B-52G for its mission as a CMC is a trade-off between time and money. If time were not critical, a minimal hardening design, incorporating the Air Launched Cruise Missile (ALCM) and Offensive Avionics Suite/Cruise Missile Interface (OAS/CMI) electronics could be built and tested at threat level. Modifications and further testing would presumably follow leading to a hardened fleet at minimal cost, but 1982, the year the President would like to begin deploying a survivable CMC fleet, would have long since past.

[redacted] (See Table 5.) Under this program, USAF 3.3(b)(4) 1.4(a),(g)

hardening kits, [redacted] would be available at almost the same time as OAS/CMI. The program meets many -- but not all -- of the guidelines presented in [redacted]

USAF 3.3(b)(4), 1.4(a),(g)

(S) A second alternative was also instigated by the Task Force and developed under the leadership of personnel of the Air Force Weapons Laboratory (AFWL). [redacted] Although the Task Force admired the creative engineering associated with the design and, indeed, has recommended that some of these concepts be incorporated into the lower-confidence design developed by the SPO, the majority of the members consider the cost and the design to be excessive; i.e., the approach is not cost-effective.

OSD 3.3(b)(8)

(U) 2.6 General Recommendations

(U) Without doubt, the best path towards obtaining high confidence that strategic aircraft are hardened to EMP is to provide a well instrumented, large volume, threat-level, EMP simulator that includes a means to inject the appropriate currents associated with a TWA. Trestle was designed and built by AFWL with these goals in mind, but it has not yet succeeded: the fields are less than threat level, the instrumentation is sparse, and there is no TWA pulser. The Task Force recommends most forcefully that additional funding on the order of $10 million be provided to complete the Trestle task as soon as possible.

(U) It is the judgment of most members of the Task Force that more reliance should be placed on injection testing of the LRUs. However, the input waveforms should be consistent with parameters of components that can be fully monitored during production; i.e., testing should be aimed at the rated rather than damage levels of the electronics. Such testing could then become a part of routine maintenance.

(U) The impact of new technologies that are being introduced into the aircraft industry are reviewed briefly in Section 6, "Trends: Good and Bad." Of these, fiber optics deserves special attention. [redacted]

USAF 3.3(b)(4)
1.4(a),(g)

(U) 2.7 Conclusion

(U) Despite the uncertainties and controversy that are associated with the effect of EMP on aircraft, it is our opinion that the problem is tractable.

It is certainly so with regard to new aircraft as (probably) demonstrated by the B-1, [redacted] It seems to us that the forthcoming experience with the B-52, whether a program minimizing time or cost is chosen, will show that shielding is feasible and -- given suitable improvements in Trestle -- demonstrable. It is our opinion that the nemesis of EMP will not long exist once there are adequate threat-level data to replace the present controversies steeped in untested analyses and extrapolated data.

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1.4(a),(g)

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(The information on this page is UNCLASSIFIED.)

[redacted]

[redacted] 3. THE STATE OF THE ART: Analysis and Test (U)

(U) Art it is! Prediction of the effects of EMP on aircraft certainly cannot be described as science; there is far too much that is subjective, uncertain, and untested. As a result, it is fruitful to review certain aspects of the problem from a general perspective before proceeding to specific considerations regarding the strategic aircraft of prime interest today. Analysis and test are reviewed in the various subsections below; hardening techniques, areas of concern, and the impact of technological trends are covered in later sections.

(U) 3.1 Prediction of the Free Field Environment

(U) Despite the limited amount of data obtained during high altitude nuclear tests conducted prior to the signing of the 1963 Atmospheric Test Ban, our review -- and the review of many other groups -- concludes that the ability to predict the free-field environment of EMP generated by a nuclear explosion above the sensible atmosphere is sufficient for the problem at hand.*

(U) 3.2 EMP Criterion

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(U) Using the theoretical models developed by [redacted] and others, the Air Force derived a criterion for the free-field environment to which aircraft (and other equipment) might be exposed. [redacted]

USAF 3.3(b)(4), 1.4(a)(g)

(U)* The Task Force had the benefit of direct discussions on this subject with [redacted] whose invited paper, "On the Electromagnetic Pulse produced by Nuclear Explosions," (IEEE AP-26 1978) provides a convincing background for our conclusion.

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USAF 3.3(b)(4)
1.4(a)(g)

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[redacted] Because the criterion are composites, there is necessarily more energy implied by any criterion than would be radiated in any given nuclear explosion. Hence, threat-level EMP simulators, designed to meet the criteria, necessarily create an energy fluence greater than that seen by an aircraft exposed to the EMP generated by a real weapon. As will be seen, this is more a virtue than a failing, and even if any particular aircraft responded to the entire frequency spectrum, which is highly unlikely, the "overstress" is less than a factor of six. There has been considerable controversy in the past with regard to this "overstress," and it is our conclusion that such controversy is, at best, a secondary consideration.

[redacted] 3.3 EMP Coupling to the Aircraft (U)

(U) There are many paths by which energy contained in the transient electromagnetic field is transmitted to damageable electronics. At resonant frequencies, large skin currents are induced on the hull and on various antennae and structures that penetrate the hull. Those aircraft that have a VLF (Very Low Frequency) TWA will also be subjected to low frequency skin currents associated with the shorting of the TWA to the hull. Despite impressive funding over many years and under a variety of programs, prediction of the resultant voltage and current waveforms on any particular conductor is not precise. While reasonable support should lead to steady progress in analytical accuracy, the Task Force concludes that it is unlikely that crash funding will increase the pace appreciably.

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[redacted] USAF 3.3(b)(4)
1.4(a),(g)

[redacted]

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(U) Our ability to predict the electrical waveform at any particular pin is further compounded by the variety of (a) flight conditions (landing gear, flaps, etc.), (b) orientations of the aircraft relative to the propagation of the EMP, (c) unique electrical configurations of each aircraft, and (d) states that can characterize the electrical equipment at the time of an EMP. We conclude that a sophisticated approach, such as that taken in the design of nuclear weapons, cannot be used here; i.e., carefully designing close to the margin, verifying by limited testing, and extrapolating to conditions other than the test case by extensive computer modeling will not work when applied to EMP survivability of aircraft. Rather, verification of a large margin of safety is required.

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[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

[redacted]

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1.4(a)(g)

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[redacted]

[redacted]

USAF 3.3(b)(4) 1.4(a),(g)

(U) Appropriate testing of the ensemble of components presents practical problems. Subjecting a component to an electrical waveform considerably outside its designed range of performance is not an accepted industrial practice. Hence, either procurement of tested components must be done from a "captive" line which is both expensive and, in today's environment, unlikely because of high commercial demand for electronic components, or lots must be procured by the Department of Defense (DOD) without specification as to damage and tested to see which, if any, can meet the unique specifications. Presumably, those lots that pass can be "tagged" and used under the tight inventory control noted above. When the lot is exhausted the procedure will, of course, have to be repeated.

(U) There is a better way, and that is to specify whatever (industry says) can be specified and to test those specifications at the 100% level during production. Whereas, industrial testing to levels that cause damage is unacceptable, testing to conditions within the design range -- which can be considerably above the operating range -- is acceptable to industry. In this approach, components would have to be protected (in a manner to be discussed later) to some level, but that level need not be the operating level. In other words, the critical, low-energy tail of the PDF for damage can be truncated at a rated level which can be well above the operating level.* As a result we recommend that this approach be studied with a view towards incorporation in the procurement process and that so-called "zap-testing" of the LRU pins at the rated level be studied as a part of routine maintenance.

*See Figure 5, which attempts to present this point in a schematic manner.

[redacted]

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

Figure 5. Typical coupling/damage convolution of probability density functions (PDF). Note that the functions can be truncated according to a variety of criteria. (U)

(U) 3.5 <u>Upset of the LRU</u> USAF 3.3(b)(4) 1.4(a),(g)

(U) EMP induced waveforms that are of sufficient strength to damage an LRU, are also of sufficient strength to confuse those LRUs that receive, transmit, or create EM control signals. Hence, those hardening techniques that reduce the EMP waveforms only to rated or operating levels of "confusable" LRUs may not be acceptable because of upset. This particular area of EMP vulnerability is even more complex than damage of key electronics.

(U) [redacted] Strategic missiles are not flown routinely, and when they are, they release large amounts of energy in extremely short periods of time and under highly automated conditions. They are and must be intolerant of any unanticipated changes in electronic state or logic. Compared to missiles, manned aircraft can react slowly and are highly adaptive to unanticipated electronic conditions. Airplanes -- and their crews -- operate routinely in the presence of electrical waveforms that are often at the signal level and occasionally a factor of ten higher than the signal levels;* i.e., aircraft must and do operate successfully in the day-to-day environment of EMI. Although one can neither calculate nor simulate the exact nature of all possible EMP induced waveforms -- nor, indeed, predict with high confidence the possible confusion of electronic states resulting from such waveforms --

USAF 5 U.S.C. §552(b)(6)

(U) * The Task Force is indebted to [redacted] of the Aeronautical Systems Division (ASD) for providing this information.

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it does appear that EMP induced upset, [redacted]

(U) The correct way to handle upset -- given that damage is not a problem -- is to design those electronics that can be upset in a manner that allows them to reacquire whatever data base is necessary and to restart whatever procedure was in operation at the time of the upset. Because of EMI, such design is often -- but not always -- the case. In future strategic aircraft, of course, such design should be routine, as it is with [redacted]

(U) It appears to us that the prudent path is to insure that damage is not a problem, to analyze and (injection) test those LRUs where upset could be a problem, to take whatever remedial steps are necessary in those cases where upset is a problem, and finally to emphasize functional tests of such LRUs during EMP simulation. It is too early to conclude that upsettable LRUs should be protected to the point where EMP induced waveforms are in the "noise" which is considerably below the EMI.

[redacted] 3.6 Simulation of EMP (U)

[redacted]

USAF 3.3(b)(4)
1.4 (a),(g)

[redacted]

(U) It should not be concluded that successful operation of Trestle (synchronized with a TWA pulser) is a panacea. Trestle is expensive to operate and can provide only limited data.** If it can perform as advertised,

(U) * [redacted]

(U) ** Preliminary estimates suggest that Trestle will cost $100K/day to operate and that less than 1000 useful measurements per day will be taken.

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Trestle should be able to substantiate that a calculated safety margin has been achieved, but it cannot provide the near-continuous testing that would be required to validate a test-fix-test approach, nor can Trestle serve as a surrogate for more accurate modelling. Although there is no basis for assuming that analysis can soon reduce our heavy reliance on threat level simulators, there is also no reason to continue to rely as heavily on such simulators as we must today. Rather, steady progress in analysis, coupled with direct comparison with a variety of simulators, is necessary to reduce our present dependence on Trestle.

(U) 3.7 Lightning as a Simulator of EMP

(U) Until recently, it had been presumed that the frequency content of the EM field created by near-by lightning strikes was considerably less than that associated with EMP. That presumption is now being questioned; it appears that the instruments employed for measurement of lightning induced fields were incapable of recording the high frequency content. In a recent paper, data by [redacted] et al,* suggests that lightning "return strokes" within 100 m of an aircraft would induce 10^5 V/m fields in the 1-10 MHz regime. While the Task Force is not recommending that strategic aircraft be routinely flown through thunderstorms, it does recommend that DOD investigate

OSD 5 U.S.C. § 552 (b)(6)

(U) * [redacted] "A case for submicrosecond rise-time lightning current pulses for use in aircraft induced-coupling studies," IEEE Symposium, San Diego, CA, October, 1979. The Task Force is (again) indebted to [redacted] of ASD for bringing this paper to our attention.

feasibility and usefulness of providing on some strategic aircraft on-board instrumentation that could record the EM field imposed upon the aircraft as a result of a nearby lightning strike. Performance of critical LRUs in the face of such an unannounced EMP test should provide a useful indicator of sensitivity -- or the lack of it -- to EMP.

(U) 3.8 Summary of Analysis and Test

(U) The discussion in this section attempted to emphasize the accuracy -- or the lack of it -- with which one can predict and test the likelihood of damage from EMP to an aircraft which had been built or designed without particular attention to EMP hardening. The central conclusion is that there is major uncertainty in such predictions and that it resides (and will continue to reside) primarily in the apriori calculation of the induced voltage and current waveforms at the input to critical LRUs. There is also significant uncertainty in the calculation of damage, but there are means to circumvent this problem provided tight inventory control in the field is feasible. As a result, it appears to us that aircraft should be hardened to EMP by providing a safety margin that encompasses the range of uncertainty with respect to damage and verifies that safety margin by limited testing at threat level. Upset induced by EMP will continue to be a problem, but given sensible design, analysis, test, and routine operation in the face of EMI, it is judged to be a secondary consideration with regard to EMP hardening of aircraft -- as opposed to missiles.

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[redacted] 4. STATE OF THE ART: HARDENING (U)

[redacted] There are three approaches to hardening aircraft to the effects of EMP which may be termed: components, shields, and adaptations. These are portrayed in Fig. 7 as a three dimensional space in which specific techniques associated with each approach are specified. Although each aircraft that we have examined uses a number of these techniques, each has tended to emphasize one technique as primary, [redacted] Unfortunately, that day appears to be far off. USAF 3.3(b)(4) 1.4(a),(g)

[redacted]

OSD 3.3(b)(4)

OSD 3.3(b)(8)

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

 OSD 3.3(b)(8)

[redacted]

(U) There are of necessity many penetrations of the hull. Each of these must be appropriately treated and maintained; [redacted]

USAF 3.3(b)(4) 1.4(a),(g)

[redacted]

OSD 3.3(b)(8)

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

(U) 4.3 Adaptations: Mission Essential Equipment (MEE)

(U) Some electronic systems are more important than others; therefore (the logic goes), only equipment that is essential to the strategic mission should be protected or hardened. While there is no faulting the logic, its detailed implementation can be contentious. It appears to us that if the definition of MEE is a necessary part of EMP survivability on specified strategic missions, then crews must have the opportunity to train for those missions using only MEE. To our knowledge, such training has not been provided.

(U) 4.4 Adaptations: Workarounds

(U) As noted in an earlier section, missiles and aircraft need not be hardened to EMP in the same manner: the adaptability of the crew to a

(U) * While such a system would provide continuous or at least periodic fault detection, it would not necessarily provide fault isolation; i.e., actual maintenance might be a significant problem.

malfunction induced by EMP is an advantage enjoyed by manned aircraft, but the extent of the advantage is difficult to quantify -- especially if there are no training programs to test and insure that the adaptivity can meet the challenge of a (perhaps unanticipated) malfunction or set of malfunctions.* It seems to us that "workarounds" are a court of last resort; they cannot be the primary means to insure that a critical strategic mission is completed on schedule.

(U) 4.5 Adaptations: Circumvention, Reset, and Automatic Error Correction

(U) Some components of strategic missiles are protected from EMP by circumvention; i.e., the nuclear event is detected quickly and the equipment is isolated before damage can occur. It is a technically demanding task, and one that has not been attempted with respect to aircraft. The Task Force concurs with this pragmatic judgment.

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

(U) * The willingness of experienced crewmen to rely on "workarounds" is understandable: it is an unfortunate fact that "boxes fail all the time," and indeed they do, but they usually fail one at a time, and the crews have learned which ones fail and how to operate when they do. However, there need not be any correlation between those LRUs with a short MTBF and those susceptible to EMP. Furthermore, the crews are not experienced with simultaneous failure of a number of critical LRUs, and on some strategic missions, time is of the essence. The requirement for near instantaneous relay of messages via UHF on the EC-135 PACCS provides a suitable example.

(U) Automatic error correction, as it relates to EMP, is simply a more sophisticated version of reset: any confusion in the transmission of digital data during the pulse or afterwards can be recognized by a variety of means and corrected -- or rejected with a request for retransmission and/or reset. such techniques will become more prevalent as modern aircraft rely more heavily on digital control of equipment. This trend need not have adverse effects with regard to EMP survival -- as suggested by preliminary EMP simulations on the F-16, the military's first "fly-by-wire" aircraft.

(U) 4.6 <u>Components: Hardening and/or Protection</u>

(U) Some electronic components are better able to withstand unanticipated electrical waveforms than others, thereby suggesting that hardening LRUs to the effects of EMP could be accomplished merely by selecting such components and subjecting them to appropriate analysis and test -- as discussed in the previous section. For the reasons given in that section, reliance on hard components strikes us as a difficult and potentially risky approach to providing survivability to EMP. Protection to the design range of the sensitive components is preferred.

(U) 4.7 <u>Summary of Hardening</u>

(U) Although each type of aircraft should adopt an approach to EMP hardening that is most appropriate to its design and missions, we have attempted in Table 2 below to state general guidelines for hardening based on our review of a variety of aircraft.

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

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[redacted]

[redacted] 5. STATE OF THE ART: WORRISOME POINTS (U)

(U) The range in suspected vulnerability of the strategic aircraft is truly monumental. Some have proclaimed that "our planes are going to fall out of the sky" while others state that "there is no real trouble."* Although the Task Force is convinced that the effect is real and that the need to hardened strategic aircraft is urgent, there can be no denying that there are worrisome points that must be considered before committing large resources to the task. The wide range of opinion is probably a direct result of two effects: insufficient threat-level testing and enormous growth in the use of sensitive micro-electronics. The major worrisome points are directly tied to these effects.

[redacted] 5.1 No Smoke - Many Anomalies (U)

[redacted] There has been no definitive demonstration of catastrophic vulnerability of aircraft to EMP. To be sure, there have been few tests that could be described as threat-level, and there have been many anomalies. As shown in Table 3, thirteen, near-threat-level, EMP simulations that could be related to aircraft have been conducted; four by AFWL and nine under the aegis of the associated SPO. Final reports, when available, lack definitiveness because of disagreement between various authorities as to what was an EMP "anomaly" and what was a "routine failure;" i.e., one not associated with EMP.

(U) * Personal communication to the chairman from [redacted]

OSD
5 U.S.C. § 552 (b)(6)

USAF 3.3(b)(4)
1.4(a),(g)

[redacted]

OSD 3.3(b)(8)

[redacted] The recent B-52/Trestle measurements have provided the Task Force with an up-to-date, first-hand view of the situation: the simulator did not perform at threat level, the instrumentation was limited to integral B-52 equipment, and a number of "anomalies" occurred.* It would appear that a well-instrumented, large, threat-level simulator is badly needed, but that leads to the second worrisome point.

[redacted] 5.2 <u>Where is the Soviet Trestle?</u>

[redacted] In 1961, the USSR conducted an extensive, well prepared series of high-altitude, nuclear explosions. As shown in a memorandum prepared by Col. Fortin at the chairman's request and attached to this report as Appendix B, we have good reason to suspect that the Soviets were aware of the phenomenon of EMP before initiation of the test series. Hence, we have reason to assume that the Soviets have an equal or better knowledge of EMP generation and coupling than we do; i.e., nothing improves theoretical analysis better than definitive data. Yet, we are rather certain that <u>the USSR has not constructed the well-instrumented, large, threat-level simulator that we think is so critical and so urgent!</u> The popular answer to this dilemma rests on the assumption that the Soviets have not incorporated sensitive micro-electronics

(U) * To be complete, it must be noted that the prime purpose of the test was to check-out Trestle; the B-52G was used as a test bed for the simulator. On the other hand, the absence of damage or upset directly attributable to EMP seems to have influenced Air Force decisions regarding funding to harden the B-52 to EMP.

into their aircraft* to the extent that the US has. Supposedly, when they do, they, too, will build a Trestle. The Task Force judges the popular answer to be unconvincing, but we have no better answer. We can only note the worrisome observation, and proceed to draw conclusions and make recommendations with regard to certain specific aircraft on the basis that the US community understands the phenomenon -- no matter what the state of knowledge or motivation is in the USSR.

[redacted]

USAF 3.3(b)(6)

(U) 6. TRENDS: GOOD AND BAD

(U) New technologies are continually being introduced into the military aircraft industry. Some will reduce the vulnerability of modern aircraft to EMP; others could increase the difficulties.

(U) Signal conditioning and transmission should be quite different in new military aircraft. New techniques were initiated in the F-16 design where digital signals -- rather than cables and hydraulic lines -- were employed to activate equipment located throughout the aircraft. [redacted]

USAF 3.3(b)(4) 1.4(a),(g)

(U) The trend toward increasing micro-miniaturization of electronic components, while offering greater redundancy and the capability to recognize and correct errors, also increases the vulnerability to EMP induced damage by virtue of requiring less power to destroy critical circuits. This problem, of course, is moot if fiber optics are used for the transmission of signals.

(U) In order to increase performance, it is apparent that designs are being developed within the aircraft industry that rely on computer driven controls to stabilize aerodynamically unstable conditions. Hence, the impact of EMP induced upset could be increasing at the same time that the probability of such upset is decreasing. The proper answer probably rests in careful design that emphasizes redundancy and, as noted above, the use of fiber optics.

(U) The same drive towards better performance is replacing metallic structures with (non-conducting) composites; thereby, reducing the inherent EMP shielding offered by the aircraft itself. This will increase the attention that must be paid to rack and cable shielding, but the use of composites need not be incompatible with EMP hardening.

(The information on this page is [redacted])

[redacted]

[redacted] 7. CONCLUSIONS AND RECOMMENDATIONS REGARDING THE B-1 (U) USAF 3.3(b)(4) 1.4(a),(g)

[redacted] but it must be tested. Therefore, <u>the Task Force recommends that the B-1 be subjected to a Trestle test in the near future</u>. This test need not be exhaustive, but it should provide a proof-of-principle; i.e., we envision an expenditure of 2 M$ and a month's testing.

(U) Until such time when fiber optics have been qualified for transmission of signals in military aircraft, it is our opinion that the approach taken by the B-1 should be applied to all new military aircraft. That approach, with the exceptions noted below, follows the guidelines set forth in Section 4.7. The exceptions are a result of insufficient time and funding -- not of intent. They are:

1. crews have not been trained to operate with only mission essential equipment,
2. the ability to monitor the integrity of the shield has been favorably considered, but not designed, and
3. as noted in the above paragraph, the B-1 has not been subjected to a threat-level test.

In accordance with these exceptions, we recommend that in addition to a Trestle test, crews attempt to operate the airplane using MEE only and that funding be provided to augment the CITS to include monitoring of shield integrity.*

(U) * We estimate the R&D cost at less than $5M.

[redacted]

(U) We have examined incremental weights, costs, and delays associated with hardening a new aircraft using the recommended approach. Whether one focuses on production or on operating and maintenance costs; on reductions in payload weight or increases in gross weight; on design, production, maintenance or flight test delays; the incremental penalty is always less than two percent -- assuming the procurement of 100 aircraft. Because we have reasonable confidence in these estimates and because the two-percent increment is so small and the costs (in more than money) to harden to EMP after production is so high, we recommend that this approach be applied to the procurement of all new military aircraft.*

[redacted] but there is no better way.

USAF 3.3(b)(4) 1.4(a),(g) OSD 3.3(b)(8)

(U) * This leaves unanswered the question of hardening new, commerical airplanes procured for military use. While it is possible that these designs could be modified to implement the recommended approach, it is unlikely that the modification could be conducted within the two-percent bound achieved by the B-1 SPO.

[redacted] 8. CONCLUSIONS AND RECOMMENDATIONS REGARDING THE E-4B (U)

USAF 3.3(b)(4)
1.4(a),(g)

[redacted]

(U) Prior to the test, an extensive effort was made to predict the electrical waveforms that would be induced on various pins, which were selected to insure coverage of all categories, or because of their critical role in mission essential equipment, or because particularly small safety margins were anticipated. Random selection was attempted only as a final sorting; construction of a control group by total reliance on random selection of pins proved to be impractical. [redacted]

USAF 3.3(b)(4)
1.4(a),(g)

OSD 3.3(b)(8)

[redacted]

*The low frequency effects of the TWA are discussed separately below.

 OSD 3.3(b)(8)

(U) [redacted]

[redacted] [redacted]

USAF 3.3(b)(4)
1.4(a),(g)

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

(U) **"The best is the enemy of the good" (Voltaire).

[redacted] 9. CONCLUSIONS AND RECOMMENDATIONS REGARDING THE B-52 AS A CRUISE MISSILE CARRIER (CMC) (U)

(U) The B-52 CMC should be viewed in three parts: the cruise missile, the new electronics required for the cruise missile (Offensive Avionics Suite/Cruise Missile Interface or OAS/CMI), and the aircraft itself. Although each is treated separately below, it must be recognized that the response of the system to EMP is collective, and as a result the maintenance of a proper EM interface between the subsystems is critical.

(U) 9.1 <u>Hardening the ALCM</u>

(U) The Task Force cannot comment in any depth on the EMP hardening of the missile, which was in source selection throughout our deliberations. We can make the observation that EMP vulnerability was recognized and that the missile's size and aerodynamic requirements should lend themselves to an EMP hard design -- provided the electronic interface is suitably designed and maintained.

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

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[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

SECRET

USAF 3.3(b)(4)
1.4(a),(g)

[redacted]

OSD 3.3(b)(4)

(U) * At the interface between OAS/CMI and the B-52 electrical system, pigtails are allowed, although their impact on EMP induced transients must be analyzed.

(U) [redacted]

OSD 3.3(b)(4)

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

(U) 9.3 Hardening the Aircraft

(U) Essentially no consideration was given to hardening the B-52 G or H until the decision to cancel the B-1 program. It was clear then that the B-52 would have to be hardened to EMP if the President's decision to field the B-52G as a survivable CMC by 1982 was to become a reality. At the same time, stringent budgetary conditions existed within the Air Force for a variety of reasons, and our initial review suggested that the hardening program was driven more by fiscal than technical considerations. Our views of this situation were presented within the Air Force during the summer of 1979, and the decision was made to defer judgment on the (allegedly fiscally restrained) approach and to develop two more forceful approaches to hardening the aircraft. One approach, Team B, was headed by personnel of AFWL, while the other, Team A, was directed by the B-52 SPO. The Task Force has reviewed both and our conclusions and recommendations regarding them are given sequentially below.

(U) 9.4 [redacted] OSD 3.3(b)(4)

(S) The six-week study developed a high confidence approach to EMP hardening of the B-52. [redacted]

(S) [redacted]

USAF 3.3(b)(4)
1.4(a),(g)

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[redacted]

would survive the EMP environment. The estimated cost is high ($2.6B), and most members of the Task Force judge that it could be significantly higher. The cost to provide a Trestle test of this design was estimated by the Study Team to cost 83M$ (in '79 dollars), but the Task Force thinks it is considerably higher.* Although the Task Force admired the creative engineering and the high morale of the team, it is our opinion that the approach represents too much of an overdesign, and we recommend against its implementation either in full or for a "full-up" Trestle test. [redacted]

USAF 3.3(b)(4)
1.4(a),(g)

OSD 3.3(b)(4)

*[redacted] estimates that the cost to take the proposed design to a Trestle test is $200M.

OSD
5 U.S.C. § 552 (b)(6)

[redacted]

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

[redacted] 9.5 [redacted]

[redacted] The philosophy of design for the study conducted by the B-52 SPO was:

[redacted]

(U) It is apparent that this approach cannot provide the same high degree of confidence as the former, nor is estimated to cost as much, and most agree that there is more confidence in the accuracy of the cost estimate. The estimated costs are presented in Table 5 as a function of year (in "then year dollars") for the same three options shown in the previous table.

(U) Comparison of the above philosophy to the guidelines presented in the previous section on hardening indicates that the Task Force is in general agreement with the Study Team with the following exceptions:

[redacted]

B-52 EMP HARDENING STUDY
COST DATA
(TY $ IN MILLIONS)

CONFIGURATION	FY79&PRIOR	80	81	82	83	84	85	86	TC	TOTAL
SHOOT & PENETRATE, ALL ECM										
B-52G										
R&D	5.1	18.2	53.3	46.1	52.8	32.1				207.6
PROD/INSTALL				263.6	181.4	192.8	181.1	124.5	133.9	1077.3
B-52H										
R&D			13.7	11.9	13.6	8.3				47.5
PROD/INSTALL				147.1	95.3	108.9	101.7	72.7	92.5	618.2
								TOTAL		1950.6
STAND OFF WITH AIR-TO-AIR ECM										
B-52G										
R&D	5.1	17.6	46.9	34.5	43.6	31.0				178.7
PROD/INSTALL				218.9	151.0	161.5	151.6	102.8	114.1	899.9
B-52H										
R&D			6.6	4.8	6.2	4.3				21.9
PROD/INSTALL				122.2	78.6	70.3	105.5	60.1	75.8	512.5
								TOTAL		1613.0
STAND OFF NO ECM										
B-52G										
R&D	5.1	17.6	29.3	20.4	30.5	27.5				130.4
PROD/INSTALL				120.6	66.2	72.1	65.6	44.6	46.9	415.0
B-52H										
R&D			5.4	3.6	6.6	5.1				19.7
PROD/INSTALL				67.3	34.8	40.1	37.0	26.0	31.5	236.7
								TOTAL		801.8

Table 5. SPO estimated costs to EMP harden the B-52G and B-52H in millions of (then-year) dollars. The configurations are the same as shown in Table 4. (U)

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[redacted]

[redacted]

[redacted]

USAF 3.3(b)(4)
1.4(a),(g)

[redacted]

[redacted] 9.6 Test - then Fix (U)

(U) It is our understanding that the Air Force has decided to postpone hardening the aircraft in order to provide six months of testing of a single B-52G (#207) on Trestle during 1980. Initiation of hardening kits would be postponed until a suitable and presumably less expensive design had been developed. In other words, this approach accepts a longer period of possible vulnerability to EMP in return for a larger data base upon which to develop a better design.

[redacted]

[redacted] Whether or not to accept a prolonged period of vulnerability is beyond the charter of the Task Force, and no one can deny that further testing of a B-52G on a threat-level simulator will give added insight into whatever design is adopted. But, there are potential disappointments in postponement:

1. The testing will be conducted on an aircraft that does not have the electronics associated with the Offensive Avionics System/Cruise Missile Interface (OAS/CMI). Hence, the most sensitive electronics will not be included. Furthermore, EMP induced effects are collective; the induced currents before and after installation of OAS/CMI could be considerably different. [redacted]

2. [redacted]

OSD 3.3(b)(4)

[redacted] the Task Force is of the opinion that this approach can only be described as "prayerful," and we recommend against it.*

USAF 3.3(b)(4) 1.4(a),(g)

[redacted] * Tacit support for this approach has been created by a recent test of a B-52G on the Trestle simulator during its checkout period. While no major malfunctions occured during this short test, no measurement of the margin of safety was obtained because no external instrumentation was used.

[redacted]

[redacted] This is not to say that the Task Force recommends against thorough testing prior to initiation of a hardening design. Indeed, this is precisely the way to approach the problem -- and it should have been approached in just this manner years ago. If time were not of the essense and if cost were the only consideration in producing a hardened fleet, the OAS/CMI would be installed on a few of the aircraft which would then be subjected to threat-level simulations in which the safety margin would be obtained under a variety of conditions. Any modifications required to obtain a satisfactory safety margin would then be implemented and installed at some convenient point in the B-52 CMC modification program. However, it is apparent that years would pass during this process and that during those years the CMC part of the Triad could be -- for all we would know -- vulnerable on a fleet-wide basis to EMP. Assuming that such an extended period of vulnerability is unacceptable, a design program should be implemented now -- not postponed on the basis of the initial shakedown test of a new simulator (which failed to provide threat-level fields) on a single aircraft provided with neither the modern electronics nor with external instrumentation.

[redacted] 9.7 Recommended Program (U)

[redacted] The Task Force recognizes that the B-52 appears to be becoming ever more expensive as its useful life is extended farther and farther. We recognize that there is a fourth option: do not harden the B-52 and seek a new cruise missile carrier, whether it be a version of the B-1, the C-X, or whatever. Such a recommendation would exceed our charter, but we cannot help but note that the EMP hardening in this case would be cheaper, simpler, and less contentious. But if the B-52 is to be hardened on a schedule reasonably

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USAF 3.3(b)(4)
1.4(a),(g)

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APPENDIX A. Terms of Reference

THE UNDER SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301

RESEARCH AND
ENGINEERING

5 JAN 1979

MEMORANDUM FOR THE CHAIRMAN, DEFENSE SCIENCE BOARD

SUBJECT: Defense Science Board Task Force on EMP Hardening of Aircraft

(U) The 1978 DSB Summer Study identified electromagnetic pulse susceptibility as one of the dominant problems facing bombers once they have accomplished base escape. Indeed, given the essential role of aircraft in assuring communications with the SLBMs and ICBMs, the ability of U.S. aircraft to survive EMP is crucial to the successful application of the entire TRIAD. While aircraft hardening programs exist for our major systems, threat level testing will not be available until the early 1980s, at which time systems like the B-52/ALCM will be so far along in development that problems uncovered in the testing might require expensive modifications and program delays for their resolution.

(U) Hardening aircraft systems against EMP is complicated by the diversity of models within a single aircraft designation, and by the tendency to create military aircraft systems from aircraft which were designed for other purposes. For the long term I am concerned that the possibility of developing a cruise missile or ICBM carrier from a cargo or commercial airframe may be compromised by the inability to achieve high confidence in survivability using practical testing procedures on a system which was not designed from the beginning for EMP hardness.

(U) In view of the issues raised by the Summer Study and those mentioned above, I request that the DSB form a task force to review the EMP hardening of strategic and tactical aircraft. Special emphasis should be placed on the strategic aircraft systems but as time permits, tactical aircraft in the following list should be examined:

C-130 TACAMO	E-3
F-111	E-4
KC-135	AWACS
B-1	F-16
CMCA and Air Mobile ICBM carrier	

(U) The task force should examine hardening and testing plans for each of the aircraft to establish compatibility with requirements, and adequacy of testing. It should determine whether the national effort in aircraft EMP hardening is well coordinated; whether there is a timely interchange of information and individual programs are benefiting from the overall effort; and whether a general and sound hardening methodology is developing. The task force should review the plans for EMP test facilities and determine if they are adequate for the job. In addition to these general issues, the task force should pay particular attention to the B-52/ALCM system to identify hardening risks.

(U) In preparing recommendations, the task force should aim for a balanced program such that the risks inherent in incomplete EMP testing and analysis are comparable to the varieties of other risks to which the system is subject.

(U) The task force should provide an interim report to my office by April 1979 and a final report by September 1979. It should pace its activities to insure timely input to the B-52/ALCM testing, scheduled for this summer.

(U) Dr. [redacted] has agreed to be the Chairman of this task force. My Deputy for Strategic and Space Systems, Dr. Seymour L. Zeiberg will be the sponsor for the task force. He will arrange for support as required. Dr. [redacted] of his staff will serve as Executive Secretary.

OSD
5 U.S.C. § 552 (b)(6)

William J. Perry

APPENDIX B

<u>Soviet Activities in NEMP Hardening</u>

HQ AFSC/DLW
July 1979

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SOVIET ACTIVITIES IN NEMP HARDENING

ABSTRACT

This paper discusses the issue, "Does the USSR have a planned program to protect their systems against the effects of Nuclear Electromagnetic Pulse (NEMP) Energy?" The answer to this question is a fundamental first step to determine the nuclear hardness of Soviet military electronics.

The approach is to layout the basics of any NEMP hardening program, then to analyze Soviet activities which could serve as indicators of a structured NEMP program, and finally to indicate any evidence of actual NEMP hardening in systems.

Finally, conclusions are drawn from the analysis. The information consolidated in this paper represents a consensus of the intelligence community agencies as reported in various official documents.

CONTENTS

SOVIET ACTIVITIES IN NEMP HARDENING

I. (U) Introduction

(U) Three basic methods exist for determining the hardness of Soviet military electronics to the effects of the nuclear electromagnetic pulse (NEMP) from a nuclear weapon. The first and most obvious method is to obtain Soviet military systems, study them thoroughly, and finally expose them to threat-level fields with a representative frequency content in a NEMP simulator. There are several difficulties inherent in this approach. The first is the difficulty, and in many cases the impossibility, of obtaining the latest operational systems. In addition, even if a system has been studied, tested, and found to be hard to NEMP, it is not always easy to decide whether hardening was deliberate or fortuitous. This limits the capability to estimate hardness levels for different and unavailable systems. Finally, even if after study a particular system has been found to be deliberately hardened, the ability to predict hardness levels of unavailable systems is severely limited without some knowledge of the overall Soviet state-of-the-art in NEMP hardening and some insight into the level of effort that they are expending on an NEMP hardening program.

(U) A second basic method is to collect intelligence (HUMINT, ELINT, and PHOTINT) on Soviet efforts to develop hardening techniques, on steps taken to harden specific systems, or on the development of NEMP simulators.

(U) A third method involves a very thorough study of the open technical literature for any indication of research directly related to NEMP hardening. Open-literature indications of Soviet state-of-the-art in NEMP hardening technology and level of effort as a function of time can hopefully be correlated with intelligence information and actual tests of operational systems to provide the best possible assessment of the NEMP hardness of Soviet military systems.

(U) Virtually all available data (open literature, HUMINT, ELINT, PHOTINT) related to Soviet NEMP hardening efforts has been examined and there is sufficient evidence indicating Soviet awareness of the NEMP threat. Soviet open technical NEMP literature and other intelligence data has been examined and there is some evidence of possible NEMP simulation efforts. Despite these indications no proof exists that the Soviets have taken comprehensive steps to harden a system.

CL[redacted]
RE[redacted]

II. (U) Nuclear Electromagnetic Pulse Hardening Program Characteristics

(U) In order to place Soviet NEMP efforts in perspective, it is necessary to outline the essential features of any NEMP hardening program.

A. (U) Awareness of the threat. An appreciation for the potentially destructive effects on electronics of NEMP can arise from data recorded in atmospheric or exoatmospheric nuclear tests, from theoretical calculations (perhaps stimulated by nuclear test data) or from a study of open literature. Without an appreciation of the potential threat to military electronics a comprehensive study of NEMP source physics, coupling modes, simulation, and hardening techniques will not occur.

B. (U) Understanding of the threat.

1. (U) Source theory - An understanding of the physical basis for generation of electromagnetic signals by surface, air and high altitude bursts is essential. This requires an understanding of the nature and time behavior of the nuclear gamma ray pulse which can only be obtained from people involved in weapons design or testing. It also requires a detailed study of Compton electron currents, air conductivity and the interdependence of electric field strength and air conductivity (so called self-consistent effects).

2. (U) Signal characteristics. Knowledge of the energy radiated as a function of frequency and distance is also important. In the US these values are calculated using computers more sophisticated than known to exist in the USSR.

C. (U) Coupling/Effects/Simulation into systems. A detailed knowledge of how free field electromagnetic energy couples into military systems is essential to assessment of the survivability/vulnerability of a system and to successful design and implementation of hardening techniques. Likewise, prior to any successful assessment program and implementation of EMP (electromagnetic pulse) hardening techniques, such as grounding, shielding, limiting devices, etc., a complete understanding of the effects of coupled electromagnetic energy on subsystems and components is required. In the U.S. this is not an exact science and our analysis capability can be off by as much as $\pm$ 25 db. Therefore, it is essential to expose systems/subsystems to the real or simulated environment to verify analysis and arrive at meaningful assessments.

D. (U) Availability of NEMP information. The U.S. NEMP program is highly visible. Information on the importance and the details of NEMP hardening is readily available. This reflects the open nature of U.S. society and the requirement to disseminate NEMP information widely enough to permit numerous U.S. firms to bid on contracts for military systems which have NEMP hardening specification. In the USSR there appears to be no such motivation for wide dissemination of NEMP hardening information.

III. [redacted] Soviet EMP Program (U)

A. [redacted] Awareness of the threat (U). Soviet awareness of the effects of nuclear weapons can be traced back to approximately the mid-1950s when A. S. Kompaneets of the Institute of Chemical Physics in Moscow translated Samuel Glasstone's book, The Effects of Nuclear Weapons. This book was reportedly very helpful in the organization of early Soviet weapon effects research.

1. (U) Since 1964 there has been a fairly steady flow of non-technical literature clearly reflecting Soviet awareness of the NEMP threat and their knowledge of hardening techniques. Many of these articles have appeared in Soviet military journals.

2. (U) Publications since 1964 clearly reflect Soviet awareness of the threat posed by NEMP from surface and near-surface nuclear bursts. The only high-altitude generation mechanism mentioned is the simple and classical "magnetic bubble" model which does not give rise to significant energy at frequencies in the megahertz range. The literature stresses that the signals have their largest amplitude for frequencies of 10 to 30 KHz, which is correct for surface and near surface bursts. Signals at these frequencies are easily detected at great distances from the burst point as a result of signal propagation in the earth ionosphere waveguide. In none of the articles reviewed is there any hint of an awareness of the magnitude of the prompt high-frequency (1-100 MHz) NEMP signal produced by a high altitude burst due to the Compton electron current turning in the geomagnetic field.

3. (U) The Soviets have carefully followed U.S. open literature on NEMP. A 1974 Soviet book is a collection of 15 U.S. NEMP papers translated into Russian and published by the Military Press, Ministry of Defense, USSR. In addition, Soviet technical papers refer to articles in Transactions of IEEE, the prime U.S. open literature source on NEMP.

4. (U) In 1974, I. L. Loginov of the Leningrad Electrotechnical Institute published a set of threat criteria for hardening shipboard electronics against nuclear weapon effects, including blast, thermal, and ionizing radiation and NEMP. The values given for electric fields as a function of yield and distance for a surface burst over water appear to be reasonable. The principal point is that the Soviets do have adequate threat criteria for NEMP hardening and have openly expressed an awareness of a need for such hardening.

B. (U) Understanding of the threat. One of the two groups in the USSR which has published technical papers relevant to the NEMP threat environment is associated with V. N. Krasilnikov who appears to be located at Leningrad State University. Their papers are abstract and academic in nature and dwell on the "magnetic bubble" model of high altitude EMP generation which predicts signals substantially below 1 MHz.

1. (U) In 1969, Krasilnikov published a form of the high frequency approximation first published openly in the U.S. in 1965. The importance of this approximation lies in the simplicity with which one can calculate the early time, high frequency (1-100 MHz) signal from a high altitude burst. There is no indication that the Soviets realized at this time the significance (i.e. the magnitude) of this early-time, signal.

2. (U) Krasilnikov's early papers as well as the overall flavor of his work suggest the possibility that he was in some way involved in the design of electromagnetic experiments which accompanied the Soviet 1961-1962 high altitude nuclear test series. These experiments may have included radar and radio propagation in the vicinity of a nuclear burst and remote detection of signals generated by or scattered from a nuclear fireball. The published work does not give any indication that this group is involved directly in NEMP hardening.

C. [redacted] The Medvedev/Stepanov Group (U)

1. (U) Yu. A. Medvedev and Boris Mikhailovich Stepanov and their associates have been involved in virtually every technical area essential to a NEMP hardening program. Stepanov is director of the All Union Scientific Research Institute of Optico-Physical Measurements (VNIIOFI) in Moscow. Medvedev is also associated with the Institute.

2. [redacted] Stepanov has been involved in the development of [redacted] OSD 3.3(b)( )

3. (U) Medvedev may have been involved in the Soviet 1961-62 atmospheric test series. Two of his early papers appear to be theoretical studies related to radar blackout or nuclear burst diagnostics.

4. (U) Since 1966, this group has produced a steady stream of papers which examine the physical basis of NEMP generation. Their work has progressed from very simplistic gamma ray source models and closed form analytical solutions to an interest in sophisticated source models and numerical solutions. They have examined the interdependence of the electric fields and the motion of Compton and secondary electrons and have used Monte Carlo techniques to calculate Compton electron currents.

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Chief, Records & Declass Div, WHS
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[redacted]

5. [redacted] The group examined MHD (magneto-hydrodynamics) EMP phenomena in a series of publications beginning in 1967. It was not until the early 1970's that MHD EMP was examined in the U.S. as a potential threat to long distance cable communication systems.

6. (U) In 1974, the Medvedev/Stepanov group submitted a paper which presented a version of the "high frequency approximation" first published openly in the U.S. in 1965. This model is still the basis for much of the high altitude EMP prediction capability in the U.S. With the exception of Krasilnikov's 1969 paper, no indication has been found that the Soviets were aware of the early time, high-frequency spike prior to 1974. Even Krasilnikov's paper does not clearly indicate an awareness of its importance.

7. (U) The Medvedev/Stepanov group has calculated the time dependent gamma ray source both analytically and numerically (using Monte Carlo techniques) and has considered the resulting Compton currents. They have also examined the propagation and remote detection of NEMP signals.

8. (U) The "Teller light" papers mentioned above are part of a NEMP oriented program involving both theoretical analysis and experimental techniques using pulsed reactors and electron beams. This work is accompanied by a NEMP oriented air chemistry effort, and possible nuclear test instrumentation work which shows an awareness of SGEMP effects.

9. (U) The Medvedev/Stepanov group has studies the problem of coupling of NEMP signals into electronic systems and techniques for shielding against such coupling.

10. (U) One paper, submitted in May 1968, describes the use of a Helmholtz coil to produce a pulsed, spatially uniform, magnetic field in the working volume to study the magnetic shielding effectiveness of hollow, nonmagnetic shields. This is precisely the technique used by Sweden as part of their NEMP hardening program for studying the effects of pulsed magnetic fields on circuit boards, radar electronics, telephone terminals, servo-systems, missiles, torpedos, and mines. Thus, the Soviets were doing laboratory scale NEMP simulation as early as 1968.

11. (U) In 1976 the Medvedev/Stepanov group submitted two papers in which they used nuclear test data reported in U.S. open literature to attempt to reconcile theory with actual NEMP measurements. Their effort was not successful.

12. (U) In 1974, the group described a surface burst code. In the same year, they described a high altitude burst code using the high frequency approximation.

[redacted]

13. (U) The technical content of the individual Soviet NEMP papers is not of great interest. The papers are typically analytical solutions to simplified models of real situations. In addition, they tend to avoid publishing material not previously discussed in Western literature.

14. (U) The scope of the Soviet work is significant. As stated earlier, the Medvedev/Stepanov group has published in virtually every technical area essential to a NEMP hardening program. The only omissions are discussions of real gamma ray source functions and implementation of hardening in systems. Details of gamma ray source functions, which can give insight into the design of nuclear weapons, and actual hardening techniques in systems should be the most sensitive aspects of a NEMP program and hence would logically be the most highly classified.

D. (U) Coupling/Effects/Simulation. A survey of the Soviet unclassified literature has revealed that the Soviets are avid readers of U.S. open literature on nuclear weapons effects. In many instances Soviet journals contain summaries of U.S. articles. Many of the journals include the effect of EMP on electronic equipment and the various hardening techniques which were used in attenuating the EMP induced signals. The Soviets apparently use some EMP simulation to verify models and determine shielding effectiveness. The one clear indication we have of Soviet NEMP simulation is the use of a pulsed Helmholtz coil for testing magnetic shielding. This tec-nique could be used for testing components and relatively small subsystems. It is probable that a NEMP hardening program in the USSR would entail development of simulators large enough to test full scale military systems for survivability. This conclusion is based on the following points:

1. (U) It is possible to conceive of a NEMP hardening program which could achieve reasonable levels of hardness without the use of a full scale system simulator. However, it is highly unlikely that such a program would produce a satisfactory level of confidence in the minds of military planners (U.S. or Soviet) that "hardened" systems would survive.

2. (U) The free-field electromagnetic signals radiated by a burst are the most important for all but the most highly blast hardened surface or buried systems which must survive in the "source region." This free-field environment cannot be effectively simulated in an underground burst.

3. (U) The scope of the technical areas discussed by the Medevdev/Stepanov group indicates that the Soviets have developed the theoretical base for a NEMP program.

4. [redacted] The Soviets have had an extensive atmospheric test program in the 1950s and early 1960s and have been conducting underground nuclear testing since the Limited Test Ban Treaty in 1962. It is conceivable that this testing was sufficient to determine hardening requirements and develop hardening techniques. However, it is highly probable that since 1962

the Soviets have developed some EMP testing facilities to complement underground nuclear EMP testing data. There is no firm evidence of [redacted] Considering the liklihood of a Comprehensive Test Ban Treaty, the Soviets may be motivated to develop a NEMP simulator facility large enough for survivability testing of large full-scale aeronautical and missile systems.

IV. [redacted] Evidence of Soviet NEMP Hardening

[redacted] The only available indications of deliberate NEMP hardening efforts are the following:

A. [redacted] SA-3 Missile Sites. In the middle 1960s, Soviet operational procedures for the SA-3 missile indicated [redacted]

B. [redacted] Military Electronics. It has been reported that [redacted]

V. [redacted] Conclusions

A. [redacted] There is neither definitive evidence showing that the Soviet military have deliberately embarked on a comprehensive EMP program, nor is there evidence that any system has been deliverately hardened for EMP. Either the Soviets do not perceive NEMP as a significant threat or they believe that their systems are inherently hard and invulnerable to the EMP pulse.

B. [redacted] The Soviet Union has been fully aware of the EMP phenomenon since at least 1962. This awareness is supported by the large quantity of Soviet technical writing published in the 1950's and 1960's. These publications imply that Soviet engineers are fully capable of hardening aeronautical systems if the decision is made to do so.

C. [redacted] There is no conclusive evidence that the Soviets have developed EMP test facilities similar to those in the U.S. It is highly unlikely that a TRESTLE-like facility exists in the Soviet Union, and it is unlikely that any aeronautical system has ever been tested in a high altitude EMP simulator. There is some evidence which suggests that [redacted]

D. [redacted] An analysis of Soviet strategy and tactics to employ forces in the nuclear environment may support the conclusions that they believe their systems are inherently hard to NEMP.

OSD 3.3(b)(1)

APPENDIX C

Comments on the Report of the Defense Science Board
Task Force on EMP Hardening of Aircraft

17 February 1981

Dr. [redacted] Task Force Member

OSD
5 U.S.C. § 552 (b)(6)

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(U) The Defense Science Board's Aircraft EMP Hardening Task Force final report improves on previous versions in several respects. I find new areas of agreement; still unchanged, however, are some fundamental issues that strongly contradict past engineering experience and practice in hardening systems against the effects of EMP.

(U) My comments fall into four categories:

- Recommendations for action
- Areas of agreement
- Fundamental disagreements
- Irrelevancies

(U) First however, a comment on the report's timeliness and responsiveness to its charter. The report suffers badly in this respect. It deals with events and arguments of more than a year past, and since then Air Force Management has taken significant actions in the form of budget and program changes. These actions, which have profoundly affected EMP hardening plans, have been justified by appealing to alleged DSB Task Force findings, even though the Task Force as a whole would not have agreed with many of the actions.

(U) In determining the responsiveness of the Task Force to its direction from OSD, one should review the charter under which it was established. That charter is Appendix A of this report. The charter directed the Task Force to review the national capability to harden aircraft to EMP, to determine if there is a productive flow of technology among past and current programs, and to critique a range of aircraft programs including several not discussed in the final report, such as the KC-135, the E-3 AWACS, the F-16, and the TACAMO Navy submarine communications relay.

(U) The charter also directed the Task Force to make timely recommendations in preparation for the B-52G testing activities carried out during 1979, but no such test program recommendations were provided, and the ensuing test program was not only technically unproductive, but also led to widespread confusion and misunderstanding in Air Force and OSD management views that were subsequently transmitted to the Congress.

(U) I. Recommendations for Action

(U) Start as soon as possible a SPO-independent EMP technology application program with an aircraft intended to intercept OAS/CMI kit installation. Require the aircraft design resulting from the program to meet at least the following constraints:

(U) - Hedge against concurrency risks by following successful EMP engineering practices such as were used on the Minuteman II and III missiles, and several other systems now in the forces. TACAMO EMP hardening is a recent aircraft example to consider.

(U) - Protect the system against functional upset as well as component damage.

(U) - Design for feasible EMP hardness validation.

(U) - Design the hardening so that its performance can be monitored comprehensively and frequently enough that degradation will be discovered before it becomes forcewide.

(U) - Design so that minor aircraft system modifications do not require a full-scale EMP hardness requalification program.

(U) - Design to minimize the novel technical, logistics, and maintenance requirements.

(U) - Use a B-52G flying test bed as a prototype. This aircraft should contain the offensive avionics system (OAS)/cruise missile integration (CMI) modifications and hardware so that it encompasses the equipment to be hardened.

[redacted] II. Areas of Agreement (U)

(U) Proof Tests

[redacted] I am pleased to see an unequivocal statement that short "Proof Tests" relying on visual observations of post-test functioning of the aircraft do not lead to an understanding of EMP hardness. I think all of the DSB Task Force who attended the 30 September - 1 October 1980 meeting and listened to the AFWL "Proof Test" briefing realize the very serious shortcomings of such an approach.

[redacted] However, the USAF management has apparently been persuaded as a result of a series of such tests on a non-cruise missile equipped B-52G (actually the tested aircraft was not fully equipped with today's B-52G armament) [redacted]

USAF 3.3(b)(4) 1.4(a),(g)

(U) Actually, the tests have resolved nothing about the EMP hardening of B-52 as a cruise missile carrier since that airplane does not yet exist. In fact, the tests have not resolved the hardness or softness of the B-52G tested. To make this clear, the report should include a few of the occurrences observed in the recent proof test. (e.g., Smoke in the cockpit, subsystem power response, radar altimeter behavior.) The "Proof Test" issue should be thoroughly documented and summarized before the impression of understanding B-52 EMP hardness leads the USAF to delay strategic aircraft EMP hardening plans beyond retrieval.

[redacted] III. <u>Fundamental Disagreements</u> (U)

(U) <u>Shield Only Mission Essential Equipment</u>

[redacted] The report recommends shielding only mission essential functions. This idea is programmatically attractive since it provides a way to ignore, from an EMP hardening standpoint, all those functions declared mission nonessential. Unfortunately, separate functions are not always embodied in separate equipment. As a practical matter, an intensive effort by some of the country's best aircraft EMP engineers could not electromagnetically untangle mission essential from mission nonessential equipment on the B-52G. This meant that the topology of a closed shield around only the mission essential functions could not be achieved within existing engineering practice.

(U) Although one might argue (erroneously, I believe) that these Team B engineers were predisposed toward findings in favor of global shielding, Team A did not provide a solution to the electromagnetic cross-coupling between mission essential and mission nonessential equipment, nor did they provide sufficient information to demonstrate they had a topologically closed shield. I believe a better display of the Team A/Team B discussions on this subject would generally negate the first of three general conclusions* attributed to the SPO approach.

(U) Functional Upset "Secondary Consideration"

(U) The Summary, Conclusions, and Recommendations of the Task Force report states, "hence, it is our judgment that uncertainty in the generation of the EMP field and electronic upset are secondary considerations; the primary uncertainties are the coupling of the EM energy to the aircraft system and subsequent damage of key electronic equipment." (Emphasis, the Report)

(U) While this statement is correct in regard to the generation of the EM field, it is completely wrong in regard to the seriousness of electronic upset produced by EMP. Functional upset without associated component damage has been the primary mode of EMP-induced system failure in all complex systems tested to date. EMI signals in aircraft electronics, which are a part of the noise background in which the system must operate, do cause severe mission-related operational problems, and as such are impossible to leave uncorrected even in peacetime. Unfortunately, EMP upset problems do not manifest themselves so clearly in peacetime operations, and therefore, cannot be expected to be corrected without full recognition of the potential seriousness of EMP-induced functional upset.

[redacted] World War II vintage aircraft were not strongly dependent upon electronics, particularly digital electronics, for their mission capabilities. However, modern aircraft, including the F-111, the TACAMO, and the B-52 have a legacy of mission-related problems associated with electronic upset produced in part by lightning and precipitation static electricity effects. Unfortunately, the report does not provide the reader with the benefit of this experience, but concludes instead that upset effects are inconsequential.

[redacted] *(a) the primary reliance on a contiguous shield, (b) a clear intent to subject all OAS/CMI equipment to test, and (c) a recognition that a nominal [redacted] safety margin is required. (In a technology where uncertainty is at least of the order of [redacted] for one standard deviation, this leaves approximately 7% of the elements stressed beyond their tolerance, if one accepts the view that the error in predicting safety margins are distributed log normally.)

OSD 3.3(b)(4)

That conclusion is a hazardous form of wishful thinking and the report should have been changed to emphasize the importance of functional upset in aircraft electronic systems.

(U) All OAS Equipment EMP Hard

(U) I also have a fundamental disagreement with the second general conclusion, not in its explicit version, but in that it implies that all OAS equipment is inherently EMP hard. The OAS equipment functions as a critical part of a complex system, and its EMP hardness cannot be assumed to be independent of that system. Furthermore, the OAS hardening specifications dictate that OAS hardening evaluations will be based primarily upon analyses of component damage under electrical overstress, an approach which ignores the potential for upset in the highly complex digital and offensive avionics system, and does not rest upon a firm technological base for predicting system change levels.

(U) Cost and Cost Effectiveness

(U) Another fundamental disagreement turns on the lack of logic that runs through the entire report having to do with cost and with cost effectiveness. The integral shielding/penetration control approach, which is widely acknowledged as a low-risk way to build an EMP hard B-52G, is termed not cost effective. Yet the TACAMO aircraft was modified for EMP hardness and the resulting hardness verified with AFWL simulators--following an avionics integral shielding/penetration control approach. Costs are therefore known from direct experience by Team B engineers for modification of an existing aircraft using this design.

(U) However, one may argue that the cost is excessive, depending on what is defined as excessive. The Task Force agrees that the integral shield/penetration control will work. Experience with the TACAMO avionics supports this view. Direct cost experience with integral shielding is in hand and was applied in forming the B-52G Team B estimates.

(U) The Team A hardening approach briefly described in the report is said to be cost effective. Yet the costs are not known from experience, since the TEAM A EMP hardening technique is not practiced by EMP engineers, and does not carefully address verification testing costs, hardness maintenance and logistics costs, and system modification costs. Team A costs have much less technical basis than those of Team B.

(U) One element of the cost effectiveness ratio is cost, however, the other element is hardness. The Team A hardening procedure relies on numerous stated and unstated nonverifiable assumptions leading ultimately to at best ambiguity about the EMP hardness of the B-52G force.

(U) It is illogical to conclude that Team A's tenuous cost estimates divided by an ambiguous hardness can equate to a cost effective hardening program while Team B's experience based costs divided by a knowable hardness can equate to a non-cost effective hardening program.

(U) COST EFFECTIVENESS OF HARDENING

	Life Cycle Cost	Resulting Hardness
Team A Approach	No Experience	Ambiguous
Team B Approach	Experience Based	General agreement will give a hard system

(U) The report gives no insight into the level of aggregation for the cost statements made. In fact, major areas of potential programmatic savings accruing to Team B's alternatives were not reported. Examples not mentioned include Class V ongoing modification savings, verification testing savings, logistics savings, etc. These can amount to substantial dollars and should be discussed in the report.

(U) Logistics and Maintenance Costs

(U) Another fundamental contradiction originates with the Team A assumptions that no severe maintenance and logistics problems are associated with protection devices and special pin-hardened LRUS in the OAS/CMI and elsewhere throughout the system. Since a viable hardness surveillance and maintenance program with costs has not been developed for such an approach, it is premature to judge either its cost or feasibility. Nevertheless, it would not be surprising to find severe burdens to the system arising in this area.

[redacted] Recent B-52 EMP Tests (U)

[redacted] A serious misperception in the eye of a reader comes from the Section of the report entitled NO SMOKE-MANY ANOMALIES. "Smoke in the Cockpit" actually occurred coincident with an EMP pulse during "Proof Test" but the technical level of reporting was so low that although the observation was recorded no explanation was offered. The section referred to above should have been removed from the DSB Task Force report and a balanced analysis of results of recent B-52 tests put in place of it. The following information on each of the recent B-52 EMP tests should have been sent to each DSB Task Force member for their review, comments, and input to the Task Force final report.

1. Dates and names of each test.
2. Test objective.
3. B-52 model and configuration tested, including armament on board.
4. Operational modes tested/not tested.
5. Sub-systems tested/not tested.
6. Instrumentation techniques used to monitor response to EMP.
7. Conclusions drawn.
8. Logic trails, including use of statistics.
9. Comments about relation of test to existing and/or planned force.
10. Official reports/briefings and other written conclusions.

[redacted] Shield to the Rated Power Level (U)

[redacted] Burnout mechanisms are not well understood and many circuits are operated normally very close to their damage thresholds. Earlier this report stated that "carefully designing close to the margin" was not applicable to the B-52 EMP hardening design. Yet later the report recommends shielding to reduce signal levels only to the rated power level. Such a level is near and on occasion above the failure level (and upset level in digital systems) of components that experience operational stress and degradation. Therefore, these two recommendations of the report that concern shielding levels are self-contradictory, the first being correct and the second being incorrect.

(U) Alternative Configurations for a B-52 CMC

(U) The report carries only indirect mention of the major theme of the Team B EMP design approach--remove all equipment not needed by the CMC mission. Much more tractable EMP hardening emerged from this design. In addition, estimated programmatic savings in B-52 mods and tanker costs amounted to several billion dollars. Such an approach warrants careful consideration.

[redacted] Design Validation Testing (U)

[redacted] The report does not mention that Team B's approach requires only minimal TRESTLE testing to check out shield effectiveness and to calibrate the shield integrity monitoring systems. $83M ($79) is stated by the report as the cost to provide a TRESTLE test of the Team B design. $5.2M was the Team B estimate. $83M was the total RDT&E for Team B approach.

(U) IV. Irrelevancies

(U) Lightning

(U) I consider the discussion on lightning more academic than useful to B-52 EMP testing. It should not have been included in the report.

(U) Incidentally, I have found serious discrepancies between the journal article referred to and the attributions to it made in the DSB Task Force report. For example, the cited article reveals no mention of using lightning "return strokes" within 100 M of an aircraft as producing 10^5v/m fields in the 1-10 MHz region, contrary to what the report states. In fact, the data suggests that an aircraft must be within 10 m to see 10^5v/m even if one could extrapolate linearly from data measured at 15 KM down to 10 m.

(U) Intelligence

(U) The final report should present more completely the intelligence conclusion drawn in the paper by Colonel Fortin. He says "there is no evidence that the Soviets have embarked on a comprehensive..." The not stated but equally true other half of the argument should be in the DSB Task Force report. "There is no evidence that the Soviets have not embarked on a comprehensive..." The attached copy of a poster found on a Soviet factory wall represents a level of propaganda pointing to Soviet concern for EMP effects. The report casts unwarranted significance to an absence of U.S. information.

(U) On a technical point, one should not expect all EMP test activities to be evident. The largest missile that the U.S. ever tested for EMP (the TITAN II) was tested entirely inside a closed building.

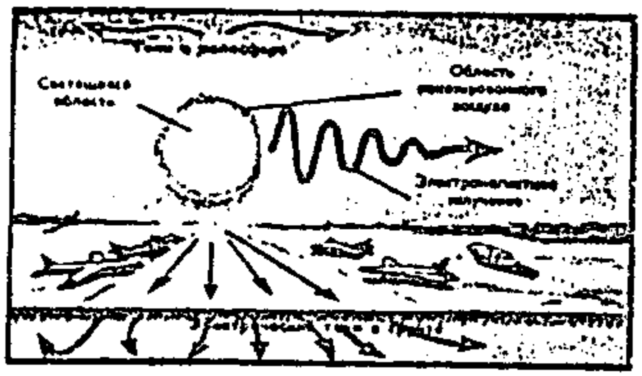
(U) Electromagnetic Compatibility (EMC)

(U) The DSB Task Force did not have the opportunity to hear, probe into, and question the assertions about operating of aircraft routinely in the presence of electrical noise at signal level and occasionally a factor of 10 higher. Such statements should not be reported as if the Task Force had considered them carefully and had concurred. We should have reconvened the Task Force to consider EMC, or deleted the discussion from the report.

(U) As a technical matter, much electronics, including most digital systems, will not operate in an electrical environment that produces spurious noise of the same amplitude as the operating signals. However, unlike EMP problems EMC problems, errors and oversights manifest themselves unsoughtafter during system development and daily operation. The identification of EMC problems is therefore difficult to avoid, and they eventually tend to be corrected, again unlike EMP problems.

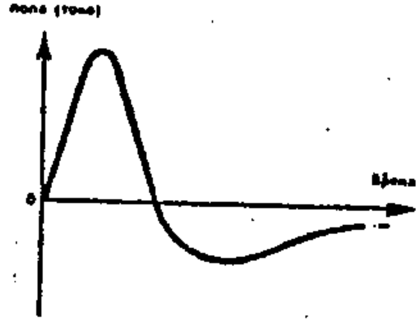
ЭЛЕКТРОМАГНИТНЫЙ ИМПУЛЬС

При ядерных взрывах возникают электромагнитные поля, которые создают импульсные электрические токи и напряжения в воздушных и наземных проводных и кабельных линиях, в антеннах радиостанций, а также радиоизлучение, распространяющееся на большие расстояния



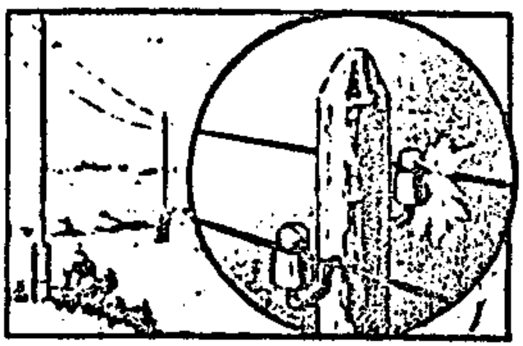
Электромагнитное поле в точке в воздухе и грунте возникает в результате образования в зоне взрыва светящейся области и большой области ионизированного воздуха, созданной проникающей радиацией

Наведенные токи и напряжения представляют собой кратковременный импульс, по своим характеристикам близкий к импульсу, вызванному молниевым разрядом. Его длительность составляет несколько миллисекунд.

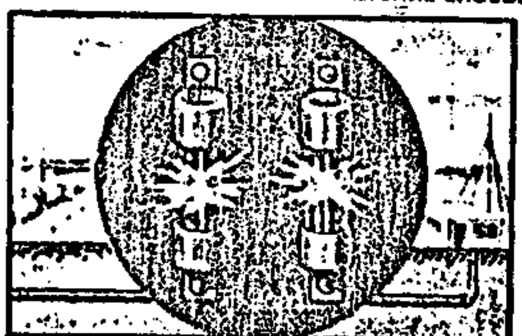


При наземных и воздушных взрывах в радиусе нескольких километров от центра (эпицентра) взрыва перенапряжения между проводами воздушных линий связи или электроснабжения и землей достигают десятков и сотен тысяч вольт, а между жилами подземных кабельных линий и оболочкой (землей) — несколько десятков тысяч вольт. Наведенные импульсы могут распространяться по линиям на большие расстояния от места ядерного взрыва.

ВОЗНИКШИЕ ПРИ ВЗРЫВАХ ПЕРЕНАПРЯЖЕНИЯ СПОСОБНЫ:



[illegible] электро- и радиотехнические устройства.



вызывать перегорание элементов электро- и радиоаппаратуры или ложное срабатывание средств защиты.

поражать обслуживающий персонал.

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OSD 5 U.S.C. § 552 (b)(6)

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