Aircraft Corrosion Control and Maintenance

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1.0 WHY CORROSION OCCURS

Corrosion reaction - decrease in Gibbs free energy (- ΔG) - increase in the entropy (+ ΔS).

Thermodynamic relationship $G = H - T S$

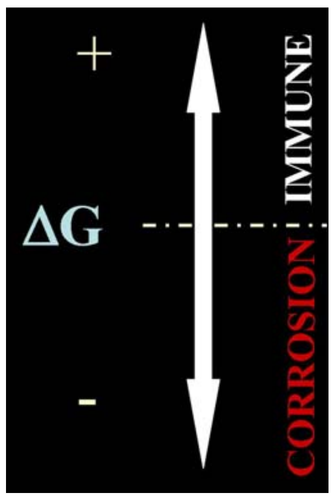


Figure 1: Why corrosion occurs.

ΔG, free energy change is a measure of the tendency of any chemical reaction, including metal corrosion. Negative ΔG indicates a pronounced tendency for a change or reaction. If $\Delta G = 0$, the system is in equilibrium.

Examples of reaction at 25°C:

- $2Al + 3/2\ O_2 = Al_2O_3$ $\Delta Go = - 409.4$ Kcal
- $Mg + H2O + 1/20_2\ c = Mg\ (OH)_2\ (s)$; $\Delta G° = - 420.6$ Kcal
- $Fe + 3/2H_2O + 1/20_2 = Fe\ (OH)_3\ (s)$; $\Delta G° = - 288.6$ Kcal
- $Au + 3/2\ H_2O + 3/40_2 = Au(OH)_3\ (s)$; $\Delta G° = + 15.7$ Kcal

2.0 TYPES (FORMS) OF CORROSION IDENTIFIED – APPLIES TO ALL AIRCRAFT PLATFORMS (TYPES)

- Exfoliation and Intergranular – ribs, spars, skins, fastener joints.
- Pitting and Crevice: localized corrosion under skins and coatings, fastener joints, overlaps, under sealant.
- Galvanic Corrosion: dissimilar metal joints – fastener holes, electronics, cable connectors, etc.
- Composite (Resin) Degradation: galvanic effects at metal joints, resin swelling or loss of fiber adhesion.
- General and Filiform Corrosion – under thin coatings.
- Corrosion Fatigue: load bearing structures such as landing gear, fastener holes.
- Stress Corrosion Cracking and Hydrogen Embrittlement.
- Microbially Induced Corrosion (MIC).

All forms of corrosion lead to:

Initiation → Growth → Fatigue/SCC Failure

3.0 CURRENT PRACTICE

NO DESIGN ENGINEERING POLICY ON CORROSION MITIGATION & CONTROL

Corrosion Control is an “after thought process”:

- Pretreatments and coatings are major defense against corrosion.
- Sealant in joints, splices and galvanic couples where possible.
- Sacrificial metallic coatings for landing gear steels.
- Ceramic coatings as H.T. corrosion barriers.
- Temporary protection schemes: CPCs, water displacing compounds and wash primers.
- Frequent equipment wash with/without corrosion inhibitor in wash/rinse waters.
- Damage assessment at ASPA/PDM cycles: select area corrosion inspection at depot level.

4.0 HOW ARE CORROSION REPAIRS DONE NOW?

During the three levels of maintenance, O, I and D:

- Remove condensed water from hidden structural cavities via drain holes and/or wicks.
- Replace components when repair is cost prohibitive.
- Fix when broken – schedule based inspection and maintenance (PDM cycle).
- Remove surface corrosion by grinding off corrosion products and applying touch up coating system.
- Repair of fastener hole crevice/pits/cracks – reaming the hole up to 30 mils wider and replacing with larger fastener.

- Use of composite patches where skin replacement is cost prohibitive.
- Strip and repaint after every 3-5 years.
- Material substitution/processing when/where possible.
- Use only MIL-SPEC approved materials and processes.

5.0 WHAT IS NOT DONE?

We do not:

- Design a system component with built-in design controls for corrosion resistance as an engineering requirement.
- Use best corrosion control fabrication practices in construction and assembly.
- Use best possible corrosion resistant construction materials – allowed under <u>acquisition cost and performance guidelines.</u>
- Use diagnostics and prognostics tools for life prediction and assessment – onboard sensors and devices.
- Use proper prediction models and software as a performance and maintenance tool.
- Use performance-based logistics strategy to determine life-cycle cost, down time and maintenance man-hours.
- <u>Apply corrosion engineering practice as a policy in all acquisitions.</u>

6.0 SOME ADVANCED TECHNOLOGIES FOR CORROSION MANAGEMENT

6.1 Corrosion Preventive/Inhibiting Compounds

P-3 operator/maintainers accepting aircraft back from depot maintenance (PDM) will being the application of WDCPS in specific areas of the aircraft. These areas are as follows:

- Aileron, elevators, flaps, and rudder control surfaces (internal surfaces/front spars/counter balance weights).
- Vertical stabilizer (internal surfaces/front and rear spars).
- Horizontal stabilizer (internal surfaces/front and rear spars/under upper and lower horizontal stabilizer-to-fuselage filler panels).
- Internal surfaces of aft hydraulic service center.
- Wings (internal surfaces of flaps and aileron shrouds/under upper and lower wing-to-fuselage fillet panels/forward and aft spar webs/wing access panel dome nut rivet heads/internal surfaces of engine nacelles and cowls.
- Internal surfaces of bomb bay doors and bomb bay.
- Main landing hear wheel wells (internal surfaces of doors and MLG wheel wells).
- Nose landing gear (internal surfaces of wheel well between FS150 and FS288 bulkhead).

- Forward fuselage of pressure bulkhead-FS156.
- Internal structure adjacent to lavatory area, including floor supports and frames.
- Internal structure adjacent to entry ladder area, including floor supports and frames.
- Internal structure adjacent to galley area, including floor supports and frames.
- APU compartment structure.
- Internal empennage structure including forward face of FS1117 pressure bulkhead.

6.2 Trivalent Chromium Pretreatment (TCP)

A trivalent chromium pretreatment for painting has been developed by the US Navy to replace the hazardous hexavalent chromium pretreatments:

- Environmentally friendly- no hexavalent chromates:
  - ➢ A room Temperature less than 5 minute process.
  - ➢ Applied by immersion, spray or sponge process.
- A US Navy patented process:
  - ➢ TCP can be used as post treatment for anodized aluminum and metallic coatings (IVD aluminum, cadmium, zinc-nickel).
- Highly flexible process:
  - ➢ "Drop in" replacement for chromate [Cr+6] conversion coatings in all applications and methods.
- Performance:
  - ➢ Performing as well as chromates in aircraft field tests.
  - ➢ Tested on four S-3s Viking; F/A-18 C/D and H-46.

Figure 2: F/A-18 undergoing re-paint.

6.3 Demonstration of Trivalent Chromium Pretreatment (TCP) H-46 Helicopters

Figure 3: H-46S masked for painting.

Figure 4: H-46S painted.

6.4 Advanced Organic Coatings

- High Performance Epoxy Primers (non-chromate version) - exceptional adhesion and chemical resistance for Al alloys. Being tested on F-18, T-45 and F-15 (joint services) aircraft.
- High Performance Polyurethane Topcoat for desired optical properties.
- Self-Priming Topcoat (SPT) – a low VOC non lead, non-chrome high solid polyurethane coating. Reduces one process step and minimizes toxic waste management.
- Appliqué Films – alternative exterior finishing in lieu of topcoat. Flexible thin film with a pressure sensitive adhesive serves as an excellent moisture barrier. Avoids VOC from painting operations.
- E-Coat Films – a bath process where charged paint particles are deposited electrochemically on an oppositely charged conductive substrate with controllable thickness.

- Powder Spray Coat – Applied by dip coating using fluid bed, depositing in electrostatic cloud chamber, and mostly by electrostatic spray process. Cure temperatures are usually ~ 150°C.

6.5 Photostrip – Photochemical Stripping of Aircraft Coatings

Process Highlights:

- Photochemical process uses UV light and inorganic chemicals to debond paint from painted surfaces.
- Process duration is less than 8 hours.
- Process applicable on a variety of substrates, such as, aluminum, stainless steel, composites, fiberglass, wood, and radome material.
- Process can be automated for each application.
- Minimal waste; no toxic waste contributed by the process and the chemicals used.

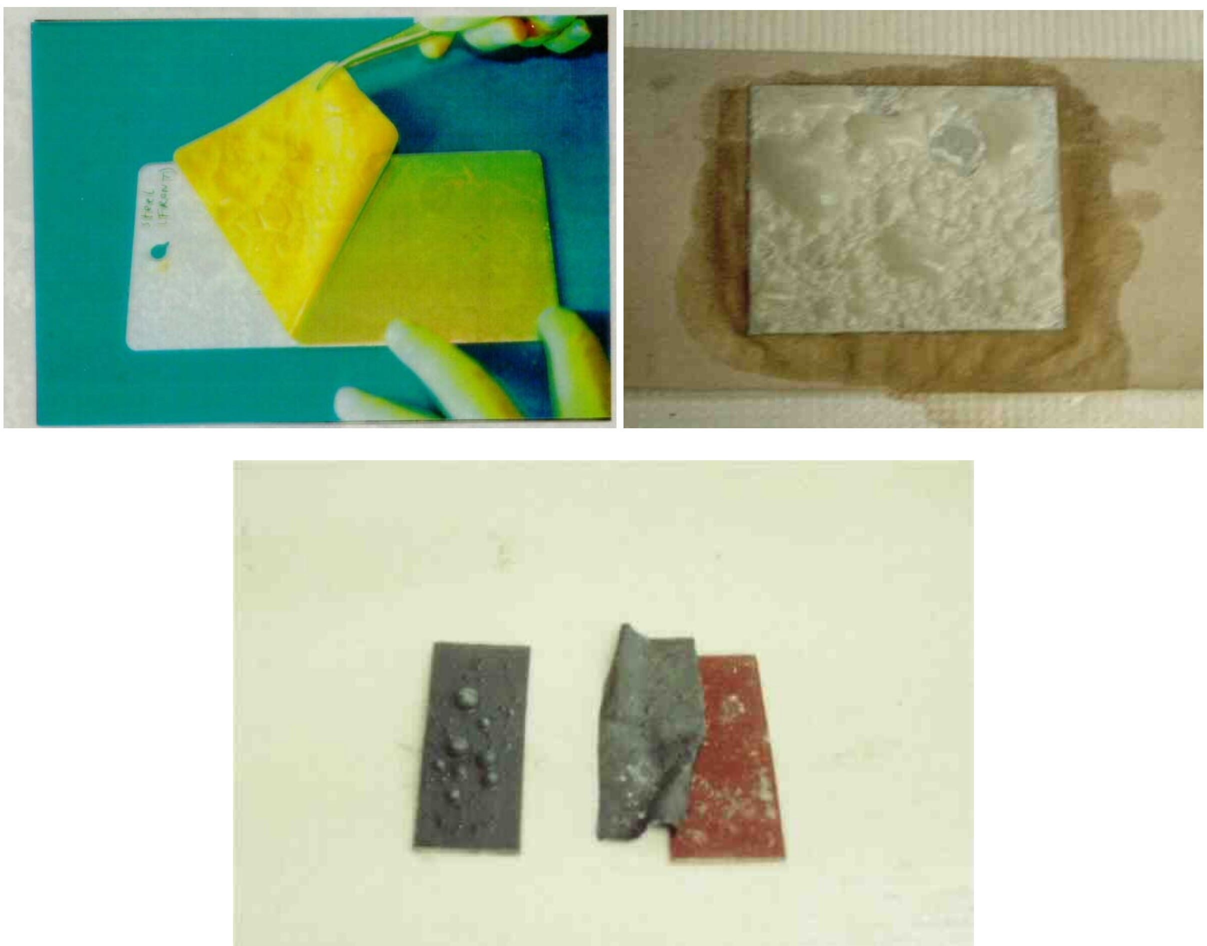


Figure 5: Photostripping of paint.

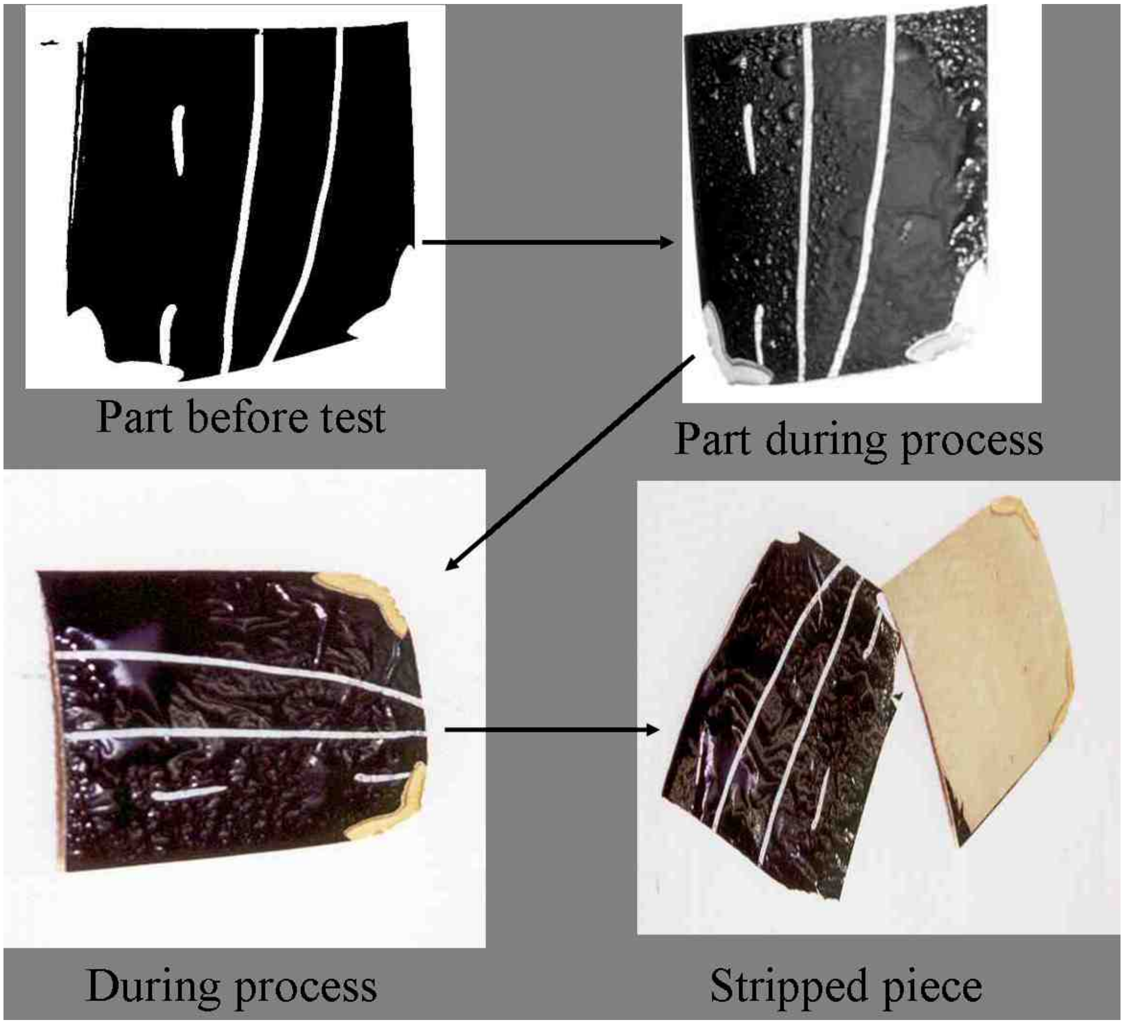


Figure 6: Photostripping of rotor blade coating.

6.6 Advanced Sealants and Adhesives

Need light weight/fast cure sealants qualified for aircraft. New sealants are 25% lighter → weight savings → lower fuel consumption → longer mission range. New sealants are faster curing (4 hours vs. 48 hours) → improved mission readiness.

There are a number of advanced sealants and adhesives that improve the effectiveness and reduce the time and cost of corrosion protection during manufacture and maintenance:

- Surface Sealants for magnesium:
  - Sermetel, Rockhard.
  - Exterior: under primer; Interior: replaces phenolic epoxy resin.
  - Required at depot repair when damage justifies stripping.

- Polysufide (RTV):
  - Hardens with age and UV.
  - Difficult to remove.
- Polythioether:
  - Stays flexible with age.
  - Good adhesive.
- Waxwrap (tape and spray):
  - Excellent dielectric (good insulator of galvanic joints).
  - Joints remove easy; leave greasy surface.
  - Not for high temperature application.
- Skyflex (TFE Foam Tape) – (for pressure joints):
  - All fastener joints.
  - All lap and butt joints.
  - Canopy seals.
  - Easily detachable.

Of these, Skyflex sealant is an outstanding example:

- An expanded polytetrafluoroethylene (ePTFE) sealant/gasket material; i.e. a "Peel and stick" Teflon foam tape substitute for 2-part paste sealants.
- Excellent environmental seal, hydrophobic and removable/ reusable; results in reduced corrosion.
- Reduced damage to parts during removal.
- Reduces need for frequent reapplication (typical for current sealants).
- Requires no mixing, masking or lengthy cure times.
- Replaces toxic polysulfide, which contains chromates and HAP solvents.
- Current Navy efforts include access panels of P-3, S-3, H-1, E-6 and H-60.
- Approved fleetwide for most aircraft platforms (access panels, floorboards), including sealing floorboards for the P-3, H-60 and H-53 platforms.

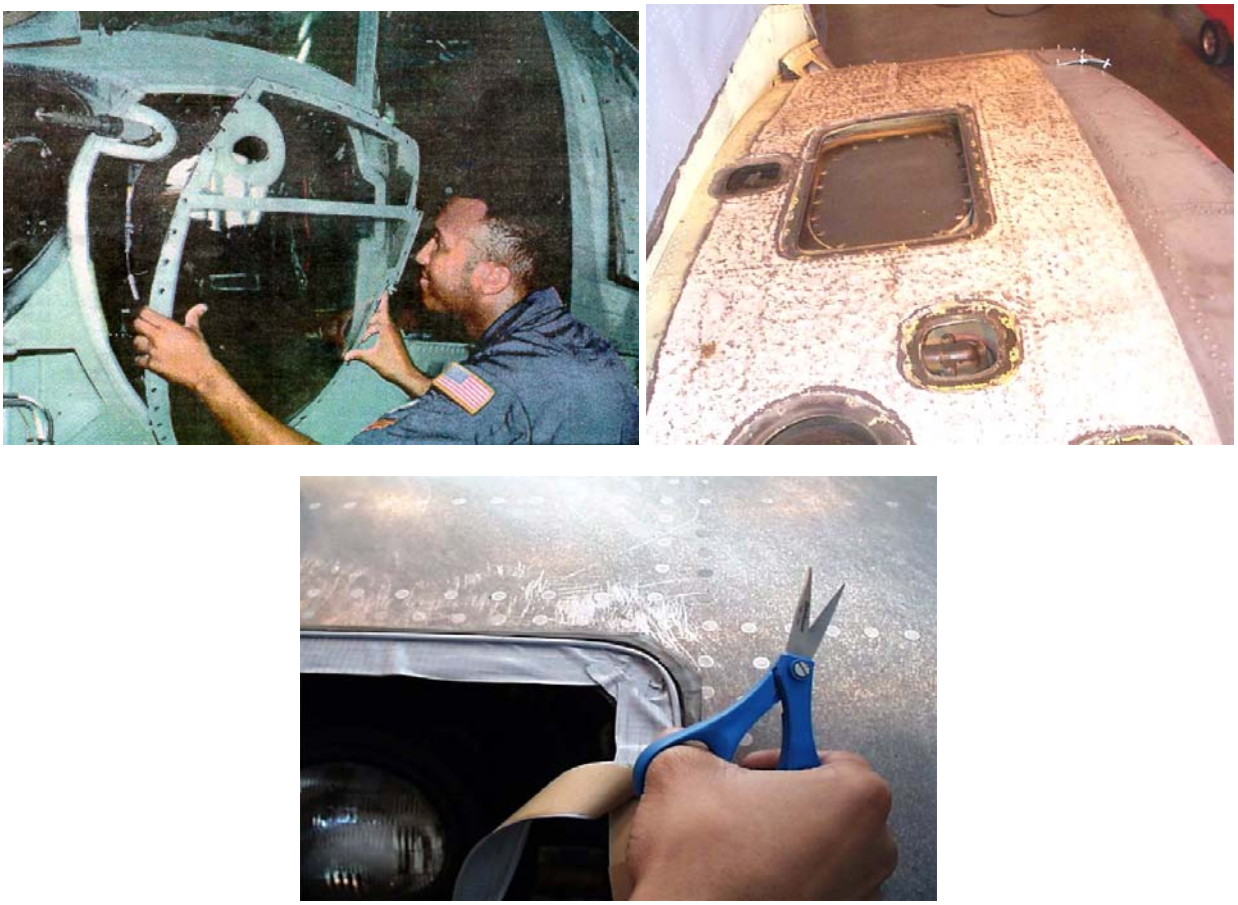


Figure 7: Skyflex Aircraft Sealant - "peel and stick" Teflon foam tape substitute for 2-part paste sealants.

6.7 Emerging Sealant Technologies

The following sealant technologies exist with limited application approval:

- Improved firewall sealants provide longer structural protection = improved survivability during fire (TA Mfg. and D-Aircraft).
- New conductive sealant provides improved durability and reduced shrinkage = lower maintenance/faster application (PRC-DeSoto Chemicals).

The following technologies are under evaluation:

- Conductive gaskets under evaluation provide environmental seal, corrosion protection, removeability option (manufacturer AV-DEC).
- Sealant removal techniques:
  - Bristle discs and rotary cutters from 3M simplify and speed sealant removal and reduce solvent use.

Figure 8: Bristle discs and rotary cutters from 3M simplify and speed sealant removal and reduce solvent use.

6.8 Fleet Outreach Program for Corrosion Management Technologies

There is a major fleet outreach program to advertise the benefits of these advanced technologies.

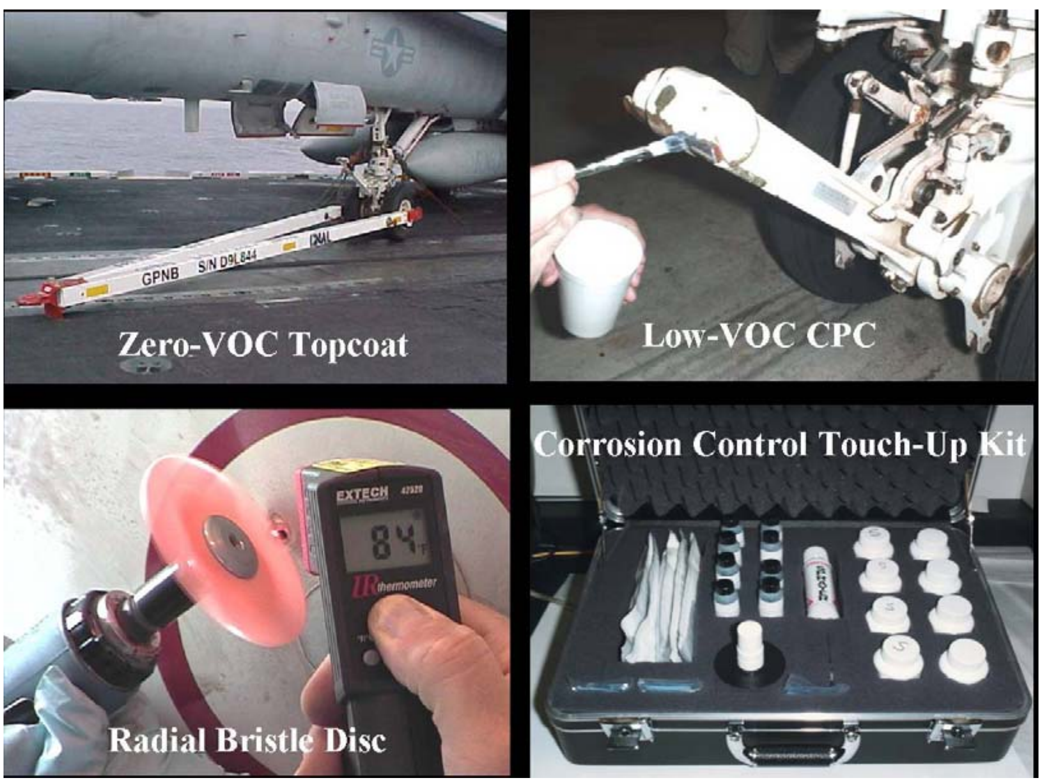


Figure 9: Fleet Outreach Program.

6.9 Aircraft Inspection – NDE of Corrosion

There are a number of new microwave NDE Concepts. An example of a hand held device for directed inspections is the Alpha MCD hand-held device:

- Routine/spot NDE for corroded areas.
- Reachable into small areas to detect oxides.
- Very useful in high risk corrosion areas.
- Simple, portable, fast, battery powered.

Figure 10: Alpha MCD unit.

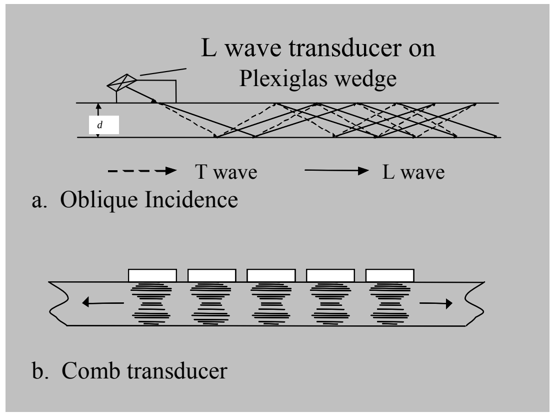
Several new NDE concepts are available for wide area coverage. Many of these are robotic with automatic evaluation and detection systems:

- “Rake-like” array device could carry 10 to 12 sensors.
- Wide area coverage for fuselage, wing, etc.
- Alarms would indicate corrosion location/ severity.

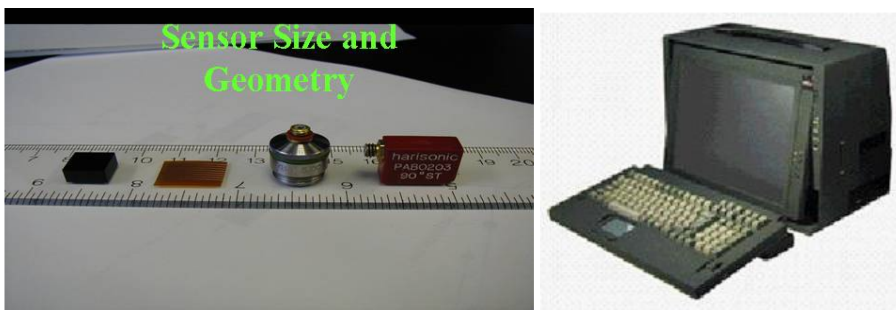
An example of the application of advanced NDE for detecting and monitoring environmentally assisted cracking is the H-60 transmission support beam cracks.

Figure 11: H-60 transmission support beam cracks.

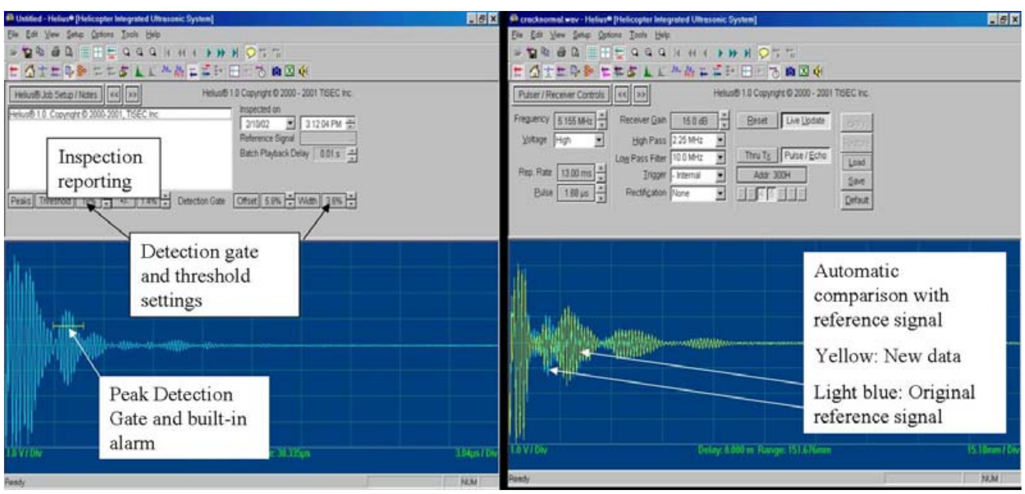
Major contributor to the problem is the increase in the working gross weight with no increase in the strength of the structure. Ultrasonic guided wave inspection was developed for the detection of the cracks.



a) Technique for the generation of guided waves.



b) Sensors (left) and HELEUS hardware
(modules in a PC environment supported by powerful software).



c) Built-in Crack Detection Gate and Reporting Guided Wave Sensor.

Figure 12: Ultrasonic guided wave inspection developed for detection of H-60 cracks.

6.10 Corrosion and Environmental Sensors

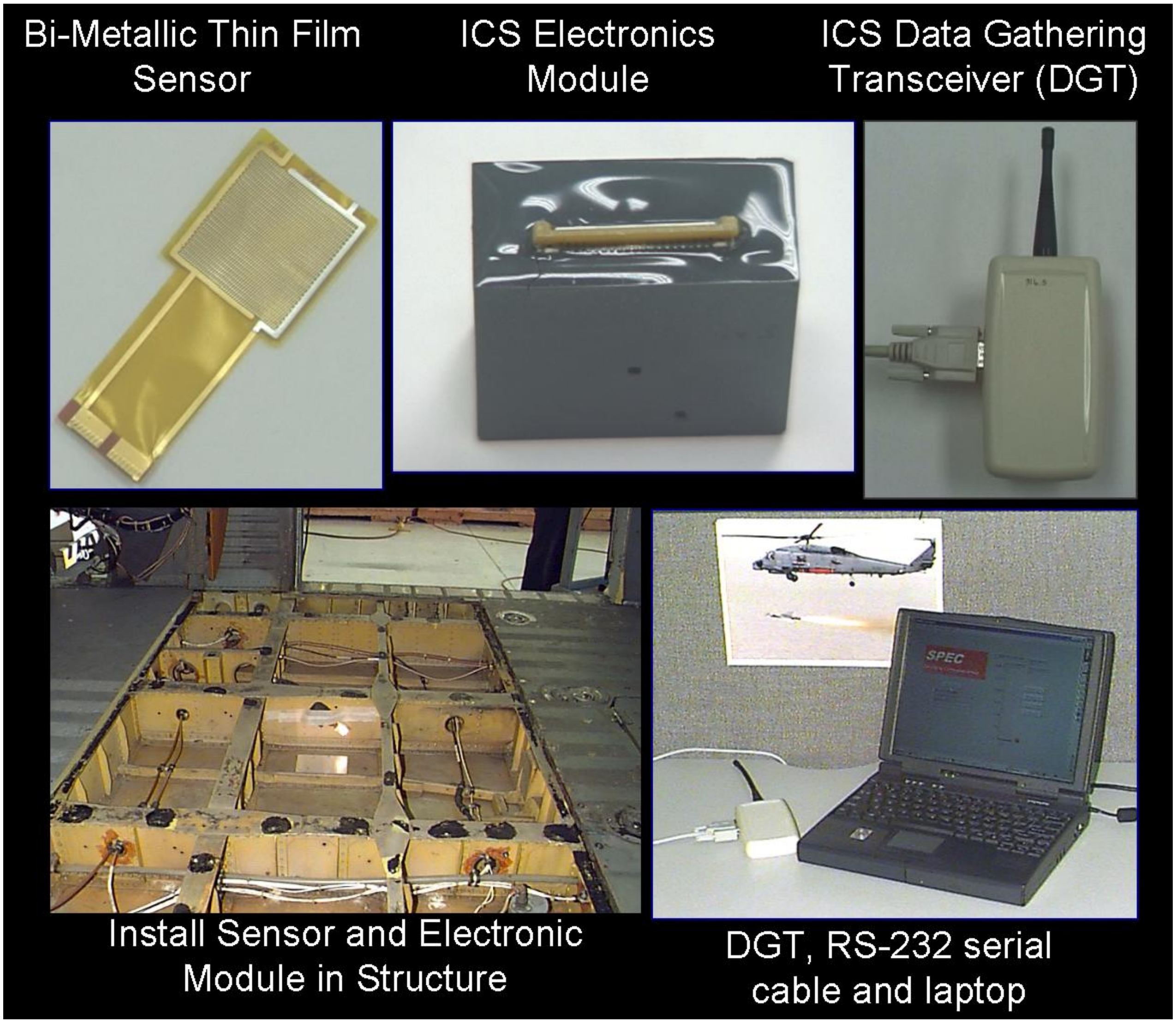


Figure 13: Environmental (moisture) sensor for use on aircraft structure.

7.0 CONCLUSION

Our challenge for corrosion control and life management:

- Re-capitalize with best corrosion control practices.
- Transition enabling technologies.
- Promote corrosion engineering education.
- Implement prognostic/diagnostic tools.

- Continue to develop innovative solutions – promote R&D.
- Modify acquisition policy.

Figure 14: Our challenge for corrosion control and life management.