August 29, 1986

Subject: Corrosion Prevention and Control Program Plan (CPC)

Contract No: DAAB07-85-D-K015, Delivery Order 0005, Analytics Project 2027.05

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CECOM COTR: Gerald Cooper

A. Background: The following CPC Program Plan Outline and Schedule has been prepared IAW the SOW of the subject DO and Task 1 of the SOW. For Subtask 1.1, a draft CPC Outline & Schedule was submitted to CECOM 30 July 1986 and for Subtask 1.2, the final CPC outline and schedule, due 29 August 1986 is hereby submitted. The Statement of Work requires that the contractor develop and prepare a comprehensive Corrosion Prevention and Control (CPC) Program Plan to include objectives and schedules as follows:

Tasks	Objective	Date Due Draft	Final
1	Corrosion Prevention and Control Program Plan	01 Aug 86	10 Sep 86
2	A detailed applications guide;	15 Nov 86	30 Jan 87
3	An in-house training program;	31 Nov 19	30 Jan 87
4	Updated CECOM Supplement;	15 Dec 86	30 Jan 87
5	A CECOM Pamphlet, CECOM Pam 702.XXX.	01 Jan 87	30 Jan 87

The draft outline and schedule of the plan was due 30 July 1986. The Final Outline and schedule is due 29 August 1986.

Task 1. Outline Plan & Schedule:

a. Literature Search:

Initially, selected members of the Army Corrosion Prevention and Control Committee (CPCC) will be contacted to obtain copies of their Corrosion Control Plans which would be used for reviewing and adapting desirable features for the CECOM CPC. It is known that AF, MICOM, Navy and certain military contractors have had extensive corrosion study programs for years and have advanced control plans in effect; especially in Avionics, Fire Control, and missile guidance systems; which would be useful for CECOM purposes. Organizations to be initially contacted would be:

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Milt Levy	AMMRC
Fred Meyer	AF
Wendel Baker	AVSCOM
B. Cohen	NACE
F. Shaffer	NADC
R. H. Sparling	MICOM
Bob Thompson	PATFA DESCOM
Ed Hakim	ET&DL, Fort Monmouth

Since most of the Corrosion Prevention Plans do not treat corrosion of electronic hardware suitably, the following periodicals will be scanned to include the corrosion failure types currently being reported that are applicable to CECOM areas of interest:

IEEE Annual Proceeding - Reliability Physics
NACE Annual Proceedings
IEEE Transactions on Reliability
IEEE Transactions on Components, Hybrids and Manufacturing Technology
RADC Series "Physics of Failure in Electronics"
Proceedings of IEEE-EIA Electronics Components Conference
IEEE Transactions on Parts, Materials, and Packaging
ISHM Symposium Proceedings
GIDEP Alerts
RADC Failure Rate Data
Bell Telephone Records
International Society for Test & Failure Analysis (ISTFA): Conference, Proceedings and Physics of Failure Reports

In addition, QDRs and Fielded System Review Reports will be scanned to search for failure types being reported and which can be attributed to corrosion mechanisms. The above data should provide a basis for establishing TNPs and highlighting problem areas.

b. Applications Guide:

After a short tutorial, which identifies corrosion problem areas, the guide will provide corrosion type identification prevention and control procedures necessary in all phases of the acquisition and fielding cycles of communications-electronics (CE) equipments. In addition, it will also include:

- A glossary of terms and definitions
- A listing of Military, Federal and Industrial standards, specifications and documents applicable to CE equipments
- A specific contract clause to place in CECOM contracts
- A warranty clause appropriate to corrosion prevention guarantees

c. In-house Corrosion Prevention and Control Training Program

This program will include the following topics:

- Estimated dollar losses due to corrosion
- Tutorial review of corrosion mechanisms, identification, impact on CE equipments
- Corrosion problems in CE equipments
- Lessons Learned
- Preventive design techniques and protective treatments
- Environmental tests and their use
- Storage Serviceability Standards (SSS)

- Preventive maintenance, field usage, field storage
- Moisture & Fungus proofing treatments
- AHC CPC Program
- DARCOM R-702-24
- CECOM Pamphlet 702-XX
- Applications Guide
- Corrosion Warranty Program
- Inputs to CECOM Zenith 2100 Corrosion Program

d. CECOM Supplement to DARCOM R-702-24:

The CECOM Supplement to DARCOM R-702-24 will be reviewed and revised to agree with the latest guidance and regulating requirements from higher headquarters and changing technology and field usage and storage practices involved in acquisition and fielding of CECOM systems.

e. CECOM Pamphlet "CECOM Pam 702-XX":

An initial draft CECOM Pamphlet will be prepared and submitted to CECOM within 4 months after award of the Delivery Order. The final draft of the pamphlet will contain procedures for analysis of failure data from all sources of QDRs, EIRs, SDRs, etc. which will be formatted to show and justify a need for developing Technical Need Projects (TNP) for submission to AMMRC as required for Corrosion Prevention/Control Correction.

Task 2. Applications Guide:

1. The Purpose of this report

→ To provide CECOM engineers with a guide to the control of the quality and design of military electronics and electrical equipments; so that corrosion failures in the field can be prevented; maintenance costs can be reduced, and the equipment appearance enhanced. → to p. 8

2. Scope:

The Guide will include the following sections:

2.1 Tutorial treatment of corrosion mechanisms, identity, prevention
2.2 Lessons-learned of field failures
2.3 Glossary
2.4 Applicable and related specifications, standards, regulations
2.5 Sample Contractual SOWs, DIDs, standard paragraphs for use in each acquisition phase
2.6 Corrosion warranty standard paragraphs

All of the above will be limited to CECOM areas of responsibilities and objectives.

2.1 Corrosion Tutorial:

2.1.1 Basic Corrosion Mechanism Types
- Galvanic Corrosion Cell
- Direct Chemical Attack

2.1.2 Root Cause of Failure Types
- Galvanic Couples
- Anodic Pinhole Effects (Pitting)
- Stress-Cracking
- Hydrogen embrittlement
- Chemical (Contaminant)

2.1.3 Electronic Design Factors
- Couples (EMF)
- Contacts
- Joining (Bonding, Soldering)
- Printed Circuit Board Assemblies:
  - Single layer
  - Multi-layer
  - Echants
  - Cleaning
  - Soldering
- Antennas
- Power Supplies
- Batteries
- Connectors
- Waveguides
- Seals:
  - Gaskets
  - Pottings
- Hybrid Assemblies
- Active Devices
- Thermal Management
- Case Hardware

2.1.4 Electron Assembly Processing

- Contaminants, cleaning, abrasives, fugitive contaminants
- Soldering, fluxes
- Finishes, platings, coatings
- Repair, fixes, "buggering"
- Storage, on-line protection
- Material, assembly processes, procedures

2.1.5 Rate Factors

- Temperature
- Time
- Corrosion products properties

- Environmental:
  - Tropic
  - Arctic
  - Marine
  - Storage

2.1.6 Preventive Factors

- Packaging
- Preventive maintenance
  - Cleaning
  - Drying
  - Touch-up
- Overhaul
- MFP treatments
- Field measures, handling

2.1.7 Environmental Testing for Corrosion Resistance

The following tests, which are part of MIL-STD-810, are used to qualify the equipment assemblies for field usage:

Method 509.2 Salt Fog
Method 507.2 Humidity
Method 512.2 Leakage (Immersion)
Method 508.3 Fungus

Each of these tests will be described sufficient to provide an understanding of its effectiveness and limitations. Good practice methods in performing these tests will be given with a listing of some serious discrepancies that usually can occur. In each case, pass/fail criteria are given; including a description of the failure mechanisms that should be identified; if they occur.

2.2 Lessons Learned:

Classical examples of serious failure types, failure analysis, recommended fixes and estimated costs will be cited. Examples of types are given as follows:

2.2.1 Waveguide Corrosion
- TPQ-37
- ASN-128 Doppler Navigation

2.2.2 Connector Pin Corrosion
- Hawk Missile Thermal Battery
- Kovar-Glass Seals

2.2.3 Plastic Encapsulated ICs, Transistors, ARC-115 (RT)

2.3.4 Gold-Aluminum Intermetalics

2.3.5 Lead-Wire Corrosion

2.3.6 Case, Container, Hardware Corrosion

2.3.7 Contacts

2.3.8 Silver Migration

2.3.9 IC & Xsistor Bonds

2.3.10 Printed Circuit Board Assemblies
- Contacts, Connectors
- Copper etch
- Undercutting
- Plated through holes
- Thermal bonds
- Activated fluxes
- Cleaning (MIL-STD-28809)

2.3.11 Antenna
- MPQ-36, 37

2.3 Glossary

2.3.1 Terms, Definitions

2.3.2 Acronyms

2.3.3 Symbols

2.4 References

2.4.1 MIL-STDs, Regulations, Specifications

2.4.2 MIL-Pamphlets, Handbooks

2.4.3 Industry Practices, Process Controls, NACE, IEEE, Physics of Failure, Reliability Physics Publications

2.5 Contractual Clauses Applicable to Acquisition Phases

2.5.1 Concept Exploration

Determine from the ROC the mission profile, the operational mode summary, the equipment's planned platform use, and planned field exposure in certain geographic areas during use, transportation, and storage. The need for environmental protection required, and the level of corrosion resistance needed in designs will be predicted as directed in Paras 4.2.2, 4.5.9 and 4.6 of MIL-STD-810D, dated 19 July 1983.

2.5.2 Demonstration & Validation (D&V)

Prepare a Corrosion Control Plan which will assure that corrosion and deterioration of protective finishes, coatings and plaints will not occur when the completed design is exposed to the environmental conditions derived from Paras 4.2.2 and 4.6 of MIL-STD-810D, AR-70-38 and MIL-STD-210. The planned design should meet design criteria and process controls listed in Para 1.4 of DARCOM R-702-24. The Reliability Program Plan shall list plans for subjecting the Full Scale Development equipments to corrosion stress testing which will establish the ability of the equipment to withstand the following environmental tests included in MIL-STD-810:

Method No.	Title
506.2	Rain
507.2	Humidity
508.3	Fungus
509.2	Salt Fog
512.2	Leakage (Immersion)

2.5.3 Full Scale Development (FSD):

FSD models should be tested during DT-II to determine the capability of the equipment to be exposed to test conditions without any evidence of corrosion. All seals should be tested for leakage. All deficiencies and shortcomings shall be corrected by redesign and improvements. During this phase, a Warranty Program shall be developed which includes a statement of liability for the contractor to prevent corrosion and liability to correct corrosion deficiencies occurring in the field.

2.5.4 Production & Development:

All the tests listed above should be applied to determine the corrosion resistance quality of pre-production, first article test, and periodic lot by lot (Group B, C&D). While some corrosion mechanisms are caused by poor design, many are caused by process controls, i.e., cleaning, finishing, smoothness of substrate etc. Periodic testing, therefore, is required to continually assure good quality finishes. Those processes, materiel and assembly, which can cause corrosion if poorly applied, shall be identified and process controls and test established; which can be periodically checked to assure compliance to quality control levels.

In field deployment, transportation, and storage, prevention of corrosion can be assured by preventive maintenance practices which should be defined in SSS and Maintenance Manuals.

During production and deployment, the Warranty Clauses will apply and all of the provisions listed in the warranty section of the contract shall be processed and enforced.

Task 3. In-House Training Program:

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An in-house training program will be developed for one and two days: A basic training course will be prepared for technical and engineering personnel who are involved in research, development and design of communication equipments and systems. A quality control course will be prepared for inspectors, Quality Assurance, logistics and procurement personnel. The two courses will be similar except the basic course will emphasize corrosion resistant designs, while the quality control course will emphasize process and assembly control, inspection, testing, packaging, preventive maintenance, field usage, and warranties.

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3.1 Basic Training Course:

The first half would describe corrosion mechanism, their rate mechanisms, their relationship to failure mechanisms, system availability and designs necessary for corrosion prevention as follows:

3.1.2 Basic Forms of Corrosion

- Galvanic Corrosion Cell
  - Simple Cell
  - Galvanic Couple
  - Electrochemical Series
  - Pinhole
  - Migration
  - Stress, Fretting
- Direct Chemical Oxidation
  - Oxidation, Ozone
  - Vapor Attack, Liquid Attack
  - Poor adhesion
  - Industrial Contaminants
  - Natural Environments
  - Salt, Fungus, Erosion

3.1.3 Rate Factors

- Electrochemical Potential
- Electrode Area
- Time
- Nature of Corrosion Product
- Electrolyte
  - Microbial
  - Contamination, Natural, Industrial
  - Salt

- Nature of Corrosion By-product
- Humidity
- Time
- Stress
  - — Hydrogen Embrittlement
  - — Fretting Corrosion

3.1.4 Electronic Hardware Corrosion

- Solder Fluxes
- Contacts
- Lead Wire Corrosion
- Printed Circuit Board, Hybrids
  - — Fluxes
  - — Undercut
  - — Contacts
  - — Cleaning
- Connectors
- Waveguides
- Antennas
- Galvanic Couple Corrosion
- Silver Migration
- Transistor, IC Bonds
  - — Purple Plague
- Gasket Seals
  - — Gaskets EMI
  - — Leakage

3.1.5 Design Factors

- Case Seals
- Couples
- Grounds
- Thermal Management
- Stresses
- Finishes
- Decontamination Capability
- Critical Circuitry Protection
  - — Pottings
  - — Encasements
  - — Coatings
  - — Seals

3.1.6 Environmental Tests For Corrosion Resistance

The role of the various environmental tests, the mission profile, operational modes and global deployment will be discussed. Starting with the statement of need, the ROC and AR-70-38, the need to select environmental tests to determine compliance to military requirements will be discussed. The corrosion resistance evaluation role of each of the following tests will be detailed:

3.1.6.1 Salt Fog, Sea Mist
3.1.6.2 Humidity
3.1.6.3 Fungus
3.1.6.4 Synergistic Effects
3.1.6.5 Tropical Field and Marine Sites
3.1.6.6 DT/OT-II Tests
3.1.6.7 S.S.S Preparation with periodic inspection

The need to apply the above tests and inspections during the four phases of acquisition and will be discussed.

3.2 Quality Control/Field Engineering Course

The second half of the course would overlap the first basic half of the course by providing a non-esoteric description of corrosion mechanisms, their recognition, and then a discussion of quality control during production, environmental testing, pass/fail criteria, field engineering, TNPs, warranties, storage, and field usage to control corrosion.

3.2.1 Forms of Corrosion
- Galvanic Corrosion Cell
  - — Migration
  - — Pinhole
  - — Stress, Fretting
- Direct Chemical

3.2.2 Rate Factors
- Temperature
- Couples
- Humidity
- Time
- Contaminant

3.2.3 Electronic Hardware Corrosion
- Solder Fluxes
- Contacts
- Lead Wire Corrosion
- Printed Circuit Board
  - — Fluxes
  - — Undercut
  - — Contacts, PC Brand connectors
  - — Cleaning
- Connectors
- Waveguides
- Antennas
- Galvanic Couple Corrosion
- Silver Migration
- Transistor, IC Bonds
  - — Purple Plague

- Gaskets, EMI, Seals
- Leakage

3.2.4 Corrosion Prevention:

During the development phases of system acquisition, the design of the hardware is established and not subject to major changes. During production, materials, processes, and assembly practices must be controlled to the extent that the corrosion resistant quality of the product is not degraded. The following quality control practices must be imposed during production and fielding:

3.2.4.1 Process Control Specifications
- Material Finishes Specifications
  - -- Cleaning
  - -- Material Grades
  - -- Finishes, Coatings
  - -- Plastics
  - -- Impregnants, Lubricants, Adhesives

3.2.4.2 On Line Inspections Stations
- Subassembly Testing

3.2.4.3 Storage, Protection

3.2.4.4 Environmental Testing
- MIL-STD-810 Tests
- Pass-Failure Criteria

3.2.4.5 Quality of Rework
- Effect on Finishes
- Cleaning, Recoating

3.2.4.6 ESS

3.2.5 Fielding Practice

3.2.5.1 Packaging
3.2.5.2 Storage
3.2.5.3 Usage/Maintenance
3.2.5.4 Depot Overhaul
3.2.5.5 Warranties
3.2.5.6 Field Surveys

3.2.6 Preparation of Course Material

Course material provided will include:

- 2 sets of audio-visual support (vugraphs)
- 1 set of camera-ready student handout masters
- 1 set of instructor's text including reproductions of class visual aids with explanations of contents

Task 4. CECOM Supplement to DARCOM R-702-24:

The CECOM Supplement to DARCOM R-702-24 will be reviewed and revised to agree with the latest guidance and regulating requirements from higher headquarters and changing technology and field usage and storage practices involved in acquisition and fielding of CECOM requirements.

Task 5. CECOM Pamphlet "CECOM Pam 702-XX":

An initial draft CECOM Pamphlet will be prepared and submitted to CECOM within 4 months after award of the Delivery Order. The final draft of the pamphlet will contain procedures for analysis of failure data from all sources of QDRs, EIRs, SDCs, etc. which will be formatted to show and justify a need for developing Technical Need Projects (TNP) for submission to AMMRC as required for Corrosion Prevention/Control Correction. A step-by-step checkoff guidance required for completion of TNP proposals with source of information, failure analysis, corrosion types, costing, scheduling, and other pertinent information will be included. All this data will be reduced and formatted for use with a Zenith 2100 Personal Computer with periodic sorting and cumulative capability. Formatting instructions for periodic and final reports on CECOM TNPs will also be included.