European Aviation Safety Agency

INTERNATIONAL TASK GROUP

(FAA/EASA/TCCA/INDUSTRY)

Chapter 3

Recapture V3C3 - 3.4.6-12 & 3.6

(outline purpose, contents, linkage to other chapters)

Wichita 12-16th November 2007

V3C3 – 3.4.6 – 12 Design Substantiation (continued)

Purpose: provide Means of Compliance guidance
(developed from 2003 Cert Roadmap – includes issues for other parts, e.g. Part 25)

Contents: 3.4.6 Structural Substantiation (Static Strength & Damage Tolerance)
3.4.7 Tools and Part Cure
3.4.8 Flaws Experienced in Production
3.4.9 Flutter Substantiation
3.4.10 Fire Protection, Flammability and Thermal Issues
3.4.11 Lightning Strike Protection
3.4.12 Crashworthiness

Linkage: - section 3.2 Certification Considerations
- section 3.3 Regulations

V3C3 – 3.4.6 Structural Substantiation (Static Strength & Damage Tolerance):

Contents:

- Static and Fatigue Strength very dependent upon flaws
(production and service flaws – possible damage sources identified)
- failure loads, modes, locations difficult to predict
(vulnerable out-of-plane strength - needs test pyramid)
- analysis v test (scatter and need for overload factors, LEFs etc)
- damage levels identified (BVID for life through ADLs to 'get home')
- large BVID damage
- residual strength
- need to substantiate repairs as per original structure
- secondary bonding issues

Linkage:

- key sub-section – implicit link to many parts of chapter 3
- link to other chapters, e.g. CMH-17 V3C3 F&DT
- external references, e.g. DOT/FAA/AR-02/121

V3C3 – 3.4.7 Tools and Part Cure:

Contents:
- tool design/maintenance is critical to consistent production
- key issues identified, e.g. tool material, surface quality, friction etc
- need to monitor key variables, e.g. temp, pressure, vacuum
- identify key variables

Linkage: implied
- 3.4.8 Production Flaws
- 3.4.6 F&DT

V3C3 – 3.4.8 Flaws Experienced in Production:

Contents:
- identify likley flaws at all levels of production and assembly
(list of damage types given)
- identify relationship between flaws and process tolerances
- understand inspection
- understand significance to F&DT

Linkage:
- 3.4.6 F&DT

V3C3 – 3.4.9 Flutter Substantiation:

Contents:
- basically as for metallic structure behaviour
- damage scenarios wrt stiffness (e.g. disbond)
- environment wrt stiffness (e.g. heat) & mass (e.g. moisture)

Linkage:
- implied link to 3.4.6 F&DT

V3C3 – 3.4.10 Fire Protection, Flammability and Thermal Issues:

Contents:

- cabin interior concerns extended to structure
- basically match metallic structure behaviour
(e.g. pool fire – collapse of structure)
- in flight and post flight fire
- stiffness and strength reduction (temporary, permanent, Tg)
- prevent heat damage/fire – engine mounts
- toxicity, fibre release etc
- part 25 issues (A350,B787)

Linkage:

- 3.4.11 lightning
- 3.4.6 F&DT

V3C3 – 3.4.11 Lightning Strike Protection :

Contents:
- higher electrical resistance than metal
- direct & indirect lightning protection
- protect structure, fuel, & systems
- part 25 issues (A350,B787)

Linkage:
- 3.4.6 F&DT
- 3.4.10 Fire Protection.

V3C3 – 3.4.12 Crashworthiness:

Contents: - basically match metallic structure behaviour

(living space, escape route, impact pulse, loose items of mass, seat dynamics, fuel tank safety)

- part 25 issues (A350,B787)
- competing failure modes
- energy management

Linkage: - 3.4.10 Fire Protection….

V3C3 – 3.5 Production Essentials:

Purpose: provide Means of Compliance guidance (new content)
- supports sections of 3.4
- key point - material and component manufacture are simultaneous

Contents:
3.5.1 Production Implementation
3.5.2 Manufacturing Quality Control
3.5.3 Defect Disposition and Manufacturing Records
3.5.4 Modification and Production Process

Linkage:
- Section 3.2 Certification Considerations
(3.2.1 Production Development)
- Section 3.3 Regulations
(3.3.2 Production Approval)

V3C3 – 3.5 Production Essentials:

3.5.1 Production Implementation

Contents:

- product conformity considered throughout production process
- test pyramids/methods – function of material form complexity
(product development and test plans important)
- identify key variables/establish sensitivities important
- changes in process/differences between cert and production/ changes in scale of production need bridging programmes
- define and control mature process (reproducibility is key)
- concession process important

Linkage:

- implicit 3.4.1, 2, 3, 7, & 8

V3C3 – 3.5 Production Essentials:

3.5.2 Manufacturing Quality Control

Contents:
- identify key manufacturing steps and sensitivities
- communication between Production and Design is essential
- typical key process steps identified, e.g. raw material management, lay-up, cure, trim, drilling, packing, transporting etc (normal audit trail – AC21-26)
- emphasis on secondary bonding, NDI, geometry, inspection

Linkage:
- 3.2.4 trained and qualified workforce is essential
- 3.4.7 tooling

V3C3 – 3.5 Production Essentials:

3.5.3 Defect Disposition and Manufacturing Records

Contents:
- need to communicate important production steps to workforce
- identify & report defects to responsible engineering
- link between production, maintenance & design necessary
- clear communication of responsibilities between production and design essential (particularly in fragmented global industry)
- must clearly identify and record concessions

Linkage:
- implicit 3.4.1 Design Documentation etc
- 3.4.8 Flaws

V3C3 – 3.5 Production Essentials:

3.5.4 Modification and Production Process

Contents:

- production and design organisations need agreed procedures to classify and manage changes (FAIs)
- impact of change upon all aspects of change must be considered, e.g. structures upon systems, production upon maintenance
- appropriate documentation revision processes must be in place

Linkage:

- implicit 3.4.1 Design Documentation etc
- 3.2.3 Product Modification

V3C3 – 3.6 Maintenance – Technical Issues:

Purpose: provide Means of Compliance guidance (new content)

- material and component manufacture/repair are simultaneous
- maintenance procedures necessary to maintain airworthiness

(match, or better, standards at certification)

- recognises operational time and cost pressures
- design, production, and maintenance are overlapped activities
- repair substantiation is important

V3C3 – 3.6 Maintenance – Technical Issues:

Contents:

Linkage:

- Section 3.2 Certification Considerations

(3.2.2 Continued Airworthiness (Maintenance and Repair and 3.2.4 Qualified Workforce and Teamwork)

- Section 3.3 Regulations

(3.3.3 Continued Airworthiness)

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.1 Repair Design and Process Substantiation

Contents:

- repair must match aircraft structure performance
- recognise field environment (OEM must work with operator)
- documentation important
- repair dependent upon damage & cut-out dimensions
- maintain fire and lightning protection

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.1 Repair Design and Process Substantiation

- very close link to Design and Production processes

- OEM has
  - initial certification experience
  - knowledge of damage and repair assumptions

  (test sequence etc - which may differ between OEMs)

- Operator has
  - 'real world' environment experience
  - further damage experience

- OEM and operators must work closely together

V3C3 – 3.6 Maintenance – Technical Issues: F&DT Test Sequence OEM A

(DRAFT EXAMPLE ONLY)

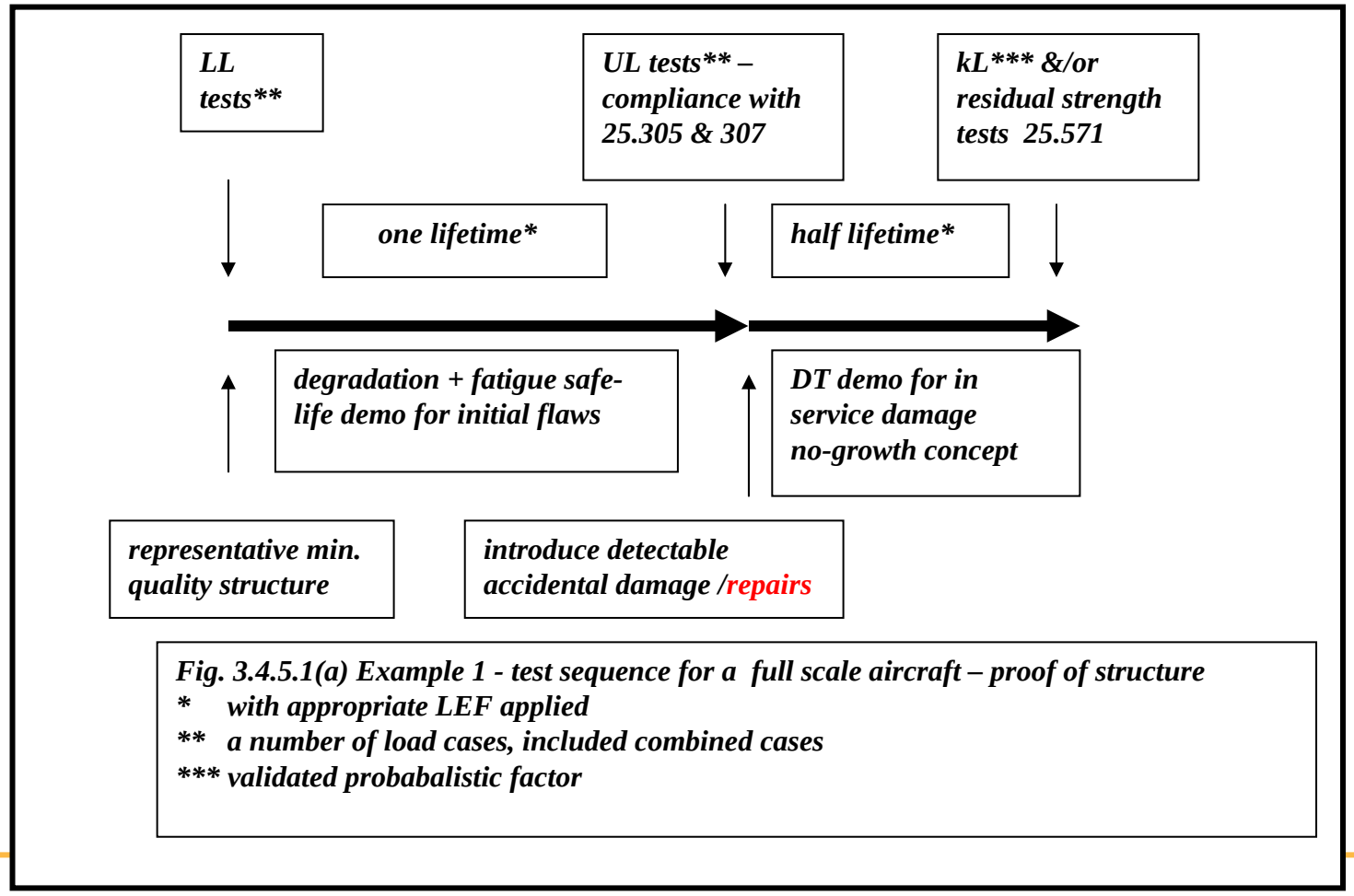


Fig. 3.4.5.1(a) Example 1 - test sequence for a full scale aircraft – proof of structure

* with appropriate LEF applied

** a number of load cases, included combined cases

*** validated probabalistic factor

V3C3 – 3.6 Maintenance – Technical Issues: F&DT Test Sequence OEM B

(DRAFT EXAMPLE ONLY)

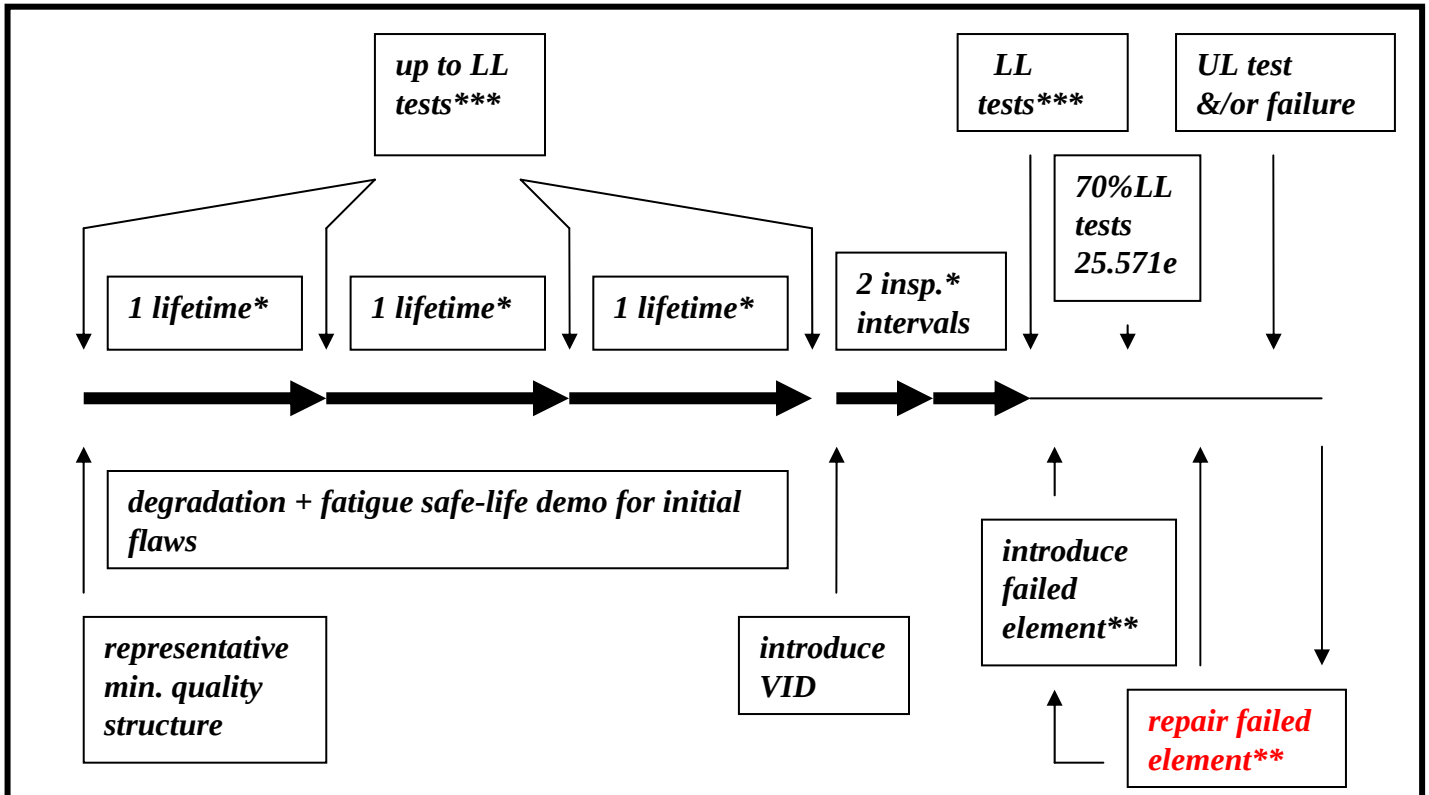


Fig. 3.4.5.1(b) Example 2 test sequence for the full scale aircraft – proof of structure

* with appropriate LEF applied to test composite, without test to metal

** elements selected (one at a time), cut, 70%LL tested, repaired, tested UL, new element cut etc

*** a number of load cases, including combined cases

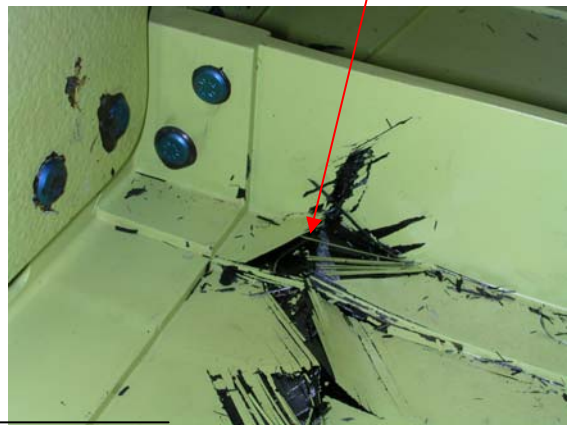
V3C3 – 3.6 Maintenance – Technical Issues:

3.6.1 Repair Design and Process Substantiation

- Primary/PSE structure main concern, but CAUTION ! large secondary structure
  (impact, loss of control – detail matters)

Large Transport Aircraft (prototype) lost due to relatively minor damage (4 lb bird strike) to large nose fairing

Horizontal stabilizer damage due to impact from small engine access panel



V3C3 – 3.6 Maintenance – Technical Issues:

3.6.1 Repair Design and Process Substantiation

- ‘reverse engineering’ processes not mature
(difficult to match production standards in the field)

- very difficult for non-OEM to substantiate repair
(Primary/PSE/large secondary structure beyond OEM limits)

- component airworthiness based upon production standards and repair (limits etc) based upon repair standards – not production based upon repair standards
(no established statistically credible production process etc)

Linkage:
- 3.4 Design Substantiation
- 3.5 Production Essentials

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.2 Teamwork and Disposition

Contents:

- many players – must recognise limitations
(if you don't know then ask!)

- 3 groups of workers

- engineer (degree, with design, regulation, and hands-on training)

- inspector (Visual (good eyesight essential!) and NDI experience and training)

- repair technician (process, tooling, and equipment training essential)

- all require good product knowledge and training
(practical, theoretical, documentation, procedures etc)

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.2 Teamwork and Disposition

Contents:

- clear disposition required from detection to repair

- recognises need for increased awareness (operations staff, aircrew etc) of unusual events (ground impact, heavy landing, unusual flight load)

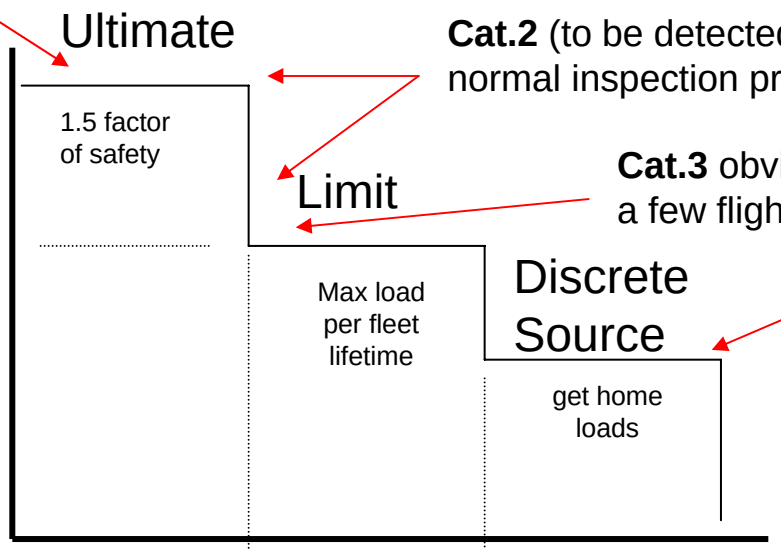
- limits of inspection and their meaning need to be understood (important to recognise damage size – inspection cycle link BVID good for aircraft life (corrective action may be necessary – protection etc), VID detected within inspection cycle etc)

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.2 Teamwork and Disposition

BVID, Allowable Damage, etc, **Cat.1**

Design Load and Damage Considerations for Durability & Design (from MIL-17 Fig. 7.2.1(a))



Cat.2 (to be detected and repaired – normal inspection process)

Cat.3 obvious in a few flights

e.g. bird strike, rotor burst, lightning– **Cat. 4**

(**ADL**) Allowable Damage

(**CDT**) Critical Damage Threshold

Increasing damage size

What is Cat.5 – hidden Cat.2,3,4?

Categories of Damage & Defect Considerations for Primary Composite Aircraft Structures

Category	Examples	Safety Considerations (Substantiation, Management)
Category 1: Damage that may go undetected by field inspection methods (or allowable defects)	BVID, minor environmental degradation, scratches, gouges, allowable mfg. defects	Demonstrate reliable service life Retain Ultimate Load capability Design-driven safety
Category 2: Damage detected by field inspection methods @ specified intervals (repair scenario)	VID (ranging small to large), mfg. defects/mistakes, major environmental degradation	Demonstrate reliable inspection Retain Limit Load capability Design, maintenance, mfg.
Category 3: Obvious damage detected within a few flights by operations focal (repair scenario)	Damage obvious to operations in a "walk-around" inspection or due to loss of form/fit/function	Demonstrate quick detection Retain Limit Load capability Design, maintenance, operations
Category 4: Discrete source damage known by pilot to limit flight maneuvers (repair scenario)	Damage in flight from events that are obvious to pilot (rotor burst, bird-strike, lightning)	Defined discrete-source events Retain "Get Home" capability Design, operations, maintenance
Category 5: Severe damage created by anomalous ground or flight events (repair scenario)	Damage occurring due to rare service events or to an extent beyond that considered in design	Requires new substantiation Requires operations awareness for safety (immediate reporting)

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V3C3 – 3.6 Maintenance – Technical Issues:

3.6.2 Teamwork and Disposition

Contents:

- once characterised – consult source documents for ADLs etc (size, proximity of other repairs etc).

- > ADL use published OEM data (e.g. SRM etc)

- > Repair Limits - go to OEM

- classify repair & only use approved data

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.2 Teamwork and Disposition

Contents:

- identifies need to consider alternative materials carefully
(improvements in some properties are often at the expense of other properties)

- OEM needs to supply Operators with adequate airworthiness documentation (SRM, MM, SBs etc)

- Operators need to record all repair data
(damage location, cause, dimensions, new materials, etc)

Linkage:

- 3.2.4 Qualified Workforce and Team

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.3 Damage Detection and Characterisation

Contents:

- Manufacture and Service damage to be considered

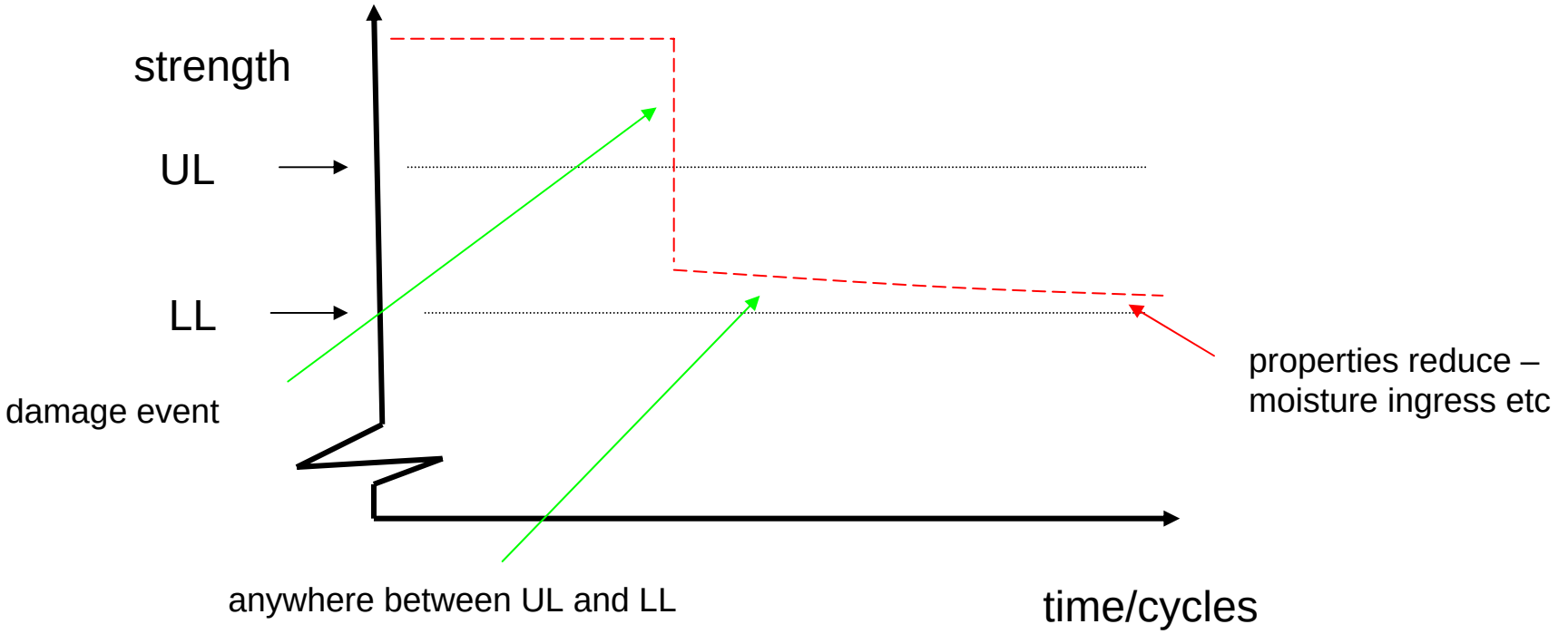
- BVID (cover by design), VID (detect in service)

- environmental degradation can be important
(monolithic and sandwich material differences
– large fleet with earlier technology)

Environmental Degradation (VID)

sizing based upon detection during inspection

design to minimise operating between LL and UL



V3C3 – 3.6 Maintenance – Technical Issues:

3.6.3 Damage Detection and Characterisation

Contents:

- composites often critical in shear and compression (damage types, e.g. delamination, matrix damage, etc can reduce the critical failure mode strength further)

- Visual Inspection mostly used in service (followed by NDI)

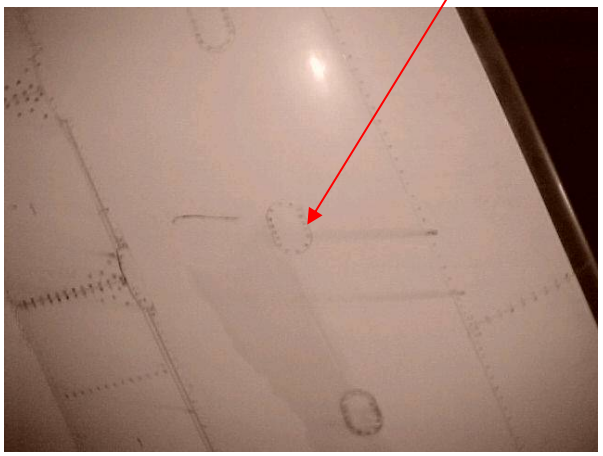
- damage detection may be difficult
  - relaxation,
  - blind side damage
  - inspection conditions (colour, finish, lighting)
  - different metrics (not necessarily a dent etc)

- correct follow-up action required

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.3 Damage Detection and Characterisation

Contents: training important - damage seen, but not followed up



V3C3 – 3.6 Maintenance – Technical Issues:

3.6.3 Damage Detection and Characterisation

- high energy blunt impact is a major concern (large hidden damage)

- important to minimise 'blame culture'

  - metallic structure has offered a number of examples of unreported obvious damage events (torn pressure hull etc)

  – composites potentially worse - easier to 'walk away' from (relaxation, blind side damage etc)

- report all unusual events (impacts, loading etc)

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.3 Damage Detection and Characterisation

- Service NDI – on-wing/off wing consideration

- NDI limited – usually tap, UT, Bond Testers
(by cost, trained staff, availability at all locations, portability)

- follow OEM processes (disassembly, paint removal, jacking etc)

Linkage: 3.4 Design Substantiation

3.5 Production - Essentials

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.4 Repair Processes (Bonded v. Bolted)

Contents:

- bolted (on-wing advantage) & bonded repair (prepreg & wet lay-up)
- small material quantities a problem (transport, lifing, storage)
- prepreg repair (off-wing, vac bag, local heat sources)
- wet lay-up (storage advantages, mixing important etc)

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.4 Repair Processes (Bonded v. Bolted)

Contents:

- bonded repair environmental control important
- correct processes and procedures critical
- cannot detect all weak bonds and tight kissing bonds

V3C3 – 3.6 Maintenance – Technical Issues:

3.6.4 Repair Processes (Bonded v. Bolted)

Contents: - bolted repair – correct equipment & training essential

- detail important

- all repairs must be substantiated

Linkage: 3.4 Design Substantiation
3.5 Production - Essentials