Chapter 2 – REPRESENTATIVE NATO CORROSION POLICIES (GERMANY)

GERMAN AIR FORCE (GAF) CORROSION POLICY

Dipl. Ing. M. Buderath
GERMANY

2.1 INTRODUCTION

To overcome Corrosion problems on aircrafts, a management working group structure was organized to support the fleet with all available expert competence.

In 1990 a national Corrosion working group within the GAF, called "AK/UAK Korrosionsschutz", was established with additional scientific and technical support of:

- Bundeswehr Research Institute for Materials, Explosives, Fuels and Lubricants (WIWEB) at Erding;
- National support company EADS MAS; and
- Independent repair facilities (Military Aircraft Service Center at Erding, etc.) and supplier on demand.

The aim of this Corrosion working group was to provide 1993 a Corrosion Prevention and Control Program (CPCP). A concept and systematic to manage and overcome Corrosion problems of aircrafts and the implementation of a Corrosion Control Register (CCR).

2.2 DESCRIPTION OF CORROSION PREVENTION AND CONTROL PROGRAM (CPCP)

The CPCP-concept was to develop a comprehensive approach for the GAF in-service military aircrafts to:

- Support environment-friendly state-of-the-art long-term technical solutions; and
- Define activities with the aim of cost benefit and cost effective proceedings.

The following figures show firstly the schematic cycle of new activities and secondly the continuously doing of prevention and repair measures during maintenance and inspections within the different maintenance levels.

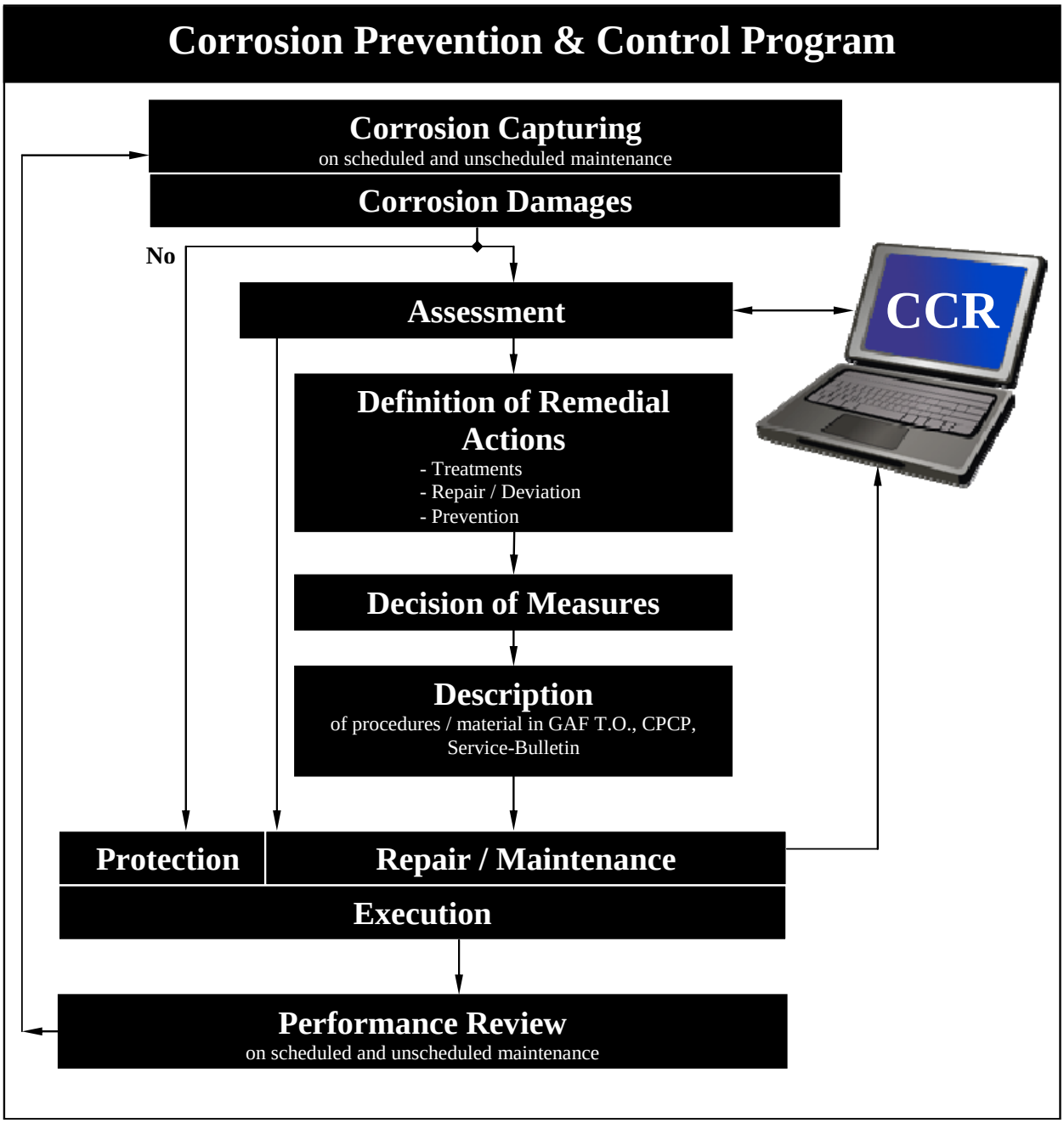

Figure 2-1: Schematic of the Corrosion Prevention and Control Program Cycle.

An example of scheduled and unscheduled maintenance measures within the CPCP program is schematically represented in the next figure.

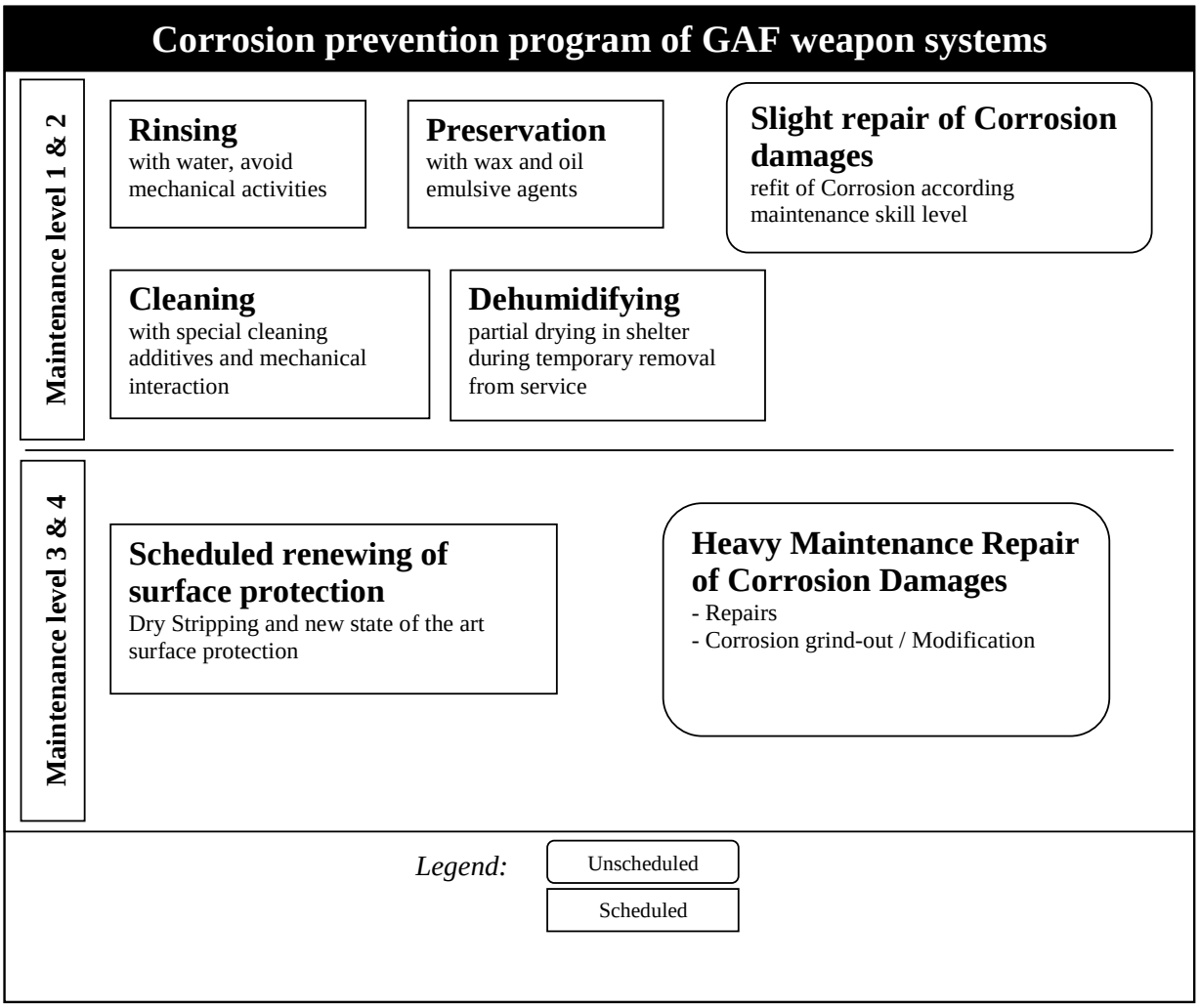

Figure 2-2: Schematic of the Continuous Prevention and Repair Measures Within the Different Maintenance Levels.

2.3 DOCUMENTATION AND CONTROL OF CORROSION

This CPCP program details the basic principle of Corrosion detection, assessment, documentation and control. With assistance of the ADP-supported **C**orrosion **C**ontrol **R**egister (**CCR**) the structure and attaching parts have to be captured from each weapon system.

Subject of the CCR is:

- To capture, control and classify Corrosion damages;
- To find out Corrosion emphases in due time;
- To define effective repair schemes; and
- The determination of efficiency to protective treatments and preventive actions.

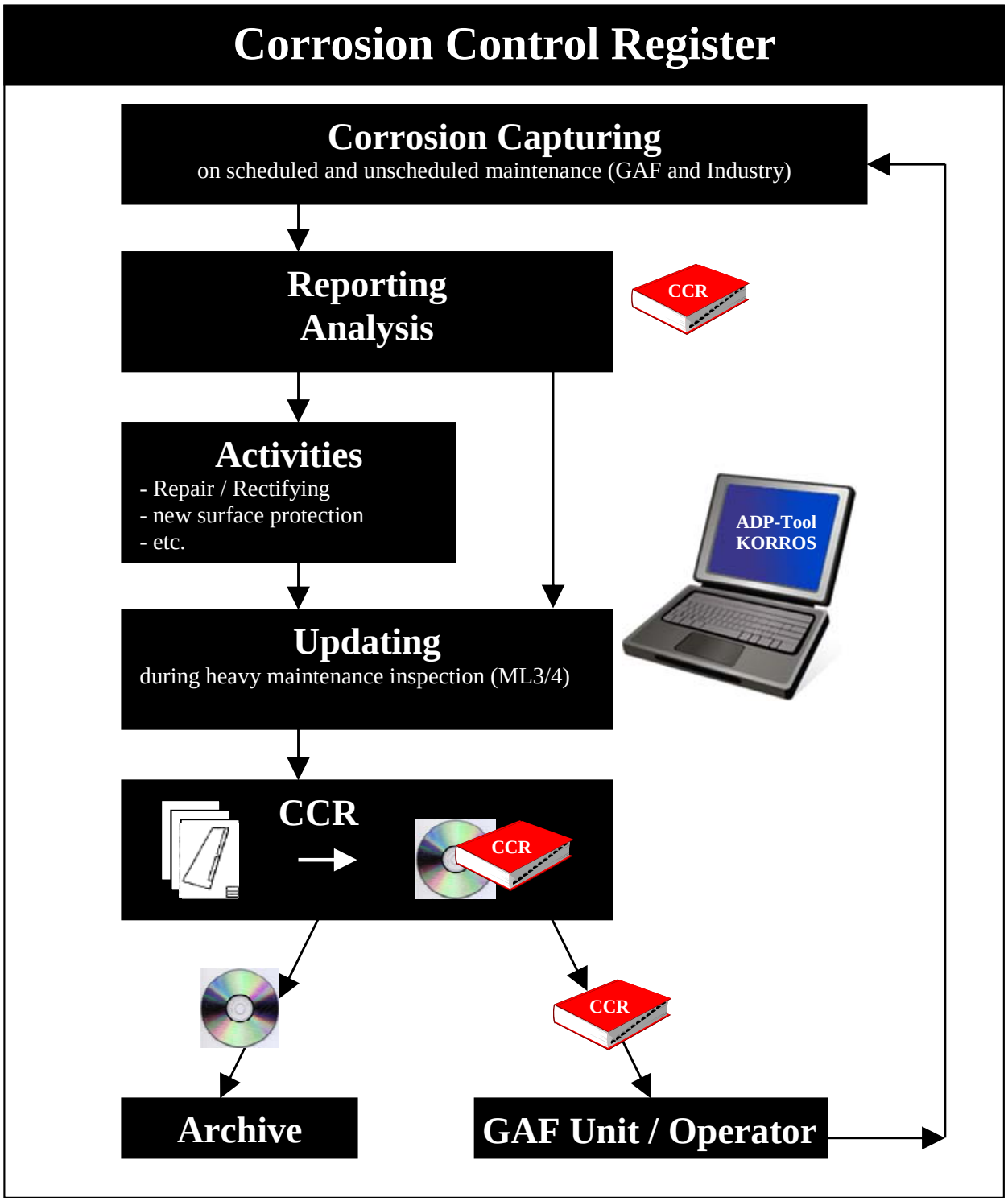

Figure 2-3: Example of CCR Documentation Concept.

The detailed position and frequency of captured Corrosion damages are registered and evaluated within the ADP system. The following picture shows an example of corresponding skin panel evaluation plots CCR-generated.

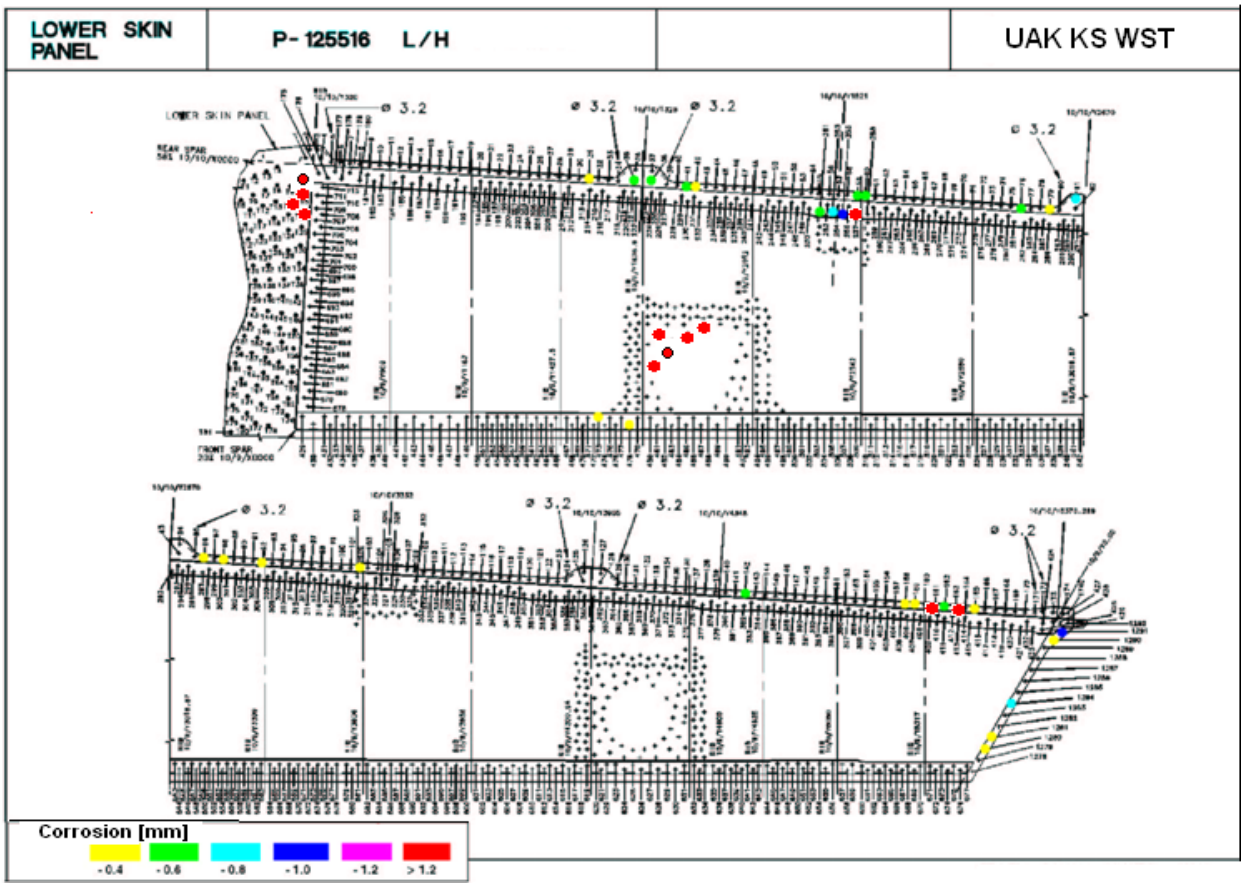

Figure 2-4: CCR Generated Evaluation Plot on Example Component.

Subject of the evaluation with the help of the CCR is to emphasise components and zones particularly concerned in order to point out statistically representative Corrosion concentration and supplies investigations of corroded areas with fatigue critical areas for example.

Beyond that further aircraft factors, like:

- flight hours,
- age in years,
- inspection dates,
- parts/serial numbers,
- dimension of corrosion grind-out and position, and
- the increase of corrosion

are represented from the aircraft/fleet over the total life cycle.

It is important that the capturing (ADP) of the Corrosion data inclusive the NDT test equipment is already available with the delivery of the aircraft.

2.4 COLLECTION DATA REQUIREMENTS

Corrosion Data capturing and collection is one of the most important parts of setting up a proper model. Without a systematic data capturing the best analysis model supplies unrealistic and wrong results. For the integrated assessment, monitoring and prediction model a considerable amount of data is needed. To facilitate data capturing and collection, the development of a support data user interface Tool is mandatory to be available from aircraft in-service date.

Beyond that unique data capturing and assessment stringent support corrective actions with a so called portable support system [PSS], which serves as the support frame for ground personnel damage documentation, during the production stage, pre and post and depot-level inspection.

A/C-Structure Maintenance
Process Steps

Figure 2-5: Example PSS – Concept of Operation.

2.4.1 Visual Inspection Module of PSS

- Checklists are available as paper-based documents.
- Electronic checklists on mobile devices:
  - Integration into existing distribution proc; and
  - Automatic updates.
- Automatic links to reference information.
- Structured data acquisition via electronic form:
  - System breakdown can be searched, e.g. by part number;
  - Facilitates pre-population of electronic form;
  - Only incident specific data needs to be entered manually; and
  - Possibility of automatic completeness and plausibility checks.

2.4.2 Non-Destructive Inspection (NDI) Module of PSS

- Structured data acquisition using mobile NDI Systems at the A/C:
  - Data storage in NDI database; and
  - On-demand generation of NDI Report.
- Electronic attachments enable remote diagnosis for out-of-area deployments.

- Links to information systems, e.g. 2D and 3D construction data available at the A/C.
- Guided damage classification.

2.4.3 Damage Assessment Module of PSS

- Damage categories and corresponding standard repair procedures approved by OEM (Best Practices).
- Damage database provides decision support for handling damages, which do not map to categories.

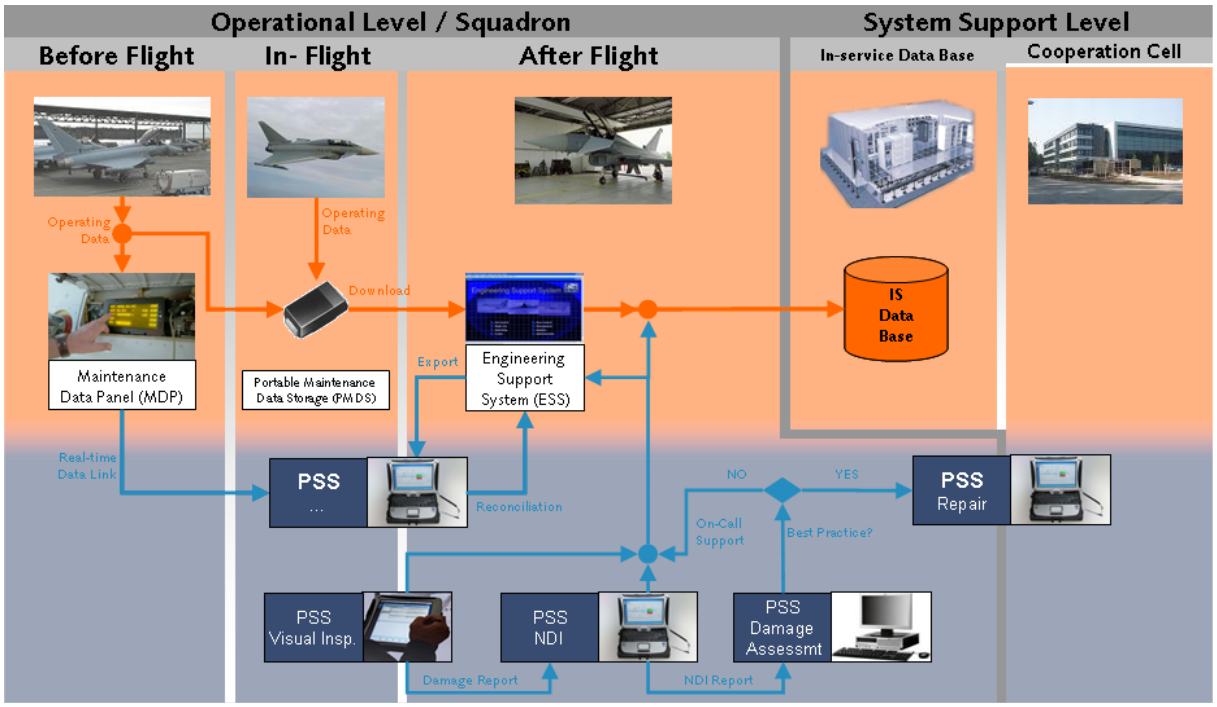

Figure 2-6: PSS Concept of Operation Example.

2.5 SYSTEMATIC CAPTURE OF CORROSION ARISINGS

2.5.1 Service History

Capturing of data for assessment of:

- Usage life/extension;
- Identification of corrosion concentration / hot spots;
- Remedial activities;
- Preventive activities;
- Change and shortfall of changeable items;
- Maintenance planning; and
- Highlights for new constructions.

2.5.1.1 Maintenance Data

2.5.1.1.1 From Scheduled Maintenance

- **Maintenance Level 1 and 2 (ML 1&2)**

  The primary objective of this maintenance is to provide safe, mission-capable aircraft to satisfy all mission requirements. In peacetime, the primary mission is training for combat. In many instances, peacetime training requirements for aircraft are almost as stringent as battle requirements. The maintenance manager must realize the significance of aircraft availability if the unit is to accomplish its mission in both battle and peace.

  It is preformed at the lowest level consistent with the tactical situation, skill, time, repair parts, tools, and NDT-test equipments.

  The proper use of specified and identified report forms is mandatory and must be managed.

- **Maintenance Level 3 and 4 (ML 3&4)**

  This method is for aircraft undergoing extensive repairs or lengthy inspections. It uses a fixed maintenance dock. The dock could be a location in a hangar or shop, a parking spot on the flight line, or any prearranged location. The aircraft normally remains in the maintenance dock until all maintenance is complete. Maintenance crews or teams rotate to and from the aircraft.

  The proper use of specified and identified report forms is mandatory and must be managed for the depth and skill of heavy maintenance and availability of appropriate repair parts, tools and NDT-test equipments.

2.5.1.1.2 From Unscheduled Maintenance

Those unpredictable maintenance requirements that had not been previously planned or programmed but require prompt attention and must be added to, integrated with, or substituted for previously scheduled workloads.

Unscheduled maintenance activities have to be viewed and reported under the skill and depth of repair of ML 1&2.

2.5.1.1.3 From Deferred Maintenance

Minor faults noted during daily inspections that do not affect mission readiness or the safe operation of the aircraft may be deferred until the next scheduled maintenance/inspection.

The proper use of specified and identified report forms is mandatory and must be managed due to direct influencing the backlog and delay when the aircraft receives scheduled maintenance.

2.5.1.2 Environment of Aircraft Operation

- **Peace Time Maintenance/Repair**

  Peace time activities follow the directives and specified maintenance shown above.

  Operating experience in varying geographical areas, in particular maritime mission, special attention concerning corrosion monitoring must be implemented.

- **Battlefield Maintenance/Repair**

  Battlefield damage maintenance must be divided into two separate but mutually supporting functions – battlefield damage assessment and battle damage repair.

  This concept requires the full range of newest technology elements for monitoring, prognostic, diagnostic and remote communication to allow specialist assessment with the best endeavor to get the situational awareness.

  This kind of maintenance/repair involves inspecting the damaged aircraft system to determine the extent of damage, classifying the equipment according to the type of repairs required, and developing a plan of action with qualified support.

2.5.1.3 Categorization of Corrosion Damages

The categorization of the individual corrosion damages is necessary to obtain the range of corrosion damages for the system. Primary considering those flight safety referred components.

Differentiation is required according

- **Category 1**
  - Damage without further measures than the simple repair.
  - Corrosion damages of low extent, not exceeding permissible grind-out depth as per specification.
- **Category 2**
  - Damage with no further additional measures required, but intensive monitoring.
  - Corrosion damages of medium extent, exceeding permissible grind-out depth, but still no flight safety-critical state and consequential damages are expected.
- **Category 3**
  - Damage of serious extension, which requires immediate measures beyond the repair of the aircraft system.
  - Corrosion damages over the permissible grind-out depth and flight safety-restrictive measures; high economic risk available and thus immediate measures are necessary.
  - With the help of categorization it is reached that in future only investigations are authorized which effecting damages of the whole aircraft fleet.

2.5.2 Corrosion and Failure Analysis Data

The production of a detailed corrosion analysis and assessment can only be established on fundamental corrosion and failure analysis data fleetwide captured. Special attention must be focused on the world wide aging aircraft fleet and the long enduring capture and collection of corrosion damage and repair data. Combined with new inspection techniques and highly sophisticated sensor applications the corrosion data capturing and monitoring requires great affords to meet the challenge solving complex corrosion problems.

With the help of adequate capturing and monitoring tools the subsequent corrosion and failure analysis data are required.

Table 2-1: Form Used for Corrosion Data Capturing and Monitoring.

Aircraft Type / Equipment	
Aircraft Serial Number	
Datum Aircraft Delivery	Aircraft handover in-service
Aircraft Unit Code	Base of operation for minimum 6 month in the past
Part Number	PN
Serial Number	SN
NATO Stock Number	NSN
System/Work Unit Code	or higher component
Corrosion Location/Position	[mm]
Original Material Thickness	[mm]
Allowed Material Thickness	[mm] according Techn. Directive
Damage Grind-Out	• Depth [mm] • Area [ø mm] or plot • Perimeter [1/8 partition]
Corrosion Appearance Code	1 – Smooth corrosion abrasion 2 – Pitting corrosion 3 – Exfoliation corrosion 4 – Crevice corrosion
Corrosion Initiation Code	1 – From fastener 2 – From drill hole / countersink 3 – From overlap/edge 4 – Free surface 5 – Others
Corrosion Extension Code	Category 1 “simple repair” Category 2 “intensive monitoring” Category 3 “immediate measures”
Corrosion Activity Code	1 – New surface protection 2 – Grind-out of corrosion 3 – Cavity conservation 4 – Compilation of deviation 5 – Repair scheme 6 – Exchange of component 7 – Deferred repair to the next scheduled maintenance
Map of Corrosion Area	History mapping with support tools proposed (3D mapping)
Total Flight Hours	Flight hours up to the time of capturing the corrosion damage
Flight Hours Since Inspection	Flight hours since last inspection
NDT Sensor Signal available	NDT Report as attachment or detailed description under Notes
Datum	Datum up to the time of capturing the corrosion damage
Initials	Initials of person performing the corrosion check
Notes	Additional information from corrosion damage capturing

2.6 COLLECTING SYSTEM

The corrosion data collection system must be a process oriented and ADP-support centered system with interactive edits. Included in the system are several integrated terminals that are used to update or enter additional information.

The purpose of data collection is to obtain information, to keep on record, to make decisions about important issues and to pass information on to others.

The formal data capture and collection process is necessary as it ensures that data gathered is both defined and accurate and that subsequent decisions based on arguments represented in the findings are valid to maximize their usefulness in compliance with state of the art engineering reporting requirements.

Furthermore the management of critical corrosion locations must be monitored, harmonized and assessed with other structural integrity issues, e.g. fatigue. Therefore the systematic usage of a data capture and collection system is significant in solving safety critical aspects of aircraft systems everywhere on maintenance and operation bases.

Therefore to support the ability for a reliable assessment and maintenance/repair performance an adequate on-site mobile ADP Support System is prerequisite. Beyond that the integration of existing processes and diagnostic systems must be supported to:

- Interface with additional Information sources;
- Analyse reliable situational awareness;
- Provide decision support;
- Realize maintenance/repair and on-the-job training; and
- Show and trace the digital collaborative workflow.

2.6.1 Data Log

For the management and assessment of different capture and collection data from data sources and data sharing across functional areas the following Data Logs are proposed.

MWO Ident No.	
Key Text	Description
Ident No.	This number is to identify a MWO (Maint. Work Order) uniquely. This section can be filled in also from another source. The number must make possible a unique allocation of the work order definition – otherwise the date has to be integrated here.
Mandatory Field	Yes.
Working Hours	
Man Minutes	The working hours for the complete work are indicated. This section is added for data capturing and can be filled in also from another sources.
Mandatory Field	No.

Checker

Worker	Because of partly working several persons under MWO, it cannot be indicated who must register itself here uniquely. Therefore this section serves rather in order to call a negotiating partner for questions concerning the damage.
Mandatory Field	No.

When Found Code

When Found Code	The When Found code indicates on which activity the damage was found (e.g. GAF T.O. -06); for example during a depot level inspection or unscheduled maintenance inspection, etc.
Mandatory Field	Yes.

When Found Date

When Found Date	This date indicates when the damage was found (dd.mm.yyyy). This section is added for data retrieval and can be filled in also from other sources.
Mandatory Field	Yes.

Event Code

Event Code	The indication on which process the damage was captured (according GAF T.O. -06 e.g.) e.g. maintenance, depot level inspection, special inspection, etc.
Mandatory Field	Yes.

Repair Date

Repair Date	This date indicates the beginning of repair. This section is added for data retrieval and can be filled in also from other sources.
Mandatory Field	Yes.

Notations

Note	All information are recorded which cannot be expressed by codes.
Mandatory Field	No.

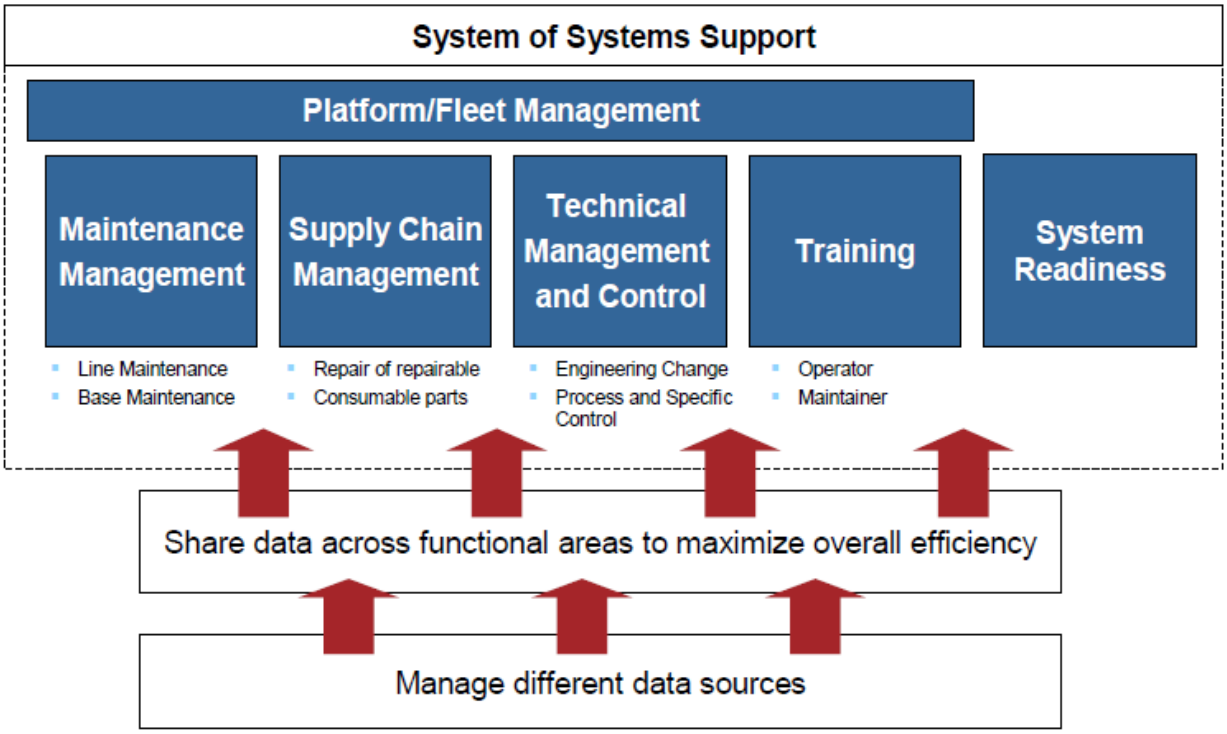

Figure 2-7: The Complexity of System Shared Data Support.

2.6.2 Analysis of Data

Data basis for the following evaluations is a corrosion data base of a combat aircraft. This data base is internationally almost singular to its extent; in the meantime other Nations use likewise corrosion data bases.

Already shortly after the aircraft delivery into service corrosion damage collection was started. It is very important to start the systematic damage capturing directly after the aircraft in-service date with a well structured and harmonized ADP data base tool.

The data capturing takes a major part of the total aircraft repair time and is mainly applied during Depot-level Inspection (DI). In this phase the aircraft is stripped and high dismantled for detailed damage investigations. Apart from the DI check several smaller inspection intervals accomplish additional capturing data just as well during aircraft operation at Main Operation Base (MOB).

Whereas the not availability of special inspection equipment and skills for more detailed damage investigation at MOB prevents accuracy of corrosion data capturing. In cases of urgency a specialist team is requested.

Nevertheless, in order to make sure a trustful data capturing validity checks are mandatory in combination with excellent skilled inspection staff.

Corrosion occurs in a wide variety of the aircraft structure and if ignored, it will threaten aircraft structural integrity, shorten fatigue lives and become a major cost driver. Therefore the corrosion reporting and analysis of data is of highly importance.

With an actively monitoring of corrosion arisings, the analysis of aircraft areas of concern (corrosion hot spots) will be possible at an early stage.

2.6.2.1 Analysis of Captured Corrosion Fleet-Wide

Basis of these analysis examples are the data specified under Section 3.1.

Distribution of Corrosion Grind-Out Depth

The figure shows the probability (y-axes) of grind-out depth exceedance (x-axes) reported from the aircraft fleet in a logarithmic scale. The average grind-out depth, according to the 50% line, reflects about 0.4 mm. “Count” general defines one corrosion data base entry.

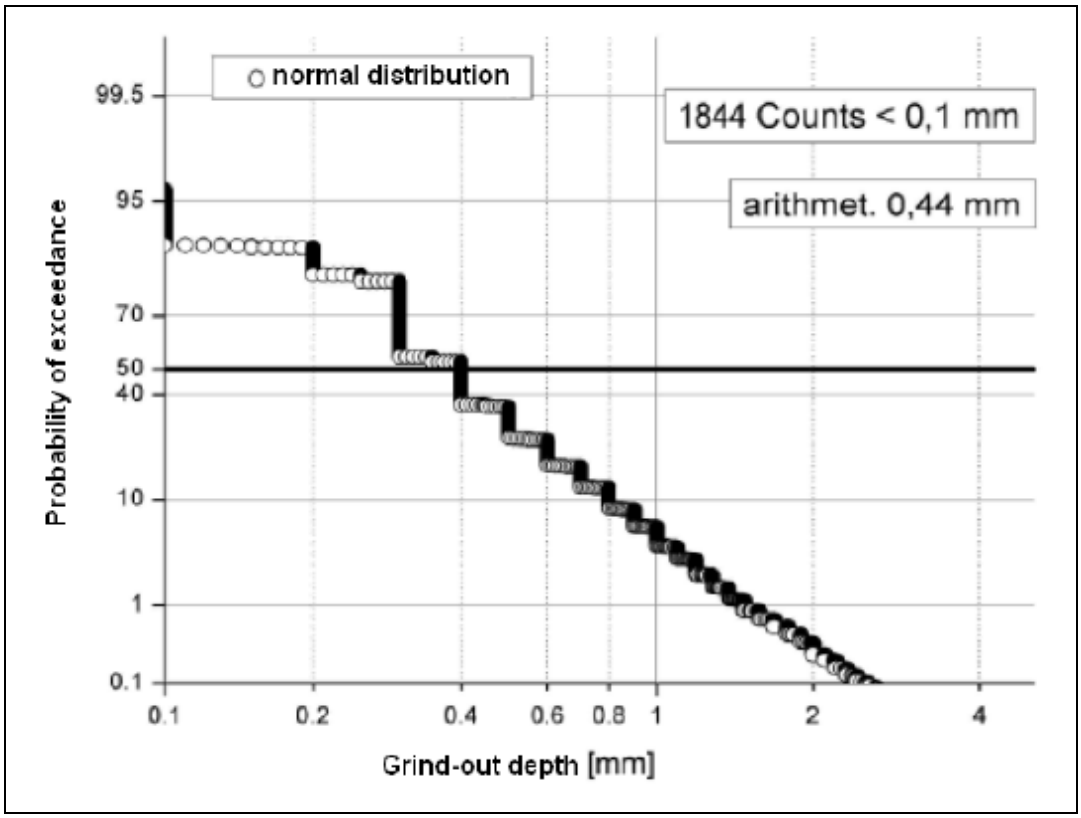

Figure 2-8: Grind-Out Depth of Complete Aircraft Fleet.

Comparison of Corrosion Over Aircraft Fleet

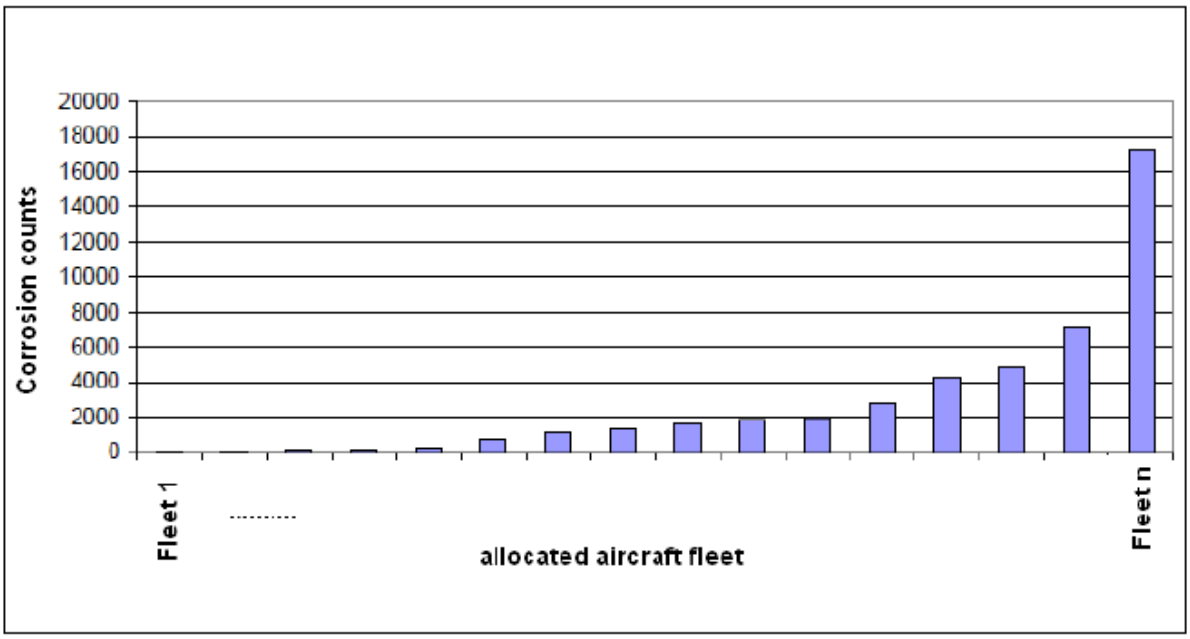

Figure 2-9: Corrosion Distribution Over Aircraft Fleet.

2.6.2.2 Detailed Analysis Example of Aircraft Corrosion

The following chapter reveals the evaluation and analysis of aircraft areas of concern. Basis of these analysis example are the data base details specified under Section 3.1.2.

For example some parameters are analysed according data base counts.

Table 2-2: Example of Analysis Centered on Data Base Counts.

Parameter	Definition	Counts acc. Data Base
Corrosion activity Code	1 – new surface protection	19
	2 – grind-out of corrosion	28971
	3 – cavity conservation	7
	4 – compilation of deviation	1464
	5 – repair scheme	3085
	6 – exchange of component	345
	7 – defered repair to the next scheduled maintenance	1

Parameter	Definition	Counts acc. Data Base
Corrosion Appearance Code	1 - smooth corrosion abrasion	654
	2 - pitting corrosion	1545
	3 - exfoliation corrosion	31693
	4 - crevice corrosion	0
Corrosion Initiation Code	1 – from fastener	221
	2 – from drill hole / countersink	32220
	3 – from overlap / edge	681
	4 – free surface	770
	5 – others	0
Corrosion Extension Code	Category 1 "simple repair"	23412
	Category 2 "intensive monitoring"	2651
	Category 3 "immediate measures"	7829

A selection of the most important parameters from the chart is graphically represented as follows.

Analysis Example According Corrosion Appearance

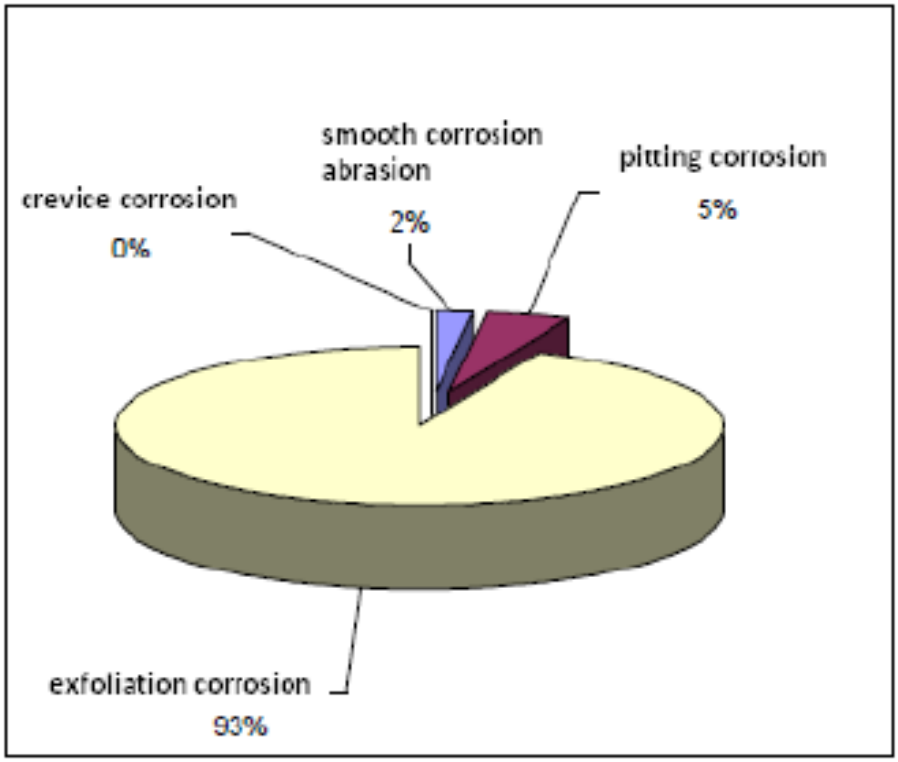

Figure 2-10: Distribution of Corrosion Appearance.

With this chart distribution of corrosion appearance becomes very clear – over 90% of the counts are subject to exfoliation corrosion.

Analysis Example of Counts per Corrosion Initiation

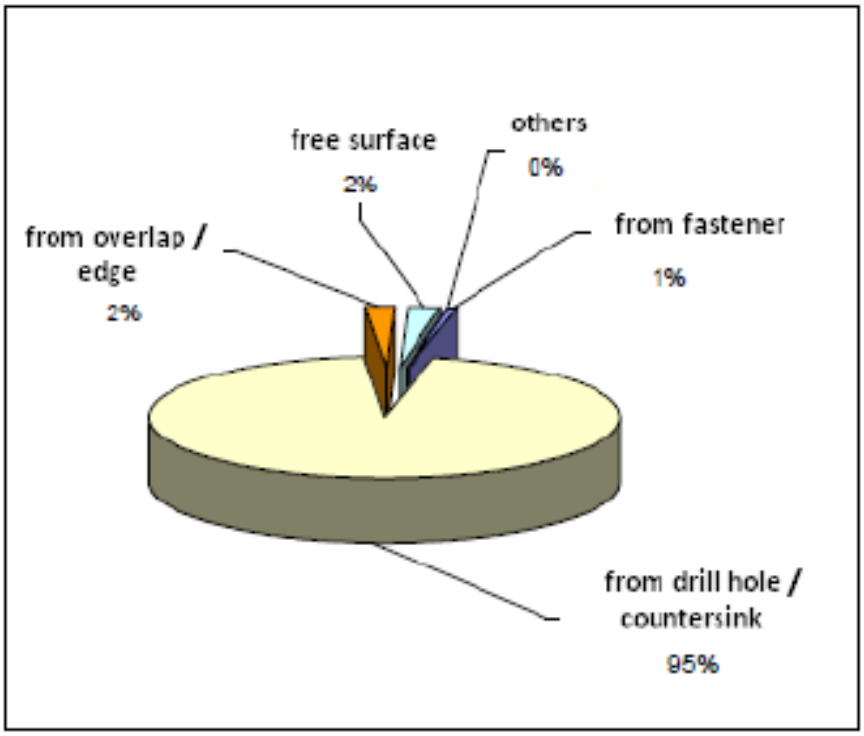

Figure 2-11: Counts per Corrosion Initiation.

With similar dominance this chart shows the focus of corrosion with 95% resulting from drill holes and countersinks.

Therewith a corrosion focus and area of concern was found. For this example high attention must be directed component-dependently to drill holes and countersinks with preventive activities against exfoliation corrosion.

2.6.2.3 Position Oriented Evaluation with Regard to Superimposition

From the previous analysis results the corrosion concentration on components becomes apparent of corrosion appearance and initiation.

In order to receive exactly allocations of the corrosion impact on components, the documentation form must be specified in due time. Due to new technologies (e.g. 3D-Viewer on PSS) in future digital views shall be preferred beside sketches as shown to realize superimposition.

For further evaluation of the corrosion regarding of measures and superimposition more analysis are necessary on data base as follows.

Analysis Example of Multiple Counts per Position

Multiple counts defines corrosion occurrence, which was grinded several times at an aircraft at the same position on a focused component.

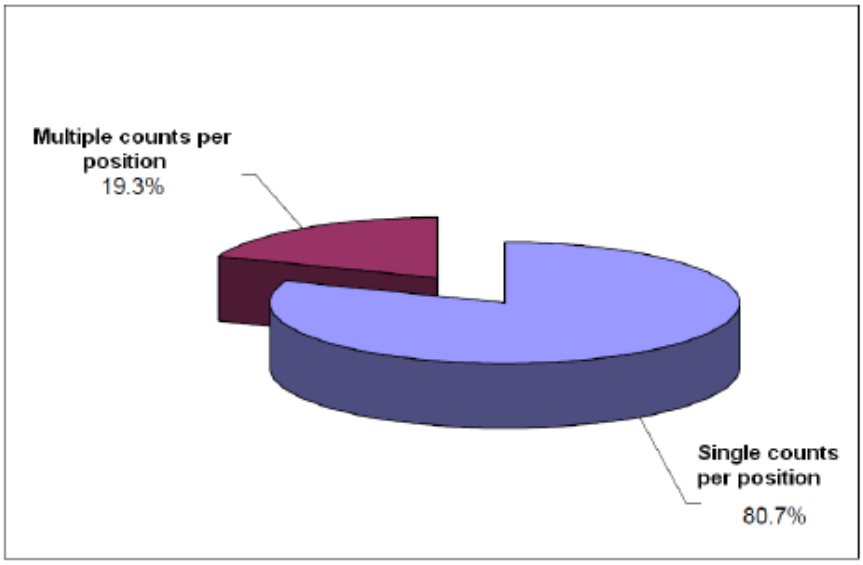

Figure 2-12: Share of All Captured Counts on Example Component.

Analysis of Grind-Out Depth Distribution on an Example Component

The chart illustrates the grind-out depth distribution of all captured counts on the example component. The average grind-out depth shows 0.4 mm.

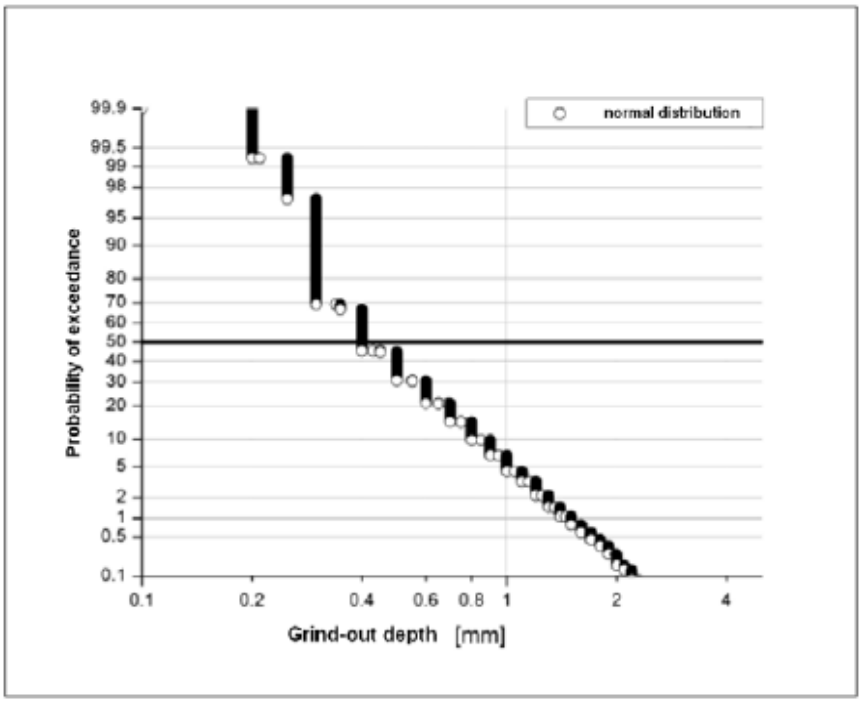

Figure 2-13: Grind-Out Depth Distribution on Example Component.

Analysis of Occurrence and Depth Distribution on Example Component

The analysis is based on documented positions on data base and allows to focus all corrosion appearances in a graphical layout (sketch or 3D-view) for the selected components.

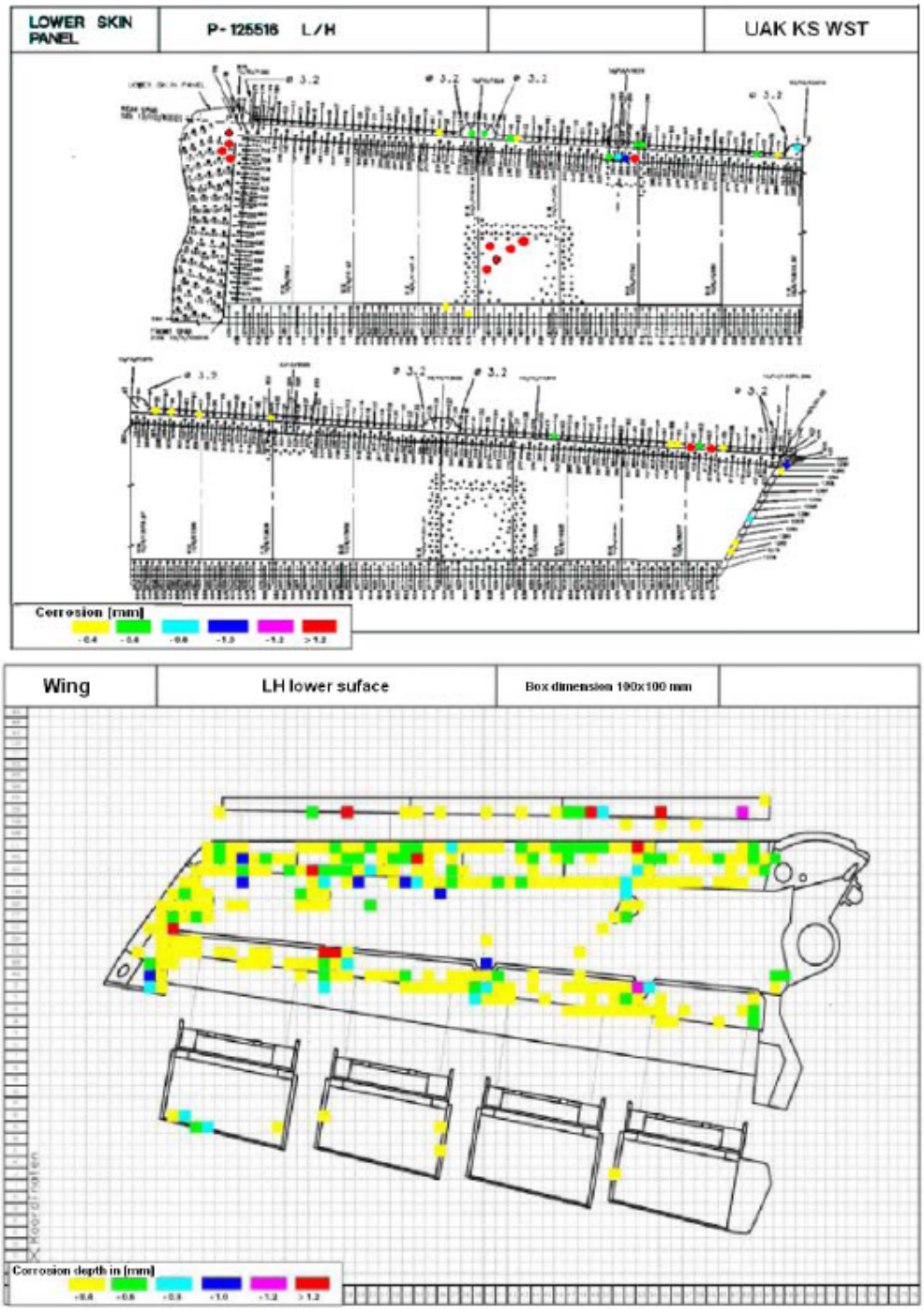

Figure 2-14: Occurrence and Depth Distribution on Example Component.

Analysis of Corrosion and Fatigue Superimposition on Example Component

A final example is given for a component. An evaluation of the corrosion database revealed a number of arisings related to corrosion. The review of the qualification evidence of the wing concludes that a number of arisings are located within the fatigue critical areas of the wing see figure below.

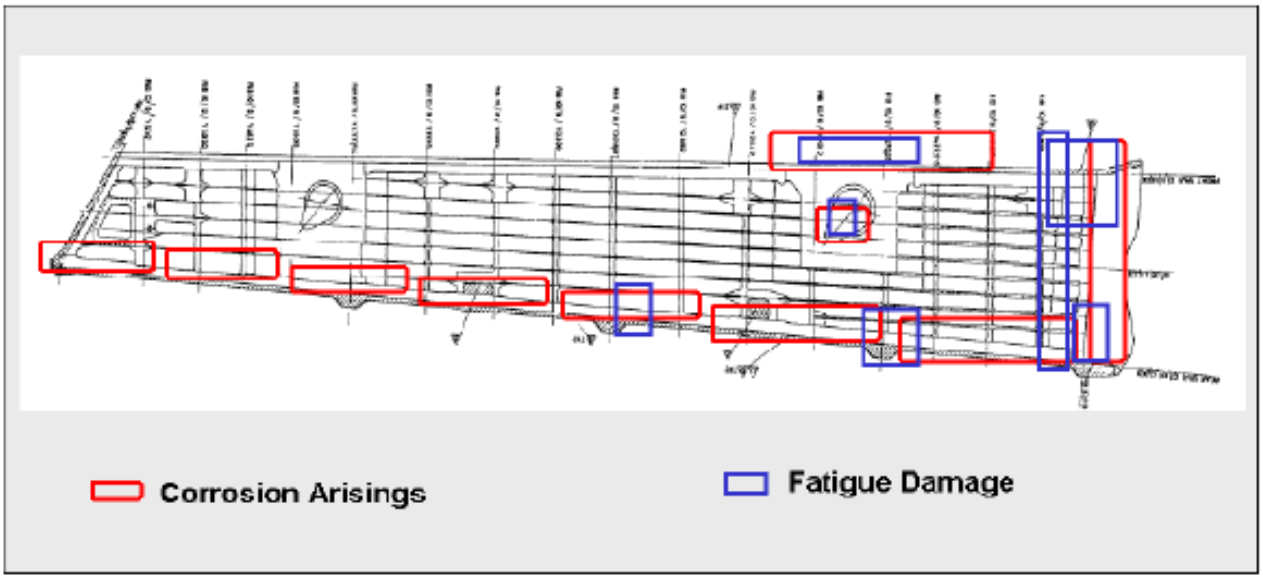

Figure 2-15: Corrosion and Fatigue Superimposition on Example Component.

In order to recognise relevant points of intersection between corrosion arisings and fatigue, a graphic comparison is used as decision criterion.

It is obvious that load monitoring alone cannot manage the structural integrity. Therefore, addition directed inspections and sampling programmes should be performed.

2.6.3 Assessment

On the basis of the database of an example aircraft evaluations were made over the corrosion arisings in the fleet. The arising frequency as well as the corrosion depth were evaluated. With advanced age of a fleet the maintenance expenditure continues to increase.

Measures are developed in order to hold the further effort under control. In the work frame of an investigation of components the focus of corrosion was selected with support of the mentioned data base. At these focus an analysis of the residual lifetime will be accomplished with additional engineering supported effort later.

Nevertheless, there is a requirement to actively monitor corrosion arisings and identify new areas of concern at an early stage with reasonable data base support – for example with Portable Support Systems (PSS).