European Aviation Safety Agency

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices

CACRC FAA F&DT Workshop

Tokyo

4th. June 2009

Introduction

- **Service Experience/Threat**
  - Hail
  - Tyre
  - Engine Debris
  - Blunt Impact

- **Service Threat/Inspection**
  - Visual Inspection Reliability
  - Preloaded Structure

- **Repair Substantiation**
  - Bonded Structure/Repair

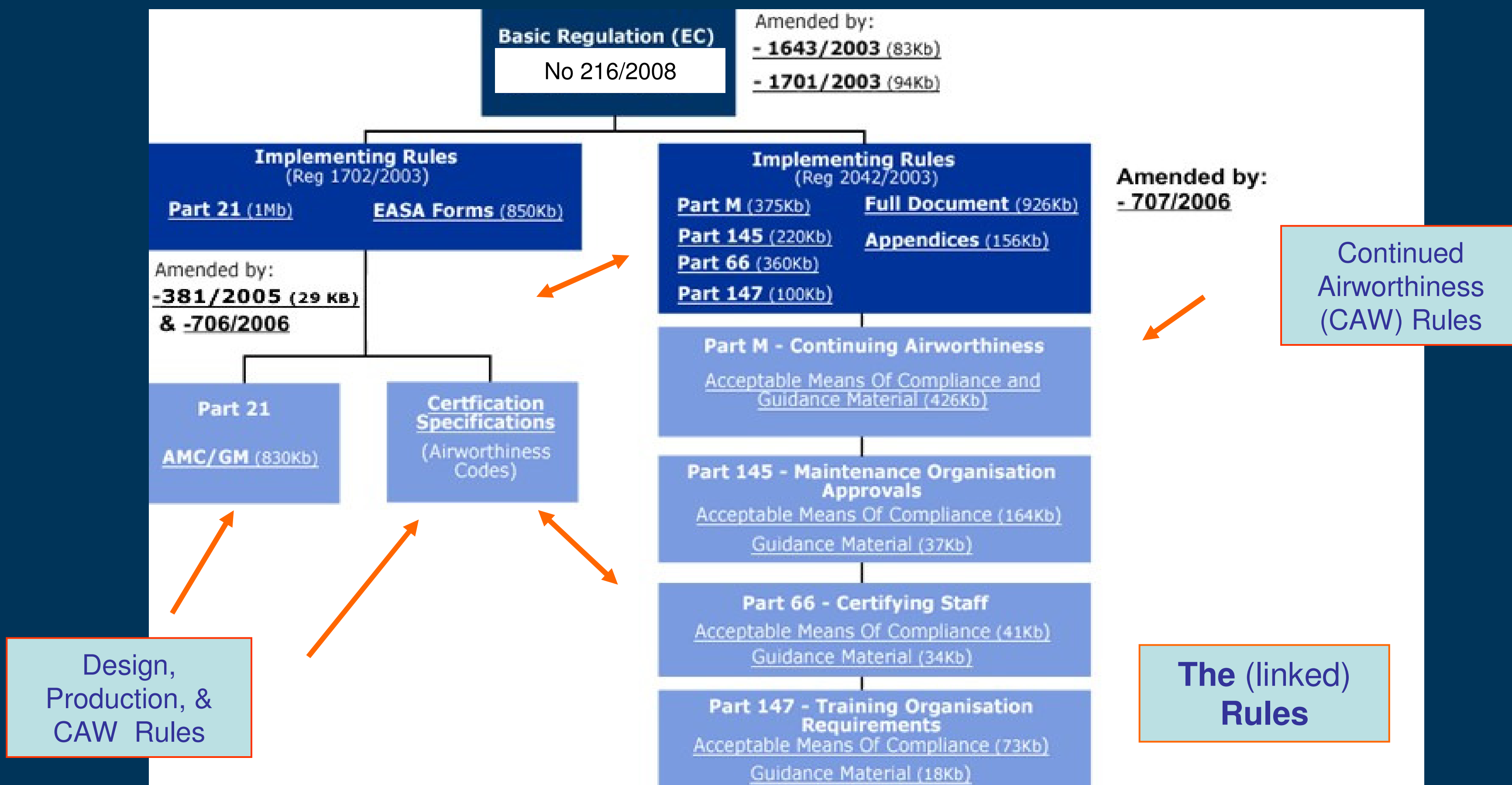
- **Training & Other Activities**
  - Operational Suitability Certificate

S. Waite

European Aviation Safety Agency

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices

- responsibility for all concerned*



* particularly important for composites – properties built into production/repair process

Safe Composite Damage Tolerance and Maintenance Practices require integration of design and maintenance* considerations.

composites
- impact threat
- NVD,BVID

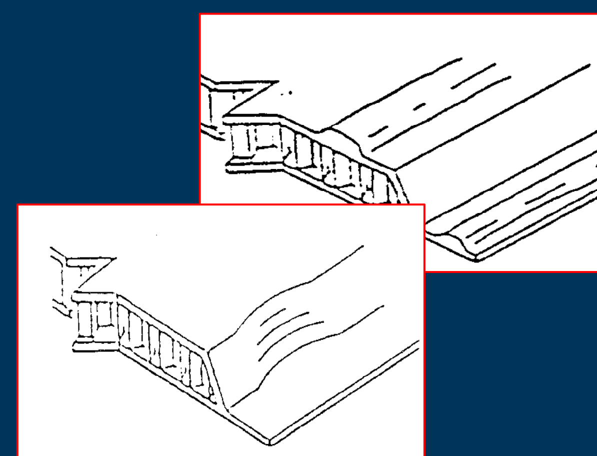
Includes understanding of:

- damage threats*
(including environment, hail, lightning, tyre debris, rotor debris, runway debris, fire, maintenance process,etc)

- damage types
(including dent, crack, fibre splitting, delamination, disbond etc)

- damage inspection and detection
(including appropriate metrics associated with damage types)

- damage growth
(no-growth generally required – no confident da/dn process yet)



* significant composite threat is impact icw NVD/BVID. Maintenance environment important!

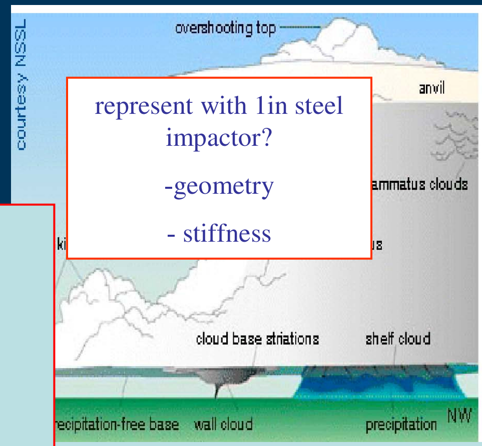
EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices

Damage Threats - Hail

UK Met Office/Qinetiq Research

e.g. Windshield std only


Standard Test Method for Hail Impact Resistance of Aerospace Transparent Enclosures



represent with 1in steel impactor?

-geometry

- stiffness

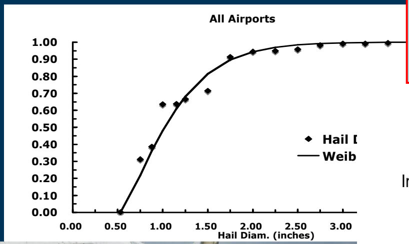
Ref: John Halpin – Amsterdam Workshop May 2007

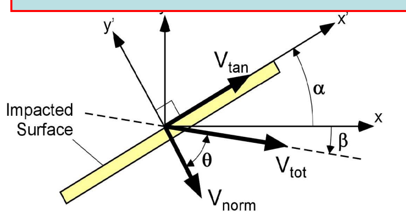
Hail Standard:

Some threats do not have common:

- reference standards
- test protocols
- statistical basis

e.g. - ground and in-flight hail
(not necessarily 'low impact velocity' events)





Projectile and surface are both moving. Velocity vector V_{tot} describes the motion of the incoming projectile relative to the surface.

α is angle between surface and horizontal (+ccw w.r.t. x-axis)
β is angle between projectile relative path and horizontal (+ cw w.r.t. x-axis)
$\theta = 90 - \alpha - \beta$ is angle between normal and total velocity components of projectile

EASA R&D in progress (task OP.28)

Objectives:

- define the global threat

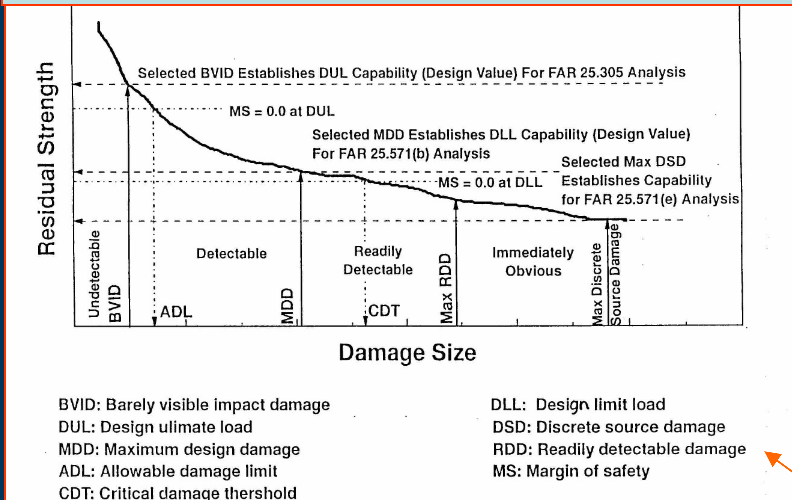
- develop standard (guidance regarding threat, simulation, and integration into design – in-flight and ground hail)

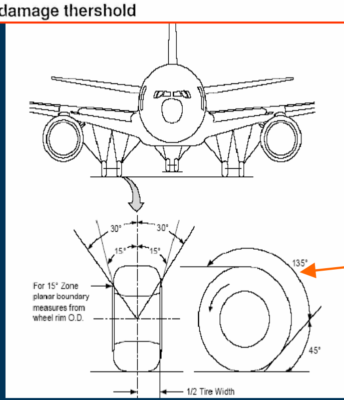
(icw FAA – long term objective)

European Aviation Safety Agency

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices Damage Threat – Tyre Debris

Residual Strength Requirements versus Additional Damage Size (from CMH-17 Fig. 12.2.2.3(a))





Special Condition: - no impacts to any fuel tank structure (not just access covers) or fuel system (within 30 deg. wheel rotational planes) may result in penetration or rupture (e.g. pressure waves) to allow a hazardous fuel leak

Beyond this obvious discrete source damage event:

-**explicitly identify link to all parts of CS 25.571** (understand less obvious damage)

- extend consideration to all PSE structure

standardise threat &, methodology – CS 25.963 model, systems model TGM/25/08 etc

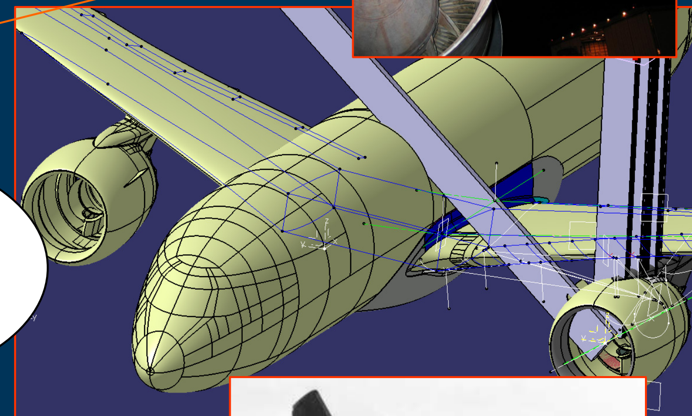
Need to standardise and understand threat for F&DT:

Harmonised Rulemaking Activity

'Protection from debris impacts'

EASA task 25.028

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices Damage Threat – Engine Debris



Engine Debris Penetration Issue MOC:

– large/medium debris slice per AC 20-128
(as before probabilistic - possibly a large notch issue)

- wing and fuselage already considered

- small debris
-AMC to CS 25.963 standard 3/8 in. cube at 700 ft/sec
(based upon historic data - adjust for larger faster engines)

- acceptance based upon ‘equivalence’ to metal and service experience

- little previous testing of metallic wing structure
(metallic testing required to define reference before composite testing!)

-beyond this obvious discrete source damage event:

- explicitly identify link to all parts of CS 25.571

- extend to F&DT for all PSE structure in debris trajectories

standardise threat, methodology, and terminology – small fragment, low energy debris etc

Need to standardise and understand threat for F&DT:

Harmonised Rulemaking Activity

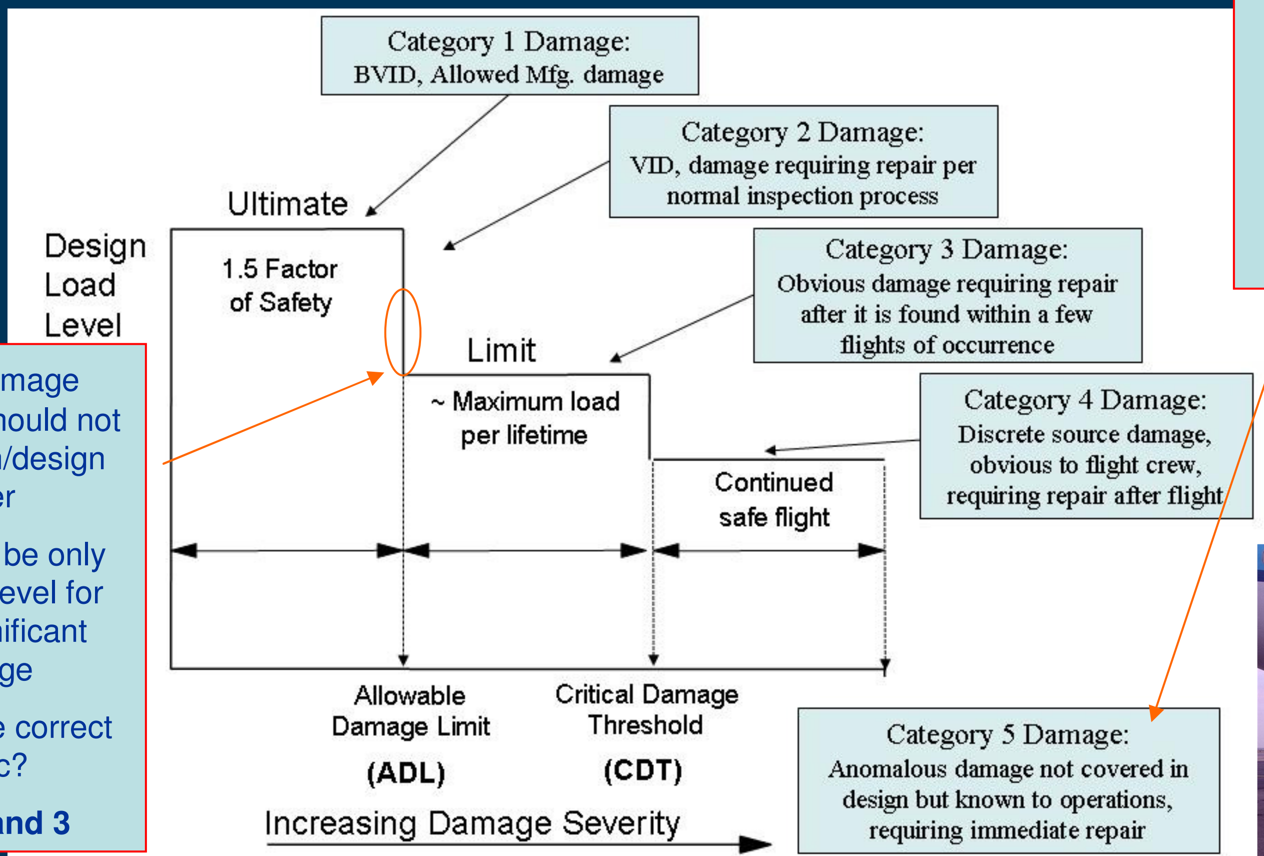
‘Protection from debris impacts’

EASA task 25.028

European Aviation Safety Agency

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices
Damage Threat - High Energy Blunt Impact

High Energy Blunt Impact:



BVID damage indication should not be concern/design driver

- but could be only indication level for more significant damage
- is dent the correct metric?
- **Cat 2 and 3**

- **Cat 5** not major concern if known

But, if not known

(or not reported) we need to minimise chance of missing damage indication

- relaxation
-'blame culture'

30-40% damage
- ground impact

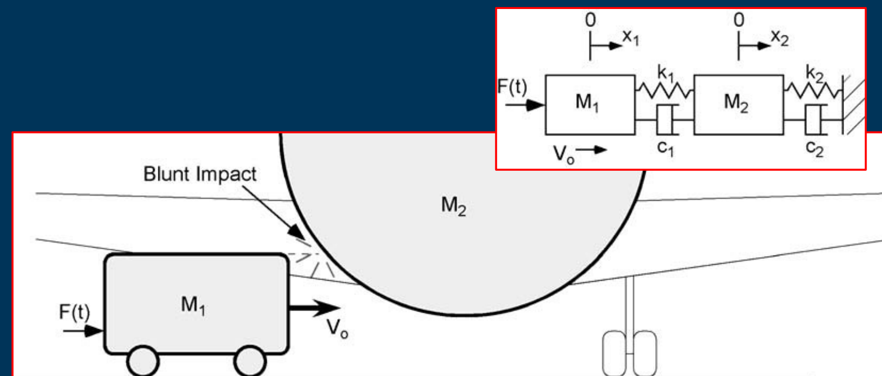
EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices Damage Threat - High Energy Blunt Impact

High Energy Blunt Impact R&D:
FAA/EASA/Boeing/Airbus Research plus others

Key objective:

- investigation of impact of **lager structure**

Note: Harmonisation is important for safety in the increasingly globalised, fragmented, and outsourced aviation industry



1. ***Impact Threat Characterization***. (many variables!)
2. ***Damage Testing and Assessment***.
3. ***Simulation of Impact Damage Formation and DT***.

EASA Priorities:

- **Blunt Impact Threat Characterization** and Prediction.

-Experimental identification of key phenomena and parameters governing high energy blunt impact damage formation, particularly **focusing on what conditions relate to the development of massive damage occurring with minimal or no visual detectability on the impact side.**

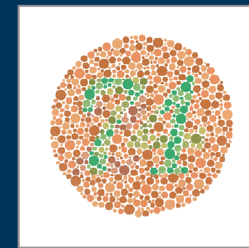
Inspection and detection:

- an integral part of maintaining aircraft continued airworthiness

- key part of damage tolerance

CS 25.571: Damage Tolerance and Fatigue Evaluation of Structure:

*'(3)…..**inspections or other procedures** must be established as necessary to **prevent catastrophic failure**, and must be included in … **Instructions for Continued Airworthiness** required by CS 25.1529'*



EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices Visual Inspection Reliability

AC20-107A para.7(a)(2)/AMC No.1 to CS25.603:

'The extent of ***initially detectable damage*** *should be established and* ***be consistent with the inspection techniques*** *employed during manufacture and in service'*

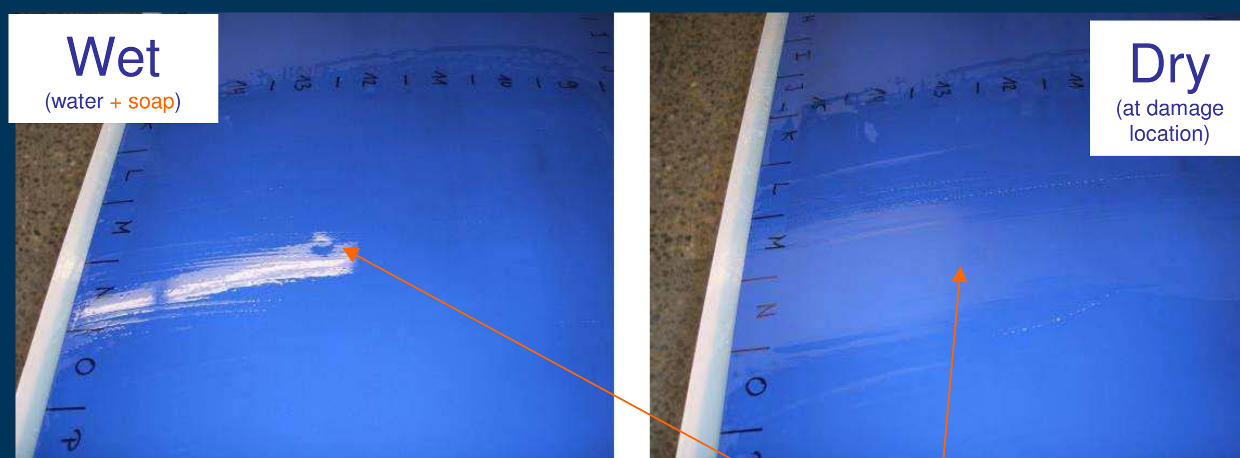


Figure 60: Surface wetting, to improve detectability of dents on matt surface.

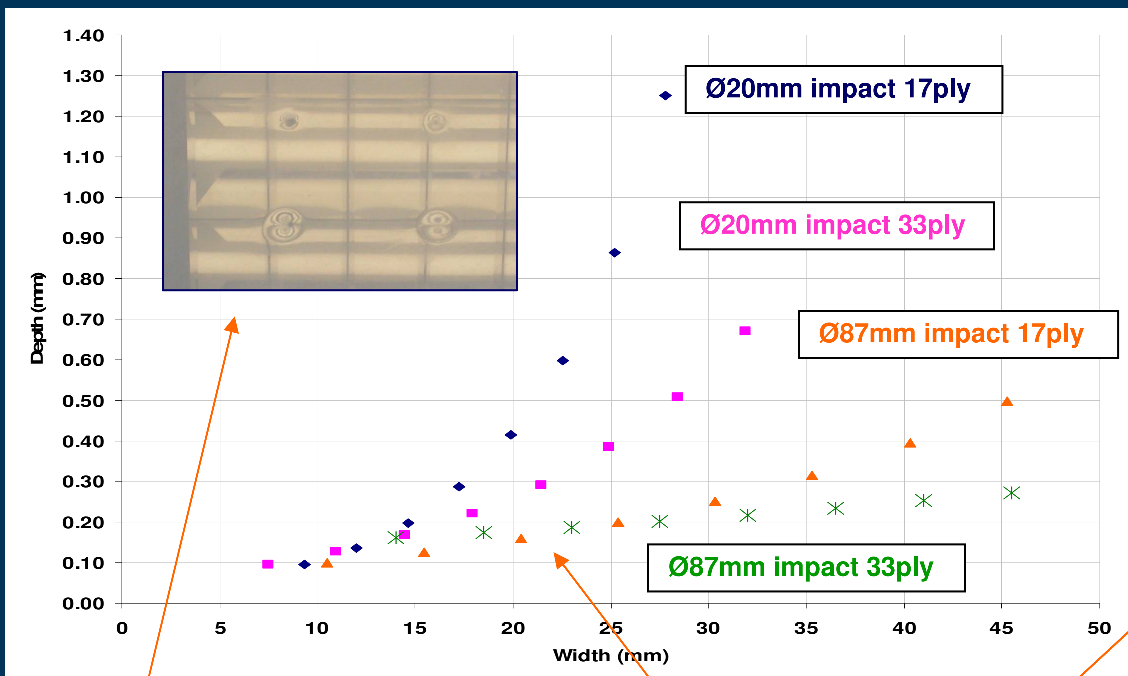
- ability to detect damage may vary with colour, lighting, finish etc… R&D in progress

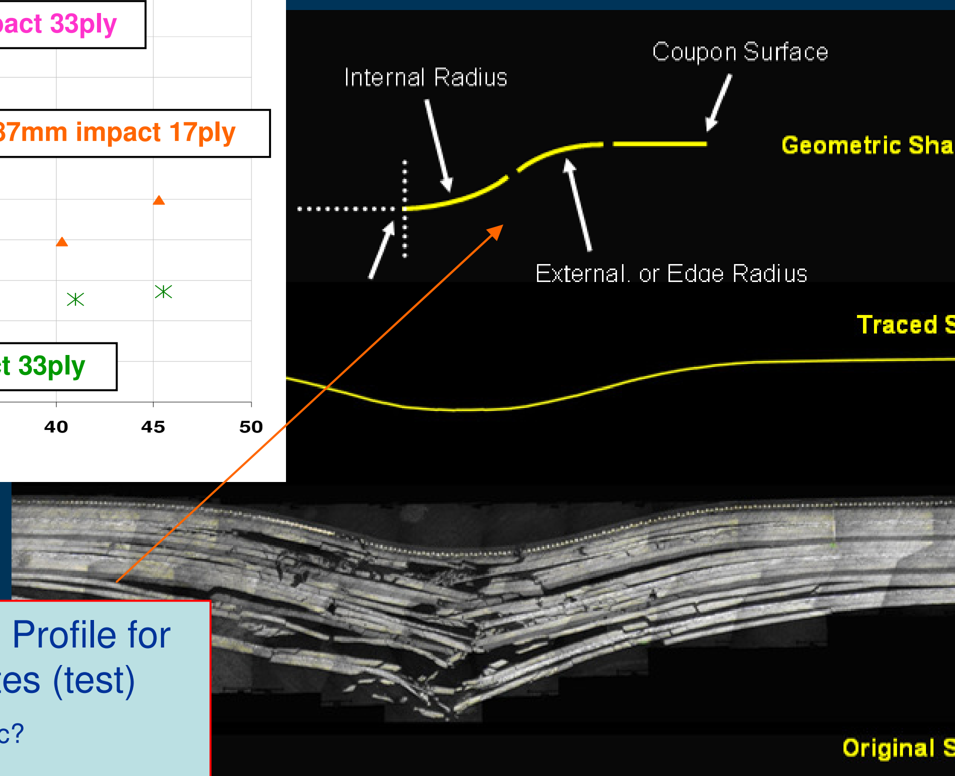
European Aviation Safety Agency

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices Visual Inspection Reliability

Cranfield University

R&D – Damage Metrics Inspection/Detection Variables





Simulate* a range of dents and inspect for a range of size, colours, and finishes

* CNC Plexiglass

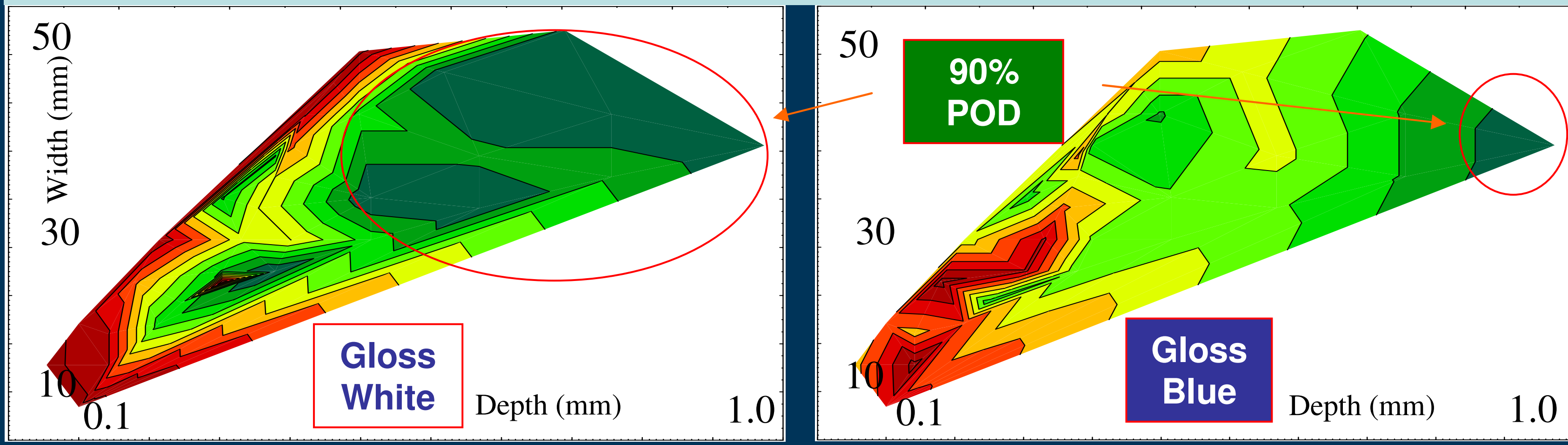
Characterise Dent Profile for range of laminates (test)

- is a dent the correct metric? (many failure modes)
- is the dent profile significant to detection
- is the classic 1 in impactor correct?

EASA Perspectives on
Safe Composite Damage Tolerance
and Maintenance Practices
Visual Inspection Reliability

Cranfield University

Bi-variate (width/depth) Dent POD - gloss white v gloss blue



- multi-variate analysis could be required for POD (rather than traditional single variate)
- "bigger" is not always "better"
- colour may change detection rates – e.g. detection rates for white > blue etc

DT Design must account for these variables

(Note: this level of damage indication traditionally should not drive design. However, it may be the only cue for more significant damage - TBD)

European Aviation Safety Agency

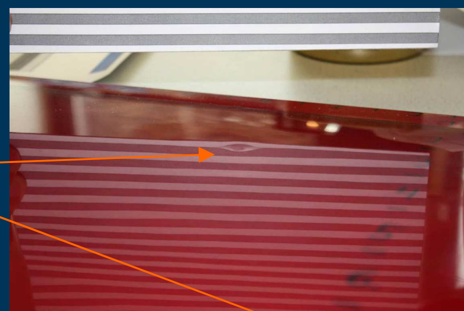
EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices Visual Inspection Reliability

DLR Research

Φ 25.4 mm

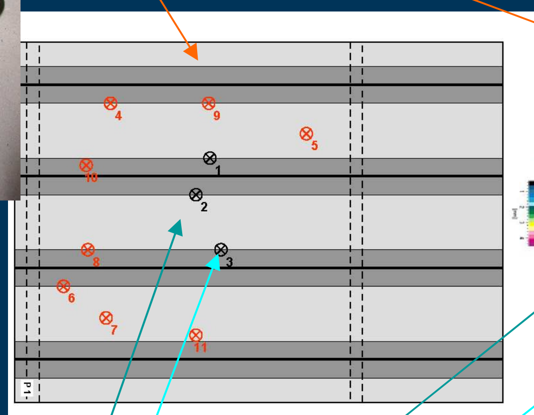
impact 9 - 60J

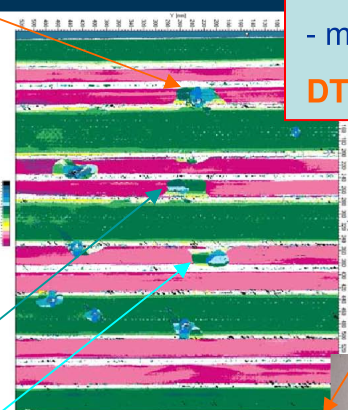
damage visible (enhanced for photo)

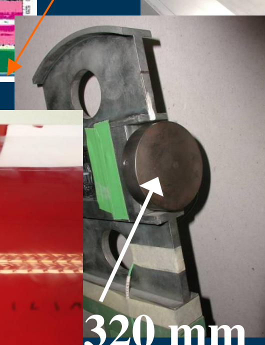


- **larger impactors** (more realistic threat?)
- representative structure
- damage at reasonable energy levels
- damage not visible (> ADLs?)
- multiple impacts?

DT Design must account for these variables



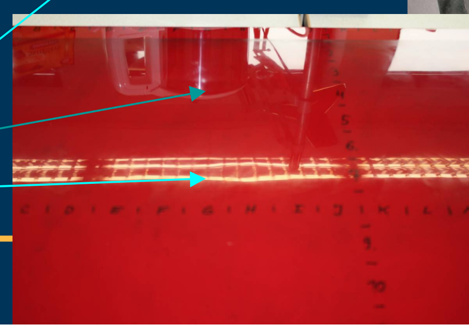




Φ 320mm

impact 2 - 60J,
impact 3 - 75J

damage not visible



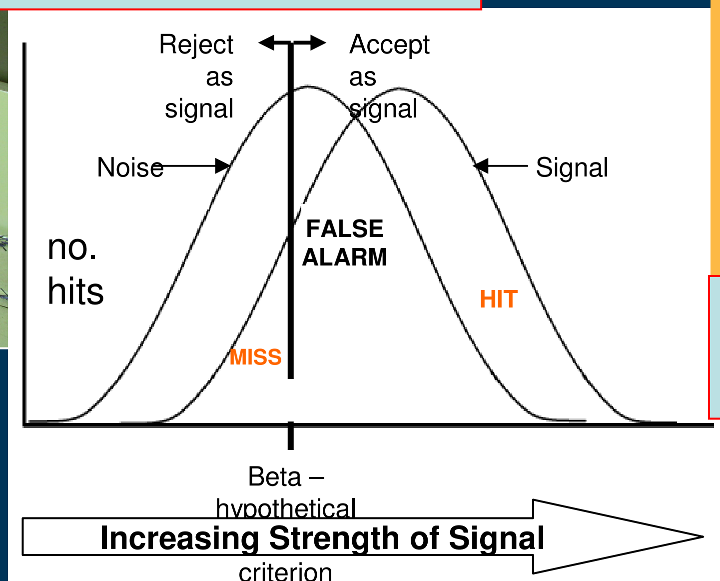
EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices
Visual Inspection Reliability – Follow-Up Action

Once damage is detected – **correct follow-up action** is required

Horizontal Stabilizer Spar
(suspected access cover impact after in-flight separation)

External damage detected, but internal damage not found until later major input…

Why no internal inspection upon finding external damage?



decision to follow-up an indication - function of:

- **Experience**
- **Job instructions**
- **Criticality of the component being inspected**
- **Expectations**
- **Personal biases**

Training Is Important!

Human Factors
- need to understand the damage detection process

European Aviation Safety Agency

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices

Visual Inspection Reliability – further thoughts

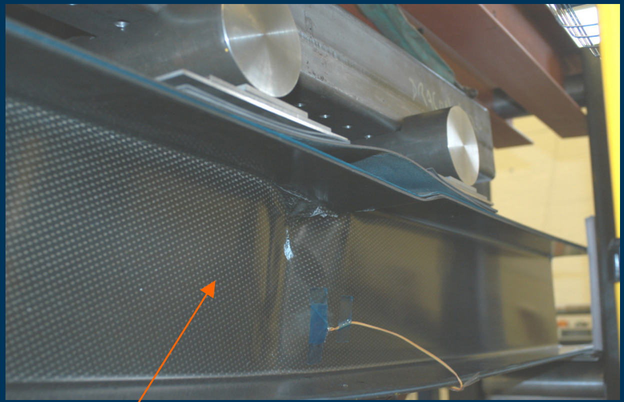
Composite Impacted when Loaded:

- structures usually impacted when loaded

- **composite** material dynamic behaviour typically **quasi-brittle** which differs to that of metal

- existing level of **metallic safety based upon experience and some R&D**

- will composites provide '**equivalent level of safety**'?



carbon composite 'C' section structure, both unloaded and preloaded, impacted with 0.25kg birds at 70-80 m/s

Preliminary R&D (impacting loaded and unloaded structure) suggests:

- damage area produced by impact was **reduced by preload**

- **residual strength** of the impacted and loaded structure was **reduced by as much as 50% with respect to unloaded structure** (failure mode not significantly changed)

More R&D required

European Aviation Safety Agency

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices
Repair Substantiation – Bonded Structure/Repair

not intended to address poor process

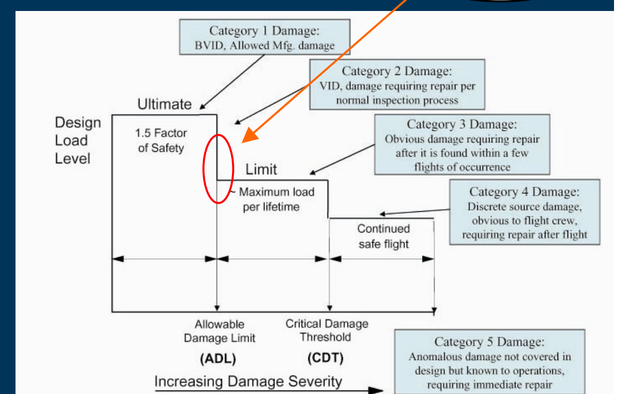
CS 23.573(a)(5): ' ....for any bonded structure*, the failure of which would result in catastrophic loss of the airplane, the **limit load** capacity must be substantiated by one of the following methods.

(i) The maximum disbonds of each bonded joint consistent with the capability to withstand the loads in para. (a)(3) (i.e. critical flight loads considered ultimate) must be determined by analysis, test, or both. Disbonds of each bonded joint greater than this must be prevented by design features.

(ii) Proof testing… *generally not practical, may not account for degradation*

(iii) NDI … *generally not considered adequate for 'weak bonds 'and 'tight disbonds'*

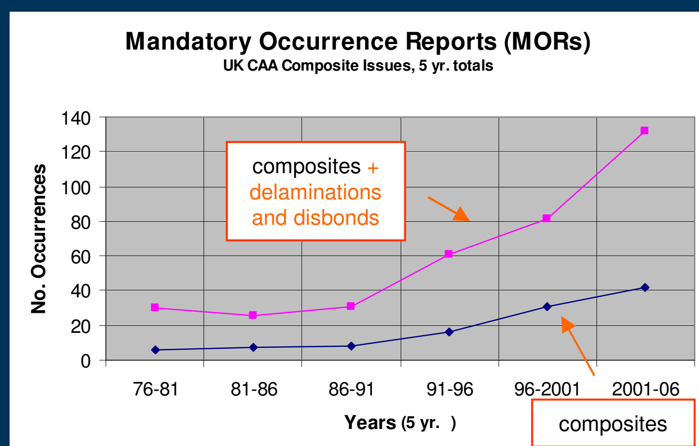
must be detected within a few cycles



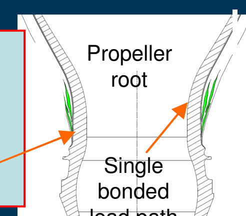
Many examples of failed bonding, e.g.

-Australian Airforce - 42% of repairs (1992) were necessary to replace previous bonded repairs which had failed... (obviously old process etc, but indicates sensitive issue)

- B767 corroded keel beam bonded repair (Boron) failed



'good' production process + NDI, but disbonded - fail safe strap functioned



Therefore,

- bonded structure/repairs must be substantiated for life of structure
- remanufactured parts unacceptable without OEM support and mature process

'* the joining together, by the process of adhesive bonding, of one or more already-cured composite parts

European Aviation Safety Agency

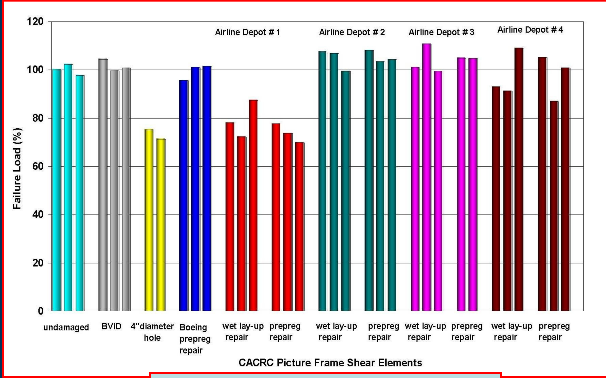
EASA Perspectives on
Safe Composite Damage Tolerance
and Maintenance Practices
Training

Training: Developing EASA Regulations

Existing situation: no formal requirement for the TC holder to establish minimum syllabus for maintenance certifying staff type rating training
(current approval by NAA. Syllabus under Part 147)

Draft FAA AC20-107B/EASA AMC 20-29 says:

'All technicians, inspectors and engineers involved in damage disposition and repair **should have the necessary skills to perform their supporting maintenance tasks on a specific composite structural part.** The continuous demonstration of acquired skills goes beyond initial training (e.g., similar to a welder qualification)…..



OEM v Field Repair variation

Operational Suitability Certificate (OSC) NPA 2009/01

(in process – comments period extended to 30th June 2009)

Proposed new regulation providing **link between Type Certificate** (TC) **and training for a broad range of operating staff**, e.g. pilots, cabin crew and maintenance certifying staff (note: not specifically a composite regulation)

- the manufacturer*, the holder of the TC**, shall apply for the OSC

- a certificate complementing the TC (must be obtained by the TC holder before the aircraft is operated by a Community operator)

- the OSC must be used by the operators of the particular aircraft type.

*probably best placed to understand how product is intended to be utilised (design assumptions etc), icw operators input
** also applies to STC

European Aviation Safety Agency

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices OSC

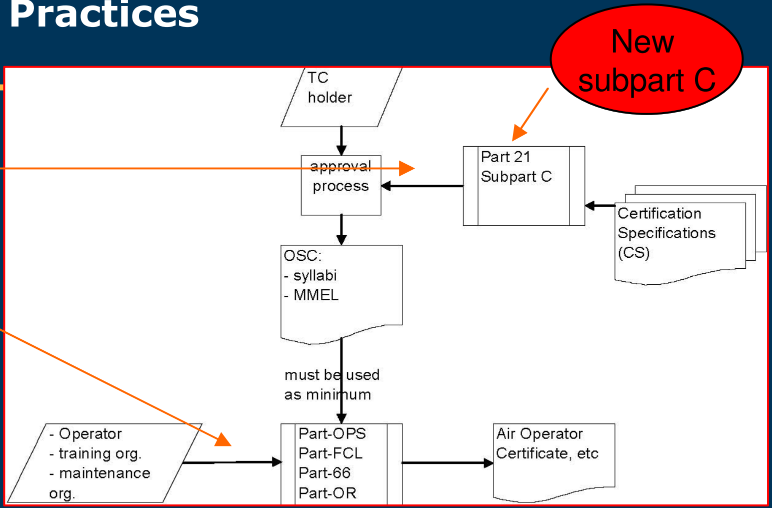
Many requirements affected,

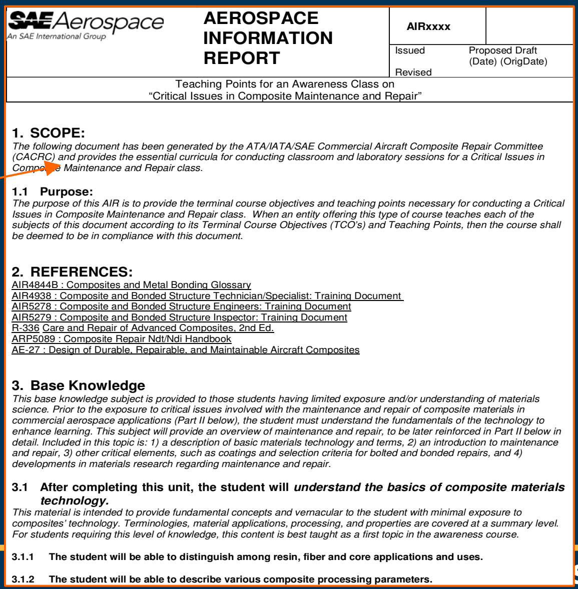
Example: Part 66 Certifying Staff

Existing situation:

- Very limited specific composite content:
  - 66.A.45 Type/task training and ratings
  - 6.3 Aircraft Materials Composite and Non-Metallic

Intent: amend Part 66 to expect composite certifying staff to have at least minimum level of knowledge per AIR 5719 **Teaching Points for an Awareness Class on 'Critical Issues in Composite Maintenance and Repair'**





SAE Aerospace
An SAE International Group

AEROSPACE INFORMATION REPORT

AIRxxxx	
Issued	Proposed Draft (Date) (OrigDate)
Revised	

Teaching Points for an Awareness Class on
"Critical Issues in Composite Maintenance and Repair"

1. SCOPE:

The following document has been generated by the ATA/IATA/SAE Commercial Aircraft Composite Repair Committee (CACRC) and provides the essential curricula for conducting classroom and laboratory sessions for a Critical Issues in Composite Maintenance and Repair class.

1.1 Purpose:

The purpose of this AIR is to provide the terminal course objectives and teaching points necessary for conducting a Critical Issues in Composite Maintenance and Repair class. When an entity offering this type of course teaches each of the subjects of this document according to its Terminal Course Objectives (TCO's) and Teaching Points, then the course shall be deemed to be in compliance with this document.

2. REFERENCES:

AIR4844B : Composites and Metal Bonding Glossary
AIR4938 : Composite and Bonded Structure Technician/Specialist: Training Document
AIR5278 : Composite and Bonded Structure Engineers: Training Document
AIR5279 : Composite and Bonded Structure Inspector: Training Document
R-336 Care and Repair of Advanced Composites, 2nd Ed.
ARP5089 : Composite Repair Ndt/Ndi Handbook
AE-27 : Design of Durable, Repairable, and Maintainable Aircraft Composites

3. Base Knowledge

This base knowledge subject is provided to those students having limited exposure and/or understanding of materials science. Prior to the exposure to critical issues involved with the maintenance and repair of composite materials in commercial aerospace applications (Part II below), the student must understand the fundamentals of the technology to enhance learning. This subject will provide an overview of maintenance and repair, to be later reinforced in Part II below in detail. Included in this topic is: 1) a description of basic materials technology and terms, 2) an introduction to maintenance and repair, 3) other critical elements, such as coatings and selection criteria for bolted and bonded repairs, and 4) developments in materials research regarding maintenance and repair.

3.1 After completing this unit, the student will *understand the basics of composite materials technology.*

This material is intended to provide fundamental concepts and vernacular to the student with minimal exposure to composites' technology. Terminologies, material applications, processing, and properties are covered at a summary level. For students requiring this level of knowledge, this content is best taught as a first topic in the awareness course.

3.1.1 The student will be able to distinguish among resin, fiber and core applications and uses.

3.1.2 The student will be able to describe various composite processing parameters.

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices

Further Developing EASA Activity:

Note broad scope of training/awareness required

'Ground Handling events cause some 200 fatalities, US$10 billion damages, and delay affecting the industry worldwide per year' *(estimate Flight Safety Foundation)*

Draft FAA AC20-107B/EASA AMC 20-29 says:

'Pilots, ramp maintenance and other operations personnel that service aircraft should be trained to immediately report anomalous ramp incidents and flight events that may potentially cause serious damage to composite aircraft structures.

not reported?

Safety Concern

Event: Ground Vehicle Impact (lower lobe near bulk cargo door)
- skin penetrated/dented across 6 stringer bays

- detected during push-back

Also Economic concerns

Repair:

- relatively quick/easy (metallic)

- composite structure?
- damage more extensive?
- repair more difficult?

EASA Perspectives on Safe Composite Damage Tolerance and Maintenance Practices ECAST GSWG

engine lowered onto steps: check for obstructions before refuelling!

Further Developing EASA Activity:

ECAST GSWG (recently formed WG!)

WP 1 - Develop ‘standardised’ Ground Handling training concepts and syllabi. Encourage adoption or mandating of minimum standards of competence. Provide training material that can be utilised as the basis of compliance to standards

WP 2 - In conjunction with the Dutch CAA research the effect of Human Factors involved in ramp safety.

European Strategic Safety Initiative (ESSI)
European Commercial Aviation Safety Team (ECAST)
Ground Safety Working Group (GSWG)

Conclusions:

EASA intends to use the rapidly developing knowledge base, increasing published data, and training guidance for composite materials, in conjunction with increased cross linking between regulations associated with production, design, and CAW, to help industry to follow

Safe Composite Damage Tolerance and Maintenance Practices

Questions?