CHAPTER 7

PROTECTION MAINTENANCE AND SURVEILLANCE

7-1. Outline. This chapter is organized as follows:

7-1. Outline
7-2. Introduction
7-3. Facility life-cycle environment
a. Major environmental factors
b. Sources of degradation
7-4. Impact of hardness maintenance on facility design
a. Choice of shielding concept
(1) Tailored approach
(2) Global approach
(3) Tradeoffs
(4) Accommodating test and repair activities
(5) In situ tests
b. Test methods and equipment
c. Minimizing hardness maintenance requirements
(1) Level of shielding
(2) Terminal protection devices (TPD)
(3) Alternatives to hardwire
(4) Entry plate
(5) Example
d. Failure mode effect on hardness maintenance
(1) Typical failure modes
(2) Tradeoffs
e. Suitability of materials
f. Uncontrolled retrofits
7-6. Hardness maintenance program structure
a. Program elements
b. Interaction of program elements
(1) Preliminary planning
(2) Maintenance concepts
(3) Configuration management
(4) Parts control
(5) Maintenance procedures
(6) Training
(7) Documentation
7-7. Hardness surveillance (HS) activities
a. Inspections
b. Testing
(1) Classes of tests
(2) Built-in test features
(3) Using similar tests
(4) Pass/fail criteria
(5) Examples of specialized tests

7-8. Cited references

7-2. Introduction. Facilities are protected against HEMP and TEMPEST through the numerous methods described in this EP. Generally, when construction is finished, acceptance tests and analyses are performed to assure that the facility meets the required hardness level and TEMPEST shielding before placing it into operation. Once the facility has become operational, it is necessary to assure its continuing HEMP hardness and communication security. To provide this assurance, some kind of hardness maintenance/hardness surveillance (HM/HS) and TEMPEST Shielding Maintenance (TSM) program is essential. The primary purpose of HM/HS/TSM is to detect any degradation of the protective measures incorporated into the facility and to take the necessary corrective action in a timely manner. Thus, an HM/HS/TSM program includes both preventive and corrective measures. This chapter describes such a program in terms of basic elements and possible variations.

7-3. Facility life cycle environment.

a. Major environmental factors. In operation, a HEMP-hardened and TEMPEST-protected facility will be subjected to environmental factors that will tend to degrade the hardness level. Major environmental factors are--

(1) Weather-related conditions including lightning.

(2) Soil chemicals and interactions.

(3) Normal aging.

(4) Exposure to miscellaneous contaminants.

(5) Operator actions causing accidental damage.

(6) Routine wear.

(7) Abuse.

(8) Changes in design configuration.

(9) Abnormal electrical transients.

(10) Changes in equipment used or operated in the facility.

b. Sources of degradation. Based on these factors, some of the most likely sources of hardness and shield effectiveness (SE) degradation may result from--

(1) Door gasket corrosion.

(2) Seam corrosion.

(3) Door gasket contamination.

(4) Deformation of door or other penetration gaskets.

(5) Shield corrosion that produces openings.

(6) Loss of proper grounding connection.

(7) Shield degradation from penetrating retrofitted conductor installation.

(8) Failure of surge arrester or filter components.

(9) Cracks in welded seams.

(10) Defects in disconnect switching.

7-4. Hardening shielding elements. The elements of a HEMP-hardened and TEMPEST-shielded (TS) facility to which HM/HS/TSM applies include--

a. Shielded doors and hatches.

b. All EMI and RFI gaskets.

c. Blast doors.

d. Air duct and ventilation filters.

e. Electrical filters in power and communications lines.

f. Shielded enclosures and zones.

g. Lightning arresters.

h. Electrical surge arresters.

i. Grounding connectors.

j. Electrical conduits, conduit fittings, junction boxes, and cable raceways.

k. Flexible shielded connections.

l. All shielded liner plate connections.

m. Cathodic protection systems.

7-5. Impact of hardness maintenance on facility design. To be cost-effective and practical in meeting user requirements, HM/HS/TSM must be considered during the conceptual and detailed design phases of a facility. The choice of design can greatly impact HM/HS/TSM requirements. Further, operational constraints often dictate the HM/HS/TSM activity and can have major effect on the facility design.

a. Choice of shielding concept. One of the first considerations in facility design impacting HM/HS/TSM is the choice of shielding concept, that is, whether to use a tailored shielding approach or a global one.

(1) Tailored approach. The tailored approach, in which small-volume shields are applied to sensitive subsystems and/or equipment, is used primarily when the system elements are widely distributed. The various elements are individually shielded and interconnected via data links. These data links may be hard-wire cables which are shielded for HEMP and TEMPEST or they may be radiofrequency (RF) communications or fiber optics data links. The impact on HM/HS/TSM activities for each type of data link in a tailored system is described in c below.

(2) Global approach. In the global approach, one outer shield is designed to protect all TEMPEST and HEMP-susceptible systems located inside a structure. The global shielding approach minimizes the number of interfaces that require protection; this reduces HM/HS/TSM activities. The global concept also allows for future modification and expansion of the housed equipment since the facility shield provides all the required protection (isolation) from external fields. Some compartmentalization, or equipment-to-room size shields, may still be required for internally generated EMI and TEMPEST considerations.

(3) Tradeoffs. Figure 7-1 depicts possible tradeoffs when considering four hypothetical shielding concepts for a system in which two vans must communicate (a). The first option (b) shows a pseudo-global concept using very heavily shielded cable. The heavy cable shields represent shield extensions that eliminate induced transients on the cable conductors, thus eliminating the need for TPDs. The next two options (c and d) use lightly shielded cable with TPDs at both vans. Option (e) uses an RF communication link with no TPDs.

(4) Accommodating test and repair activities. Whatever shielding concept is chosen, it must accommodate the periodic HM/HS/TSM test and repair activities. For example, if a global shielding concept is used for an underground facility with the shield placed on the outside, shield performance will be very difficult to test. Inspection of the shield will be out of the question if the facility is direct-buried (that is, no free space exists between the structure and the earth). Moreover, testing with radiated fields is very complicated and the data are difficult to interpret. An alternative design would be to build test sources, exciters, and/or sensors into the

facililty to obtain qualitative performance data on the shield and assess any degradation.

(5) In situ tests. The same considerations apply to room and even equipment shields. In determining if the SE of an equipment enclosure has degraded, tests must be conducted without disturbing the shield. This testing can be done by external illumination of the equipment shield and built-in pickup devices inside the shield. Shielded connectors (normally capped) and cables are then used to measure the pickup from inside the shield. The most common approach is to use external loops to generate the field and internal loops to measure internal pickup. This procedure does not give quantitative shielding effectiveness data, but is useful for comparison with baseline data. The internal pickup devices must be incorporated during the design and construction phases of the facility.

b. Test methods and equipment. In making provisions for HM/HS/TSM testing at the facility, the types of test procedures to be used and special test equipment requirements must be considered. These procedures and instruments must not degrade the protection element being tested (such as surge arresters) or the HS activity will be self-defeating. Further, if at all possible, they should have limited injection levels (voltage, current, or energy) such that if the protection element has failed, no damage occurs to the system itself. The specific techniques must be determined based on the protection levels required and the typical (common) failure modes of the device being evaluated. (See para d below.) Note that absolute performance to specification is not required for HM/HS/TSM activities; HM/HS/TSM testing is done to detect any changes from a baseline established at the time the facility was certification-tested.

c. Minimizing hardness maintenance requirements. Another aspect of HM/HS/TSM that must be considered during the design phase is to minimize the need for HM/HS/TSM activities. However, any steps to reduce these activities must be balanced carefully with the facility HEMP hardness and TEMPEST requirements.

(1) Level of shielding. If a facility uses a tailored shielding approach with hard-wire cables as data links, the level of cable shielding and system protection requirements will impact the HM/HS/TSM activity level. For example, if the cable SE is equal to that of the system element shields, a global shielding concept is achieved in principle. However, because of the distributed nature (size) of the shield systems, coupling to the HEMP field will be large and the SE must be increased accordingly. This means a higher level SE must be maintained which will require a much more complex HM/HS/TSM program.

(2) Terminal protection devices (TPD). If the data link SE is less than that of the system element shields or is not increased to account for the higher induced shield currents, terminal protection devices (TPDs) must be employed. These TPDs must be installed at each cable termination (where a

system element shield will be penetrated). This requirement greatly increases the number of TPDs that must be used, checked, and maintained.

(3) Alternatives to hardwire. Alternatives to hard-wire cable data links are RF communication links and fiber optic data links. These options are especially advantageous when a tailored shield concept must be used since they do not couple to the HEMP fields or prevent emanations. If, in the case of the RF links, the operating frequency is far removed from the highest EM frequency (by 400 megahertz or more), little or no terminal protection is required; thus, HM/HS/TSM activities are reduced. Optical links do not require TPDs, which also lowers the HM/HS/TSM requirements.

(4) Entry plate. If a global shield is used, only a single cable terminus (entry plate) must be considered since a single shield volume is being penetrated. As noted in paragraph a above, this design minimizes HM/HS/TSM requirements.

(5) Example. An example of a facility design with minimal HM/HS/TSM requirements is the North American Air Defense (NORAD) complex at Colorado Springs, CO. Because the facility is underground, high-frequency components of the incident HEMP field are greatly attenuated by the earth overburden. This design allows the use of waveguide-beyond-cutoff personnel doorways in the facility which are essentially maintenance-free compared with shielded doors that employ spring-finger contacts. These latter doors are highly susceptible to corrosion and damage if not designed properly with some form of mechanical protection. Sliding, pneumatic-type doors require far less maintenance than the spring-finger doors; however, the waveguide-beyond-cutoff doors used at this facility represent the lowest maintenance requirements of the three door types.

d. Failure mode effect on hardness maintenance.

(1) Typical failure modes. Catastrophic failure of protective elements may be evidenced as degradation of normal facility performance, depending on the failure mode of these elements. For example, semiconductor surge arresters normally fail short under catastrophic conditions. If they are used as shunt elements, such a failure will be evident by its effect on normal operations. Gas-gap-type surge arresters, on the other hand, usually fail open with time. These failures will not affect normal operations. Similar considerations apply to filters. If a shunt capacitor fails short, noticeable degradation will occur; if the capacitor fails open, the failure will not degrade normal facility performance.

(2) Tradeoffs. Thus, the failure mode of a device helps determine how often the device should be checked. If the failure of a device impacts (degrades) normal operation, HS/ TSM requirements will be lower than for devices without this potential effect. However, while devices that fail short are desirable in the sense of potentially reducing HS, they are not desirable from the aspect of overall system operational reliability. Thus, tradeoffs

will have to be made during the design phase when the protection concept and protection devices are being selected. Table 7-1 provides examples of some tradeoff elements with qualitative comparisons.

e. Suitability of materials. Attention must be given to the materials comprising protective devices and features to ensure long-term performance in the facility environment. Items such as RFI filter covers, RFI gaskets, and grounding hardware are available in a variety of materials with different degrees of resistance to corrosion, structural deformation, and other stresses. Some shielding materials can be coated with special paints to give them more corrosion resistance. Surfaces to be mated with RFI gaskets, however, must not be painted. RFI door jambs are generally plated with tin to impart nonoxidizing, high-conductivity contact between the fingerstock gasket on the door and the shielded enclosure. Dissimilar metals used at electrical contacts often conflict with ideal corrosion control. However, tin-plated gaskets are compatible with a large number of other materials.

f. Uncontrolled retrofits. Once a facility has been hardened against HEMP and TEMPEST, the protection can be compromised easily by uncontrolled retrofits and modifications. The most typical example of an uncontrolled retrofit is the routing of cables through the shield at points other than the normal vault area with terminal protection. This is often done with a simple hole drilled through the shield. Modifications that compromise the SE must not be allowed. The effect of all modifications on HEMP hardness and TEMPEST protection must be analyzed carefully to ensure the protective system's integrity.

7-6. Hardness maintenance program structure.

a. Program elements. The major elements of an HM/HS/TSM program include--

(1) Preliminary planning.

(2) Concept development.

(3) Configuration management.

(4) Parts and circuit control.

(5) Maintenance procedures.

(6) Training.

(7) Documentation.

b. Interaction of program elements. Figure 7-2 shows how these program elements interact.

(1) Preliminary planning. Ideally, the HM/HS/TSM program should be developed concurrent with development of requirements, criteria, and design plans and to specifications of the facility itself. Since life-cycle hardness requirements can have major impact on the overall facility design, a properly developed HM/HS/TSM plan can reduce facility life cycle costs.

(2) Maintenance concepts. Concurrent with facility design concept development, specific HM/HS/TSM concepts should be developed based on sound technical requirements and realistic test and inspection activities. It must be possible to implement these concepts on-site taking intoaccount the system to be protected, its potential disruptions, and available maintenance personnel.

(3) Configuration management. During a HEMP-hardened/TEMPEST-protected facility life cycle, the configuration of mission-critical systems may be changed. These changes may affect the HEMP hardness or TEMPEST protection. Thus, every engineering change proposal (ECP) should be reviewed to evaluate its potential impact on hardness. The reviewers must have enough HEMP and TEMPEST expertise for proper evaluation. Depending on the facility size, function, criticality, and the major command using the facility, various types of configuration management programs can be used. Figure 7-3 shows a typical program.

(4) Parts control. A system developer uses parts control to influence future decisions on parts procurement toward preserving HEMP hardness and TEMPEST protection. Decisions that can be important include those for obvious hardness and TEMPEST protective items, such as transient suppressors, gaskets, cable shields, and other sensitive equipment. Detailed specifications are required for these items so that proper parts can be selected based on the manufacturer's specifications and on product performance testing. The design for interfacing pieceparts and subsystems also must be specified properly when overall system hardness or SE depends on the inherent survivability or hardening of these parts. An example would be a system with an electronics module that requires no hardening because it has a damage threshold exceeding the HEMP threat waveform by more than the specified margin. The system survivability depends on the module's ability to withstand induced threat-level transient pulses. Therefore, parts procurers at some later date will need guidance in selecting components of comparable hardness that will be compatible with the system.

(5) Maintenance procedures. A well defined set of maintenance procedures specifically tailored to each HEMP-hardened and TEMPEST-protected facility is a major part of the successful HM/HS/TSM program. From the HEMP hardening/TEMPEST protection standpoint, maintenance procedures include all measures that must be taken to prevent degradation of the facility HEMP hardness/TEMPEST protection level. The corrective measures for specific hardening elements should be determined by studying the potential deterioration mechanisms to which the element is subjected. Maintenance events have four major purposes:

- Preventing hardness and TEMPEST deterioration to the extent necessary. Preventive maintenance in HEMP-hardened and TEMPEST-protected facilities may involve replacing RFI gaskets, applying cleaners and lubricants to gaskets, cleaning door surfaces that mate with gaskets, dismantling and cleaning seams of demountable shielded enclosures, replacing gaskets in equipment cabinets, replating critical surfaces by brush-electroplating, cleaning air-duct filters, and replacing RFI tape when necessary.

- Determining if any deterioration mechanism detected has acted on the protective element such that HEMP/TEMPEST protection is jeopardized. Deteriorated conditions can be detected by testing or by inspections as discussed in paragraph 7-6.

- Doing corrective maintenance to repair, replace, or refurbish elements found defective. Corrective maintenance includes replacement of any shielding element found defective during inspection or test. It may involve completely replacing the element, patching shields, replacing electrical filters, replacing gaskets, and other such actions.

- Verifying the adequacy of repair. This requires inspection, testing or both.

(a) The maximum allowable time interval between maintenance events is based on the environment, susceptibility of the protective element, severity of element usage, wear, and all other factors related to degradation. These factors include the item's location, nearness to personnel traffic, and number of operational cycles per given time period; the life expectancy of protective items; and on-site experience with installed equipment.

(b) Failure criteria must be developed to provide maintenance personnel with information they will need to determine if critical hardware items have deteriorated below acceptable levels. The failure criteria must be stated in measurable go-no go quantitative units that do not require qualitative judgment for deciding if an item is acceptable. For inspection, meaningful quantitative criteria may be difficult to define. Examples would include minimum torque values for bolted connections and maximum misalignment of the door with the frame. For testing, criteria may include minimum RF attenuation values and maximum resistance across ground connections.

(c) HM/TSM events should be a part of regular maintenance for the facility. HM/TSM data and instructions can be included with the regular maintenance data and instructions. The integration of HM/TSM with regular facility maintenance optimizes overall maintenance efficiency. Figure 7-4 shows an example of a specific system and associated maintenance procedures.

(6) Training. Operating personnel must have a general understanding of what HEMP is, how its effects can be reduced, and what TEMPEST is and how to prevent compromise. Operators and maintenance persons for HEMP-hardened and TEMPEST-protected systems need a general knowledge of HEMP and TEMPEST effects as well as specific knowledge of the HEMP and TEMPEST protective features for the systems on which they work. Facility managers must know all these things in addition to program, schedule, and cost effects of HEMP hardening and TEMPEST protection.

(a) Training goals for O&M persons at HEMP-hardened and TEMPEST protected facilities include: identifying items critical to system hardness and TEMPEST protection; learning system hardness philosophy; learning TEMPEST regulations and procedures; developing proficiency in all maintenance procedures; developing skills in hardness and SE testing; becoming familiar with documentation and manuals; and learning to interpret test results.

(b) Achieving these goals will ensure that the O&M staff does not inadvertently degrade the built-in HEMP/TEMPEST protection. Further, it will enable greater efficiency in time spent by test and inspection personnel, improving the probability of overall mission success for the facility.

(c) There are several resources for training test and inspection personnel (ref 7-2). For example, these individuals might attend DNA- or NSA-sponsored courses (joint staff, service agencies, NATO) for test and inspection of HEMP hardening and TEMPEST protection. Another possibility is that the facility develop site-specific training materials for its personnel. In addition, personnel may acquire HEMP and TEMPEST expertise in industry and Government labs under special training programs.

(7) Documentation. The success of a life-cycle HM/HS/TSM program depends heavily on the documentation compiled to support hardness assurance, maintenance, and surveillance.

(a) System configuration management is largely based on the documentation identifying items critical to hardness or TEMPEST protection. This information clearly defines the baseline to be managed. The baseline is focused on elements that comprise the system hardening mechanism. Information on the hardening/TEMPEST protection design also supports O&M, and, indirectly, training and surveillance testing. Specifications for system components support these activities as well.

(b) The HM/HS/TSM plan defines which measures must be taken to ensure the system's hardness/tempest protection throughout its life. Measures taken during initial hardness validation and those scheduled for after the system is operational must not comprise the plan.

7-7. Hardness surveillance (HS) activities. HS consists of activities for monitoring a facility's continued hardness to HEMP events, and TSM consists of activities for monitoring and controlling a facility's compromising emanations. The primary activities of HS/TSM are inspection and testing. Inspection, testing, or both will be required on a periodic basis to ensure the system's continued hardness and SE or to verify the adequacy of a repair. The procedures to follow in these inspections and tests must be developed on a system-specific and facility-specific basis. Further, as maintenance experience is gained, it may become apparent that changes in procedures are necessary. In addition, if retrofits or repairs are made, specific inspection and test procedures should be designed to validate the resulting hardness and SE.

a. Inspections. For some protective elements, visual inspection can reveal deterioration or damage. Inspectors should be trained to perform visual inspections. This training should provide knowledge of the protective elements' hardening and TEMPEST protection function, including what the normal acceptable condition is. Examples of visual inspections derived from the SAFEGUARD protecion integrity maintenance (PIM) plan are (ref 7-1)--

(1) Inspect shielded doors and hatches for gasket cleanlines and condition.

(2) Inspect air-duct filters for cleanliness, integrity, and proper bonding or gasketing to mating surfaces.

(3) Inspect power-line or communications-line filters for properly gasketed covers and for evidence of leakage from sealed components.

(4) Inspect grounding circuits and straps for proper condition.

(5) Inspect transformers for leakage or other damage.

(6) Inspect sealed conduit systems and components for excessive corrosion.

(7) Inspect flexible conduits for corrosion.

(8) Inspect shield seams for evidence of corrosion, cracks, and other damage.

(9) Inspect cathodic protection systems for deterioration.

(10) Inspect shielded cable trays for damage or corrosion.

(11) Inspect piping, traps, sinks, and drains for proper seams.

b. Testing. The starting point for HS/TEMPEST shielding (TS) testing, as with all post-acceptance HM/HS/TSM activities, is hardening and TEMPEST protection acceptance documentation. This documentation specifically defines what to test, when to test, and how to test to ensure that the system stays hard, despite the effects of wear and corrosion. Surveillance testing is based on the survivability analysis, hardening, and SE approach taken to protect the system against HEMP effects and TEMPEST compromise. The test program focuses on the features essential to hardness and SE, such as shielding, transient suppressors, and critical parts. Potential effects that could damage system hardness and SE are also considered. Items likely to degrade such as gaskets, are tested if the degradation would compromise hardness and SE. In some cases, particularly when errosion is a concern, testing must be done at regular intervals. Other tests are event-specified; for example, "after a thunderstorm" might be suitable for checking possible lightning damage to HEMP-hardened equipment. The documented procedures identify the test equipment to be used and provide guidance on performing the test.

(1) Classes of tests. The tests used will generally be of the types described in chapter 6 of this EP. The general classes of tests include--

(a) Some form of electromagnetic illumination.

(b) Seam leak detection.

(c) Special methods for filters and surge arresters.

(2) Built-in test features. Some facilities are designed with built-in features for hardness assurance tests. One such approach is to use three orthogonal loops or coils around the entire facility. These loops are excited at a fixed frequency and field levels are measured at specified points inside the shielded zone. Usually, an initial set of data is obtained during facility acceptance testing. Retest data can then be compared with original data for evidence of deterioration.

(3) Using similar tests. The best type of test program would use similar equipment and methods for both initial acceptance and life-cycle hardness testing.

(4) Pass/fail criteria. Simple pass/fail criteria should include instructions to guide operating personnel in what actions to take next should the test indicate failure. Additional testing may be needed to define how serious the failure is. Another response may be to repair or replace an item.

(5) Examples of specialized tests. In many cases, specialized tests are applicable to various system components or evaluation procedures. Some examples are listed below.

(a) A specialized test method called PLACER was developed for the SAFEGUARD system to test buried conduits. This example shows the need to consider maintenance in the research, development, test, and evaluation (RDT&E) or system design hardening process to ensure successful maintenance.

(b) The SAFEGUARD ABM maintenance testing program included electromagnetic illumination tests at only two discrete frequencies to evaluate the SE of doors, shield membranes, seams, and shield penetrations. These hardness critical items (HCIs) were tested at 200 kilohertz using loop antennas and at 3 gigahertz using horn antennas. Data were compared with acceptance test data to show deterioration trends.

(c) Power line filters are examples of items that require specially designed test techniques. Often the test must be nondisruptive and therefore done with power flowing through the filters. It is essential that engineering personnel with HEMP and TEMPEST expertise have input into the HS/TSM test plan.

7-8. Cited references.

7-1. Program Plan, Protection Integrity Maintenance (PIM) for SAFEGUARD Facilities, Vol 2, HNDSP-73-NO-ED-R (U.S. Army Corps of Engineers, Huntsville Division, December 1973).

7-2. EMP Course Study Guide (Defense Nuclear Agency, April 1983).

Table 7-1. Qualitative tradeoff study results

	Design Comparison		
Criteria	Intersection-welded rebars	Small volume critical area shield	Envelope shield
Cost analysis	Costly	Costly	Least costly
Performance estimate	Unpredictable	Reasonably predictable	Reasonably predictable
Future needs	Permits expansion	Expansion costly	Permits expansion
Satisfactory	Difficult	Satisfactory	Maintenance
Maintenance	Satisfactory	Difficult	Satisfactory
Grounding and cabling plan	Satisfactory	More difficult	Satisfactory

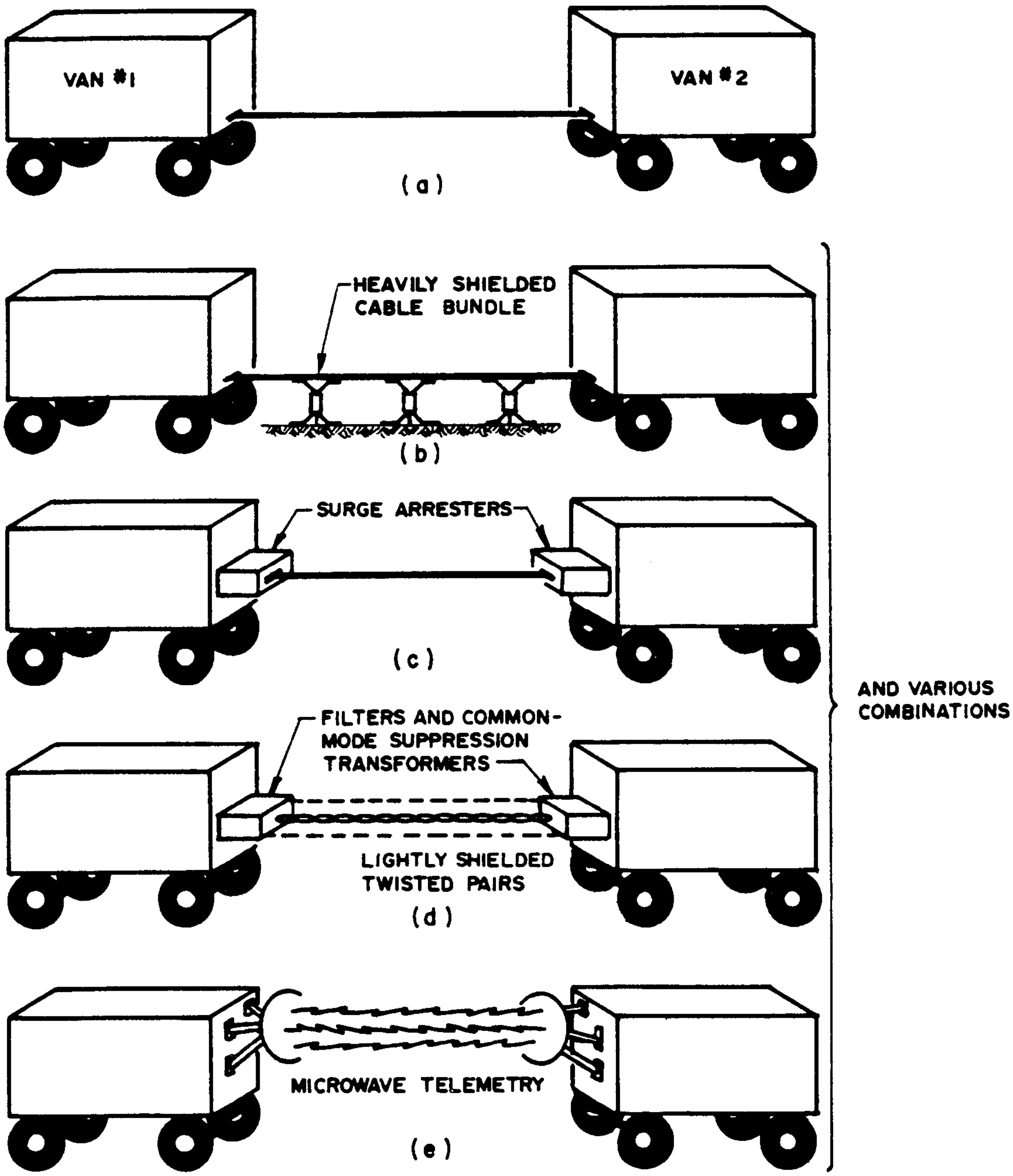

Figure 7-1. Effect of hardening approach on subsystem design.

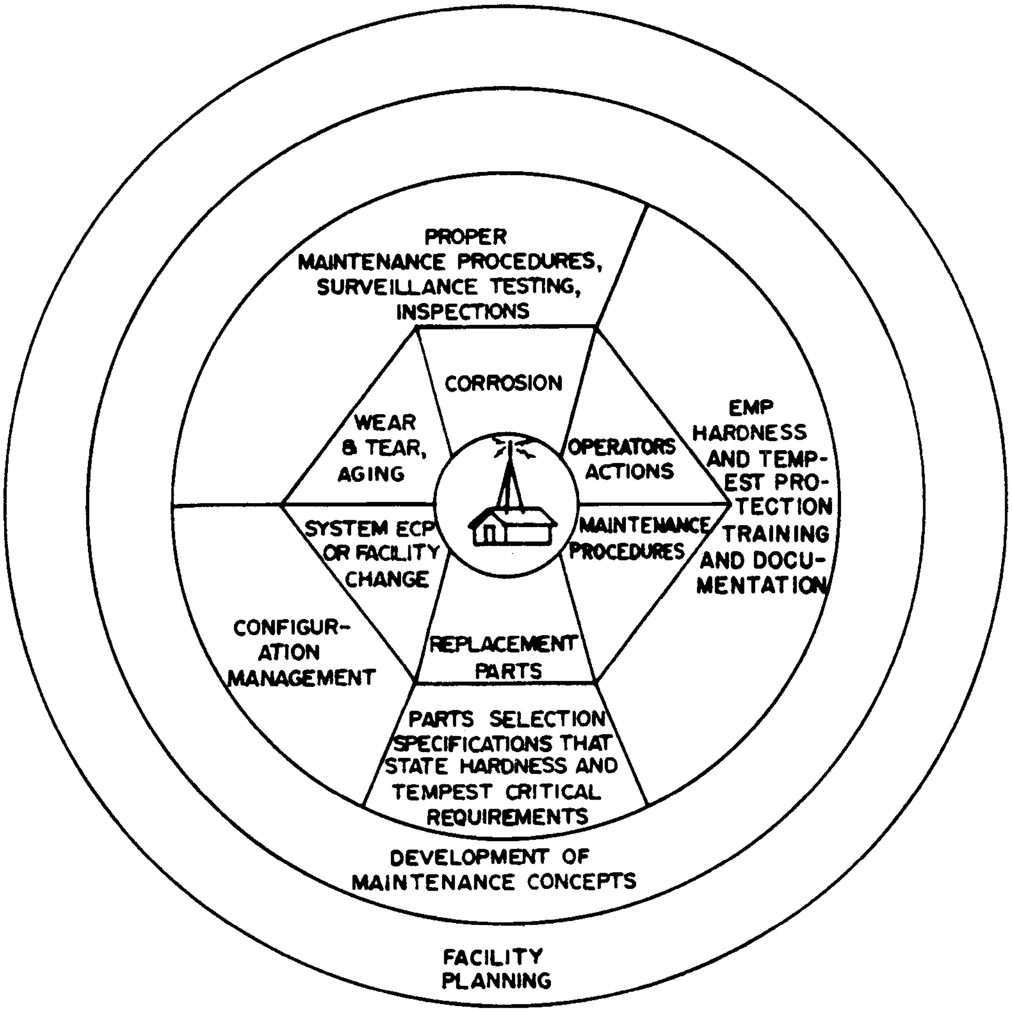

Figure 7-2. Interaction of HM/HS/TSM program elements.

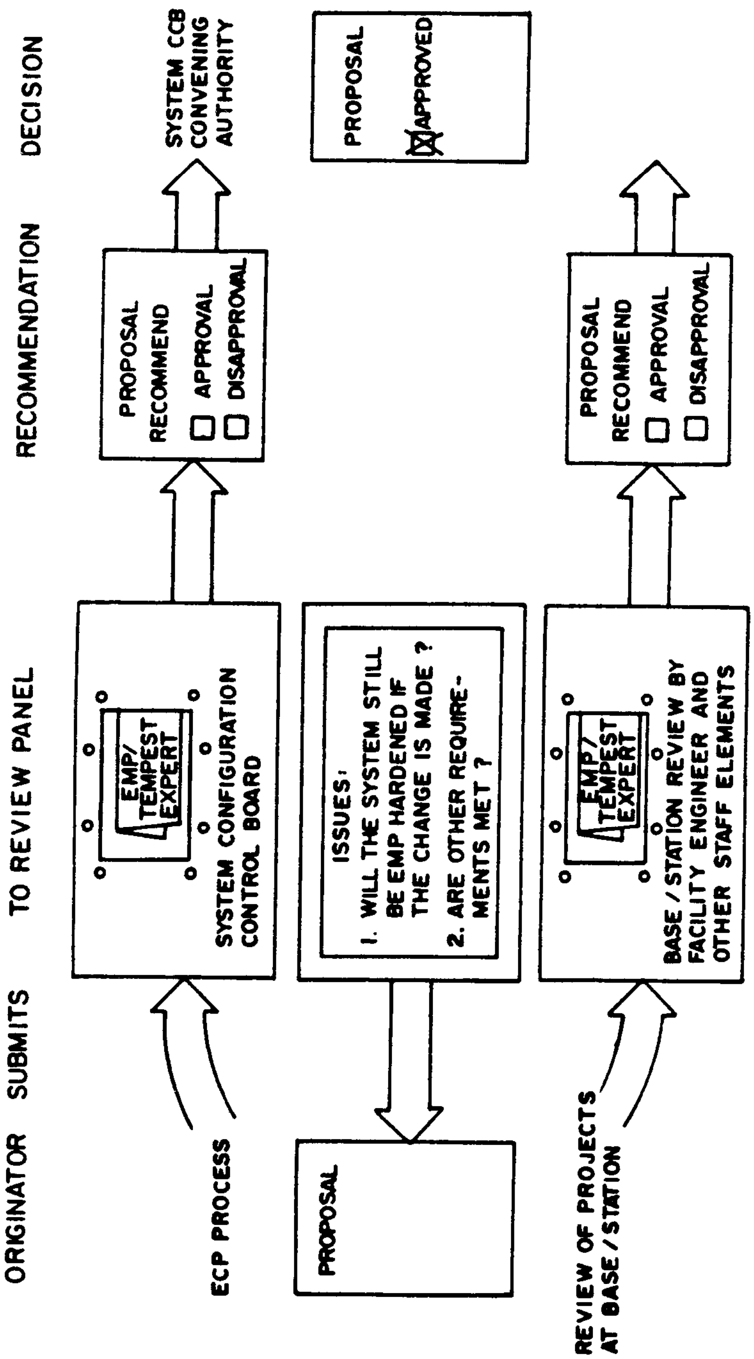

Figure 7-3. Configuration management process.

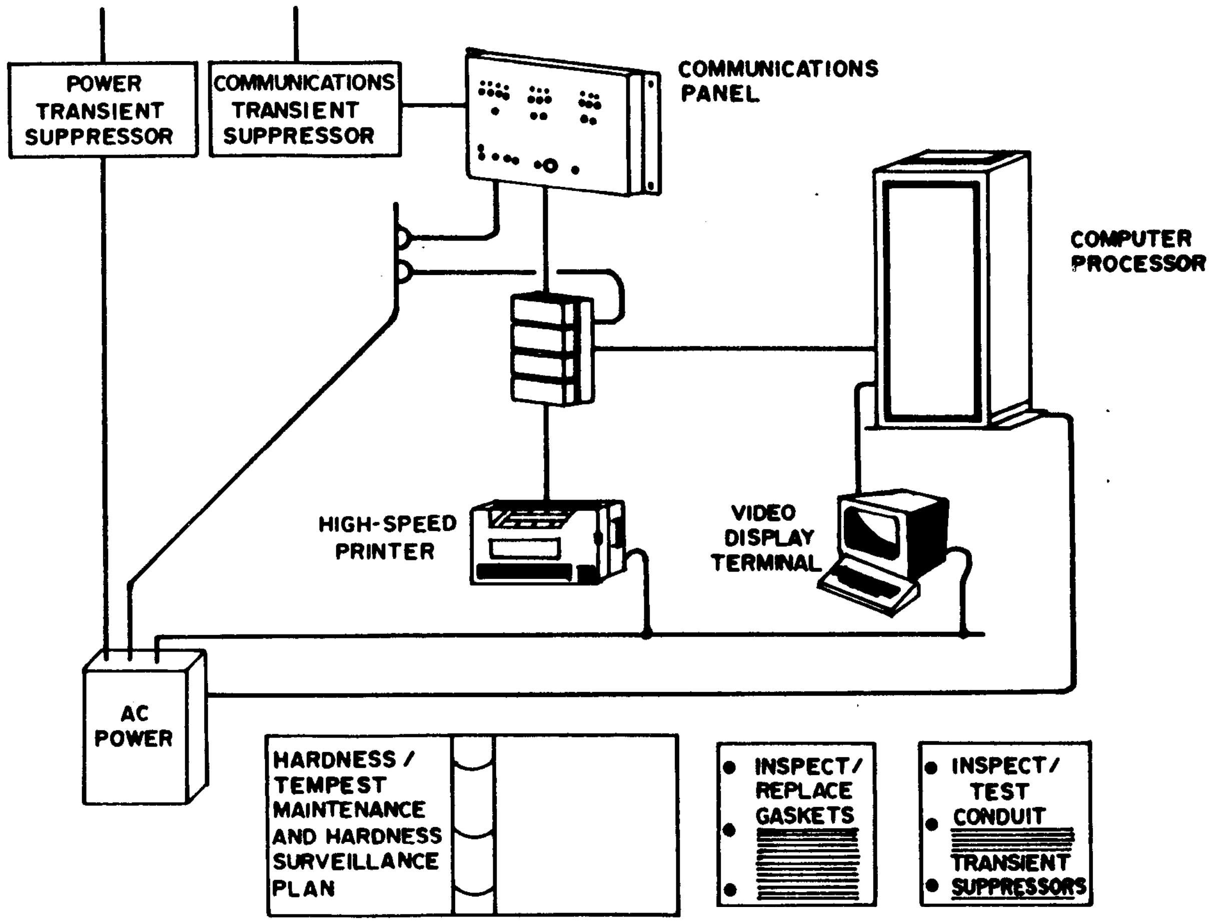

Figure 7-4. Example of maintenance procedures.