FAA Composite Damage Tolerance and Maintenance Research & Training Initiatives

Federal Aviation Administration

Presented to:

FAA/CACRC/EASA Workshop on Composite Damage Tolerance and Maintenance

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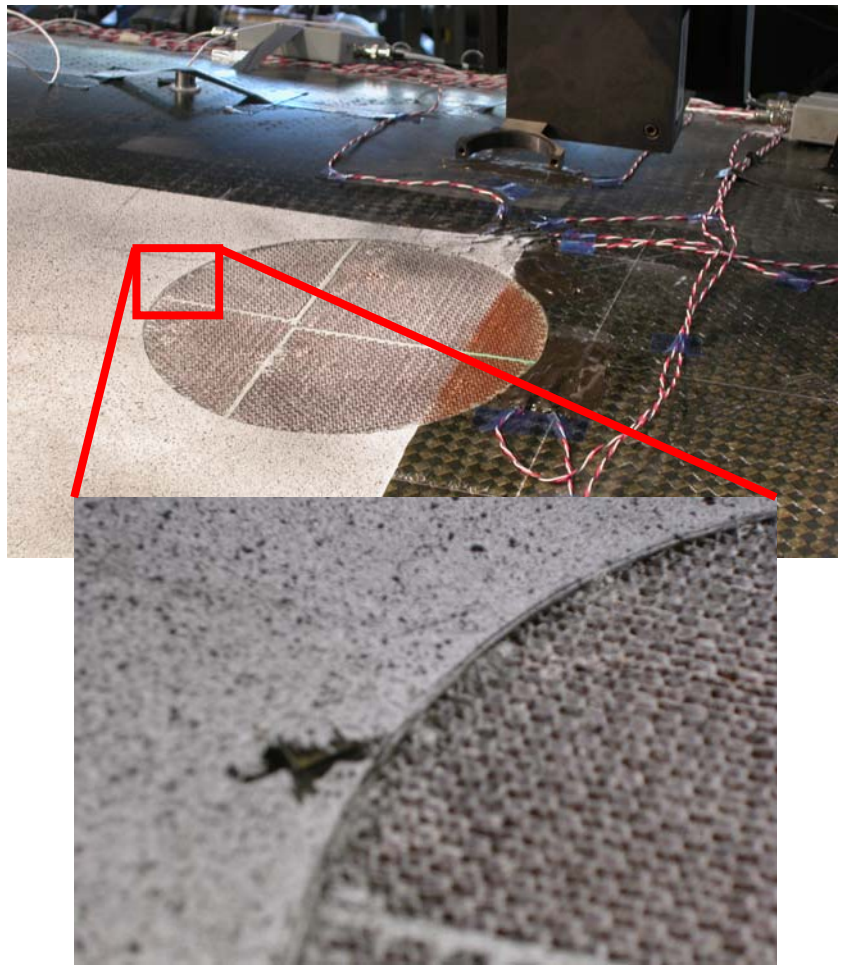
Overview of FAA Work in Damage Tolerance and Maintenance

- **Damage Tolerance of Sandwich Panels***
- **Repair of Composite Structures***
- **Damage Tolerance of Fiber-Metal Laminates**
- **Damage Tolerance and Durability of Adhesively Bonded Composite Structures**
- **Composites Maintenance Training Initiatives**

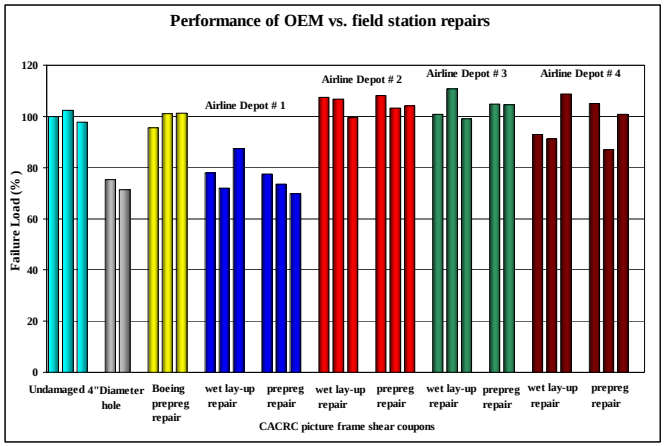
***Details available at actlibrary.tc.faa.gov**

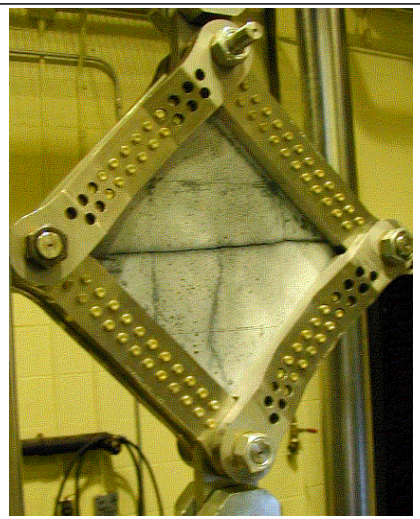
Damage Tolerance of Sandwich Panels

- **Full scale validation test underway**
- **Baseline undamaged panel tested**
  - Not planned to fail
  - Additional damage applied to panel
    - 3” X 3” cross no failure
    - Extended Longitudinal 3” to 10” Failure above predicted load
- **10” hole in outer surface panel tested**
  - Exceeded prediction
  - Local delamination
- **Four additional panels in queue for testing**
- **Conclusions waiting completion of all tests**



Repair of Composite Structures

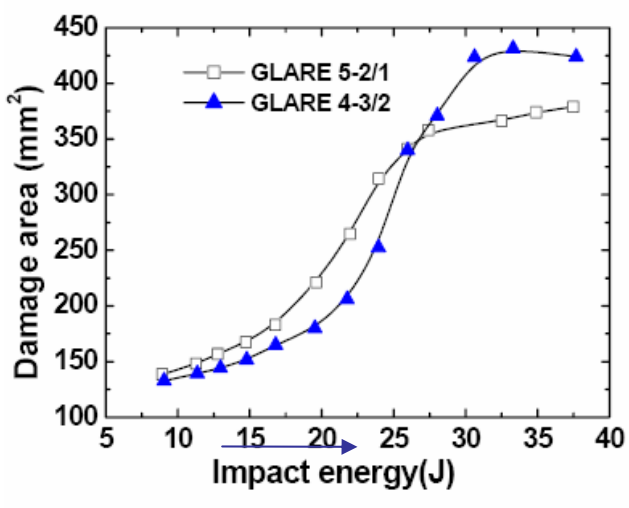




- **Findings of Past Work**
  - All the repaired picture frame shear elements restored at least 90% of the average pristine strength except elements from one airline depot
  - Field repair equivalent to prepreg repair
  - Successful repairs require trained personnel
  - Comparable results can be achieved by either a 0.25” or a 0.5” scarf overlap
  - All the NDI field methods underestimated the damage size with the tap hammer being the least conservative
- **Present Work**
  - **Effects of poor repair procedures on repair integrity**
    - low pressure, low cure temperature, contaminants, pre-bond moisture

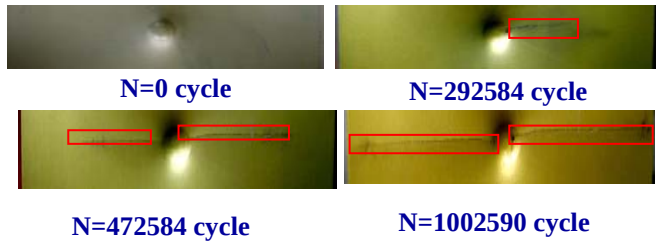
Damage Tolerance of Fiber-Metal Laminates

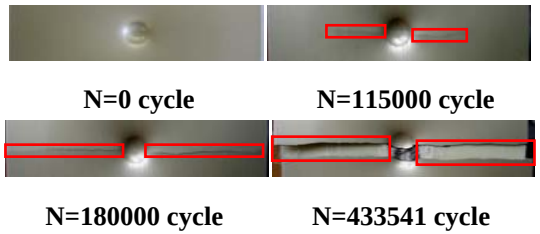
Impact Characterization



Fatigue Crack Growth

GLARE 4



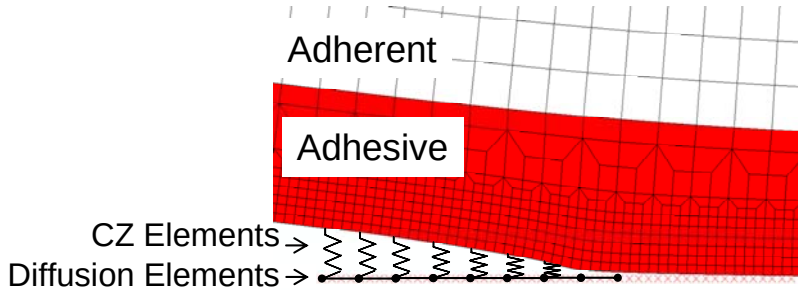


GLARE 5

Cracks initiate on the impacted side

Damage Tolerance and Durability of Adhesively Bonded Composite Structures

- **Developing basic knowledge of fracture of bonded joints.**
  - Strength of single lap joint increases as bondline thickness increases
  - In DCB fracture test, toughness increases as bondline thickness decreases.
  - For thinner bondlines the interfacial stresses between the adhesive and adherend are higher than those for thicker bondlines.
  - CTOA for crack growth in adhesive is independent of bondline thickness
- **supports use of more sophisticated computation-based design and analysis tools**
  - failure process prediction, including adhesive plasticity
  - CTOA criterion simple to implement
  - VCCT and cohesive zone (cracked & un-cracked) now available in commercial codes
  - simulation tools can reduce time to conduct extensive environmental degradation tests
- **addressing important issues of bondline thickness**
  - quantify phenomena governing why “properties” seemingly depend on bondline thickness
  - definition and use of local failure criteria that are not bondline thickness dependent
- **simpler test methods to obtain fracture and constitutive data**
  - seeking to define simpler tests and remove necessity to collect data as function of bond thickness



Finite element model with cohesive elements & H_2O transport

Composites Maintenance Research and Training Initiatives

- **Awareness course development update**
  - Objectives and process
  - Outcomes: Three FAA Technical Center Reports
  - Content
  - Lessons Learned
- **Future initiatives in training**
  - Ideas from prior workshops and collaborations

Awareness Course Objectives

Standardize an awareness course on Critical Composite Maintenance & Repair Issues

- **Involvement: Achieve consensus with industry, academic and regulatory experts**
  - Awareness course, not skill-building
  - Feedback: Series of workshops throughout 2004 to 2005
- **Process**
  - Define framework by identifying ‘terminal course objectives’, or TCOs
  - Establish safety theme by documenting ‘safety messages’
  - Develop content to populate TCOs as a tool for course developers

Awareness Course Process Overview

- **Series of workshops to bring regulators and industry together on critical technical issues**
  - May 2004 FAA/NRC workshop in Wash. DC Executive review of systematic, repair, NDI & training issues
  - August 2004: Beginning of EdCC cooperative agreement with FAA
  - November 2004 workshop to evaluate training needs
  - 2005 and 2006 FAA workshops to:
    - Review progress in establishing awareness training on critical issues
    - Solicit feedback from industry experts
- **FAA research at JAMS COE**
  - Practical, introductory-level course for engineers, technicians and inspectors
  - FAA/Edmonds C.C. Cooperative Agreement (2004-2007)
    - Short course (5–7 days), incl. labs, worth 4 credits
    - Current efforts include web-based, distance learning

Modified from presentations and seminars by L. Ilcewicz

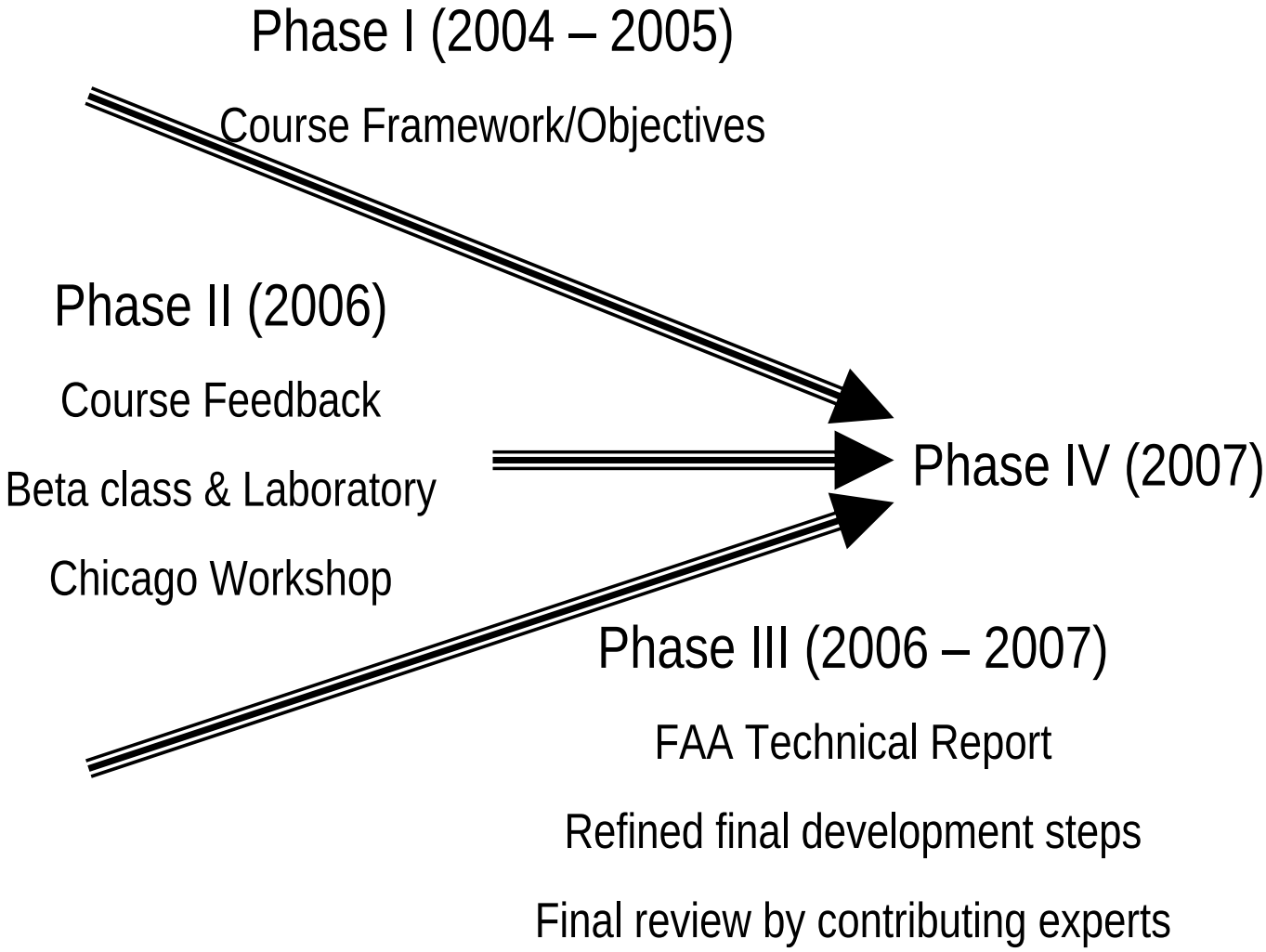
Awareness Course Outcomes Three FAA TC Reports

- **Goal: Standardize an awareness course on Critical Composite Maintenance & Repair Issues – 3 TC reports**
  1. FAA Technical Center Report
     - Terminal Course Objectives (TCOs)
     - Safety messages
     - Narrative description of critical issues
     - Instructor's guide
     - Class design guidance
  2. FAA Technical Center Report: Training repair manual (TRM)
  3. FAA Technical Center Report: Course development
- **Teaching points: Assessment tools to guide content (proposed to be AIR)**

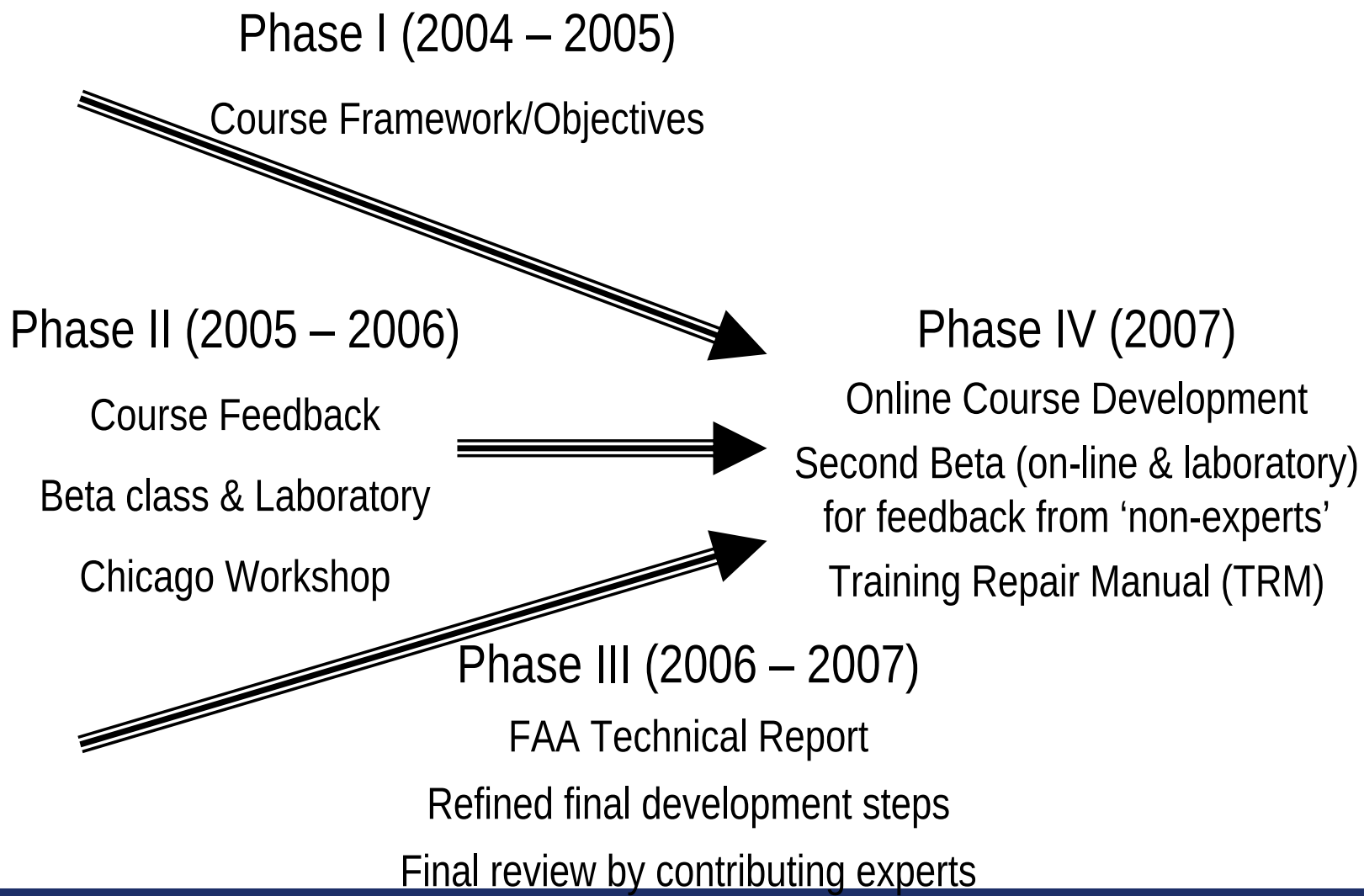
Awareness Course Process Establishing the Framework

- **November 2004 workshop**
  - Over 60 experts from global community
  - Professional facilitators provided by Boeing
  - Step 1: Identify necessary skills for engineers, technicians and inspectors
    - 500+ skills identified
  - Step 2: Categorize skills into categories summarized as course objectives
- **Result: Course objectives (62 TCOs, later categorized into 13 terminal course modules). Additional information included**
  - Obstacles to overcome
  - Alternative approaches
  - Parking lot issues (outside scope of awareness class)

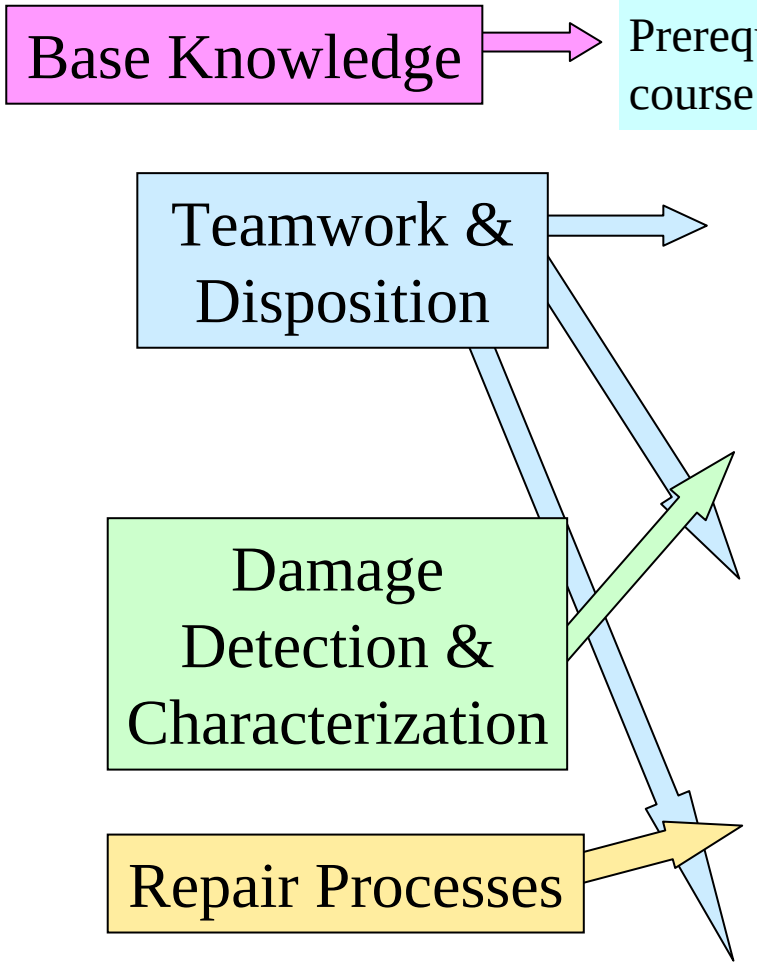
Awareness Course Process



Awareness Course Process



Awareness Course Content



Prerequisite: Students take assessment prior to main course

Main Course

Understand the roles & responsibilities of key teammates

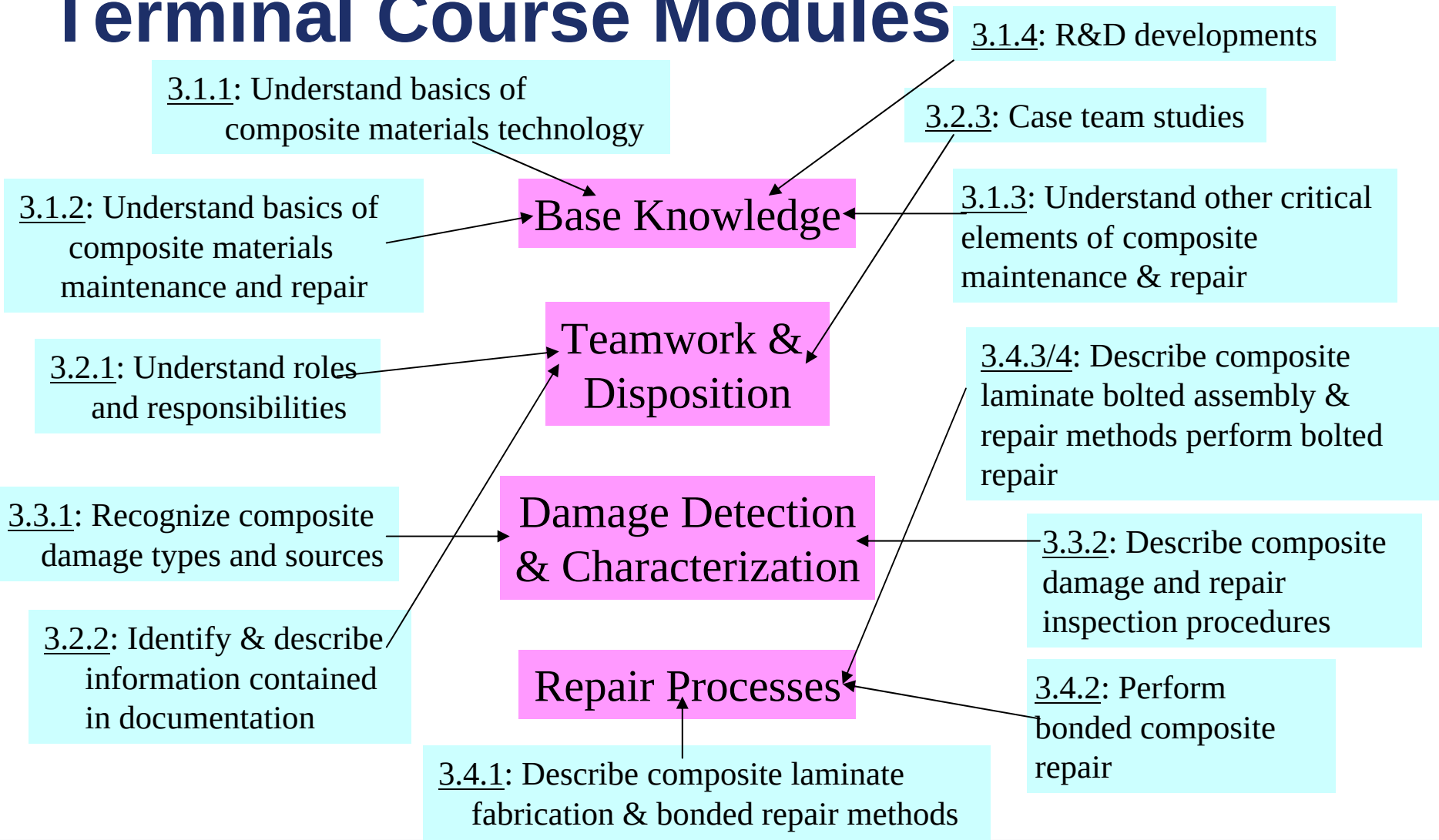
Recognize composite damage types and sources and describe composite damage and repair inspection procedures (2 labs)

Identify & describe information contained in documentation for approved maintenance & repair

Describe composite laminate fabrication, bonding, & bolted assembly methods and perform bonded & bolted repairs (2 labs)

Participate in case team studies (lab)

Awareness Course Content
Terminal Course Modules



Awareness Course Development Lessons Learned

- **Creating a standard course framework from diverse experts is possible!**
  - Process of consensus
  - Feedback mechanisms
- **Creating a standard course framework from diverse experts requires patience and considerable funding**
- **Synergy among dedicated industry, academia and regulatory organizations and people is high with sufficient interest**
  - Must meet needs of organizations and individuals
  - Must fit with business interests of contributing organizations
- **Collaborations have resulted in ideas for future training initiatives**

Future Training Initiatives

- **Basis: Any ideas below are subject to future discussions and business plan approval**
- **High – training group**
  - Integrate CACRC document content into training AIR, with assessment of maturity of knowledge base by originators
  - Expand training repair manual being proposed in Phase IV of awareness course development to beyond Chapter 51.0
- **Medium – training group**
  - Training to ensure best practices in repair design
  - Establish training requirement for ramp personnel
  - Further develop 3 training AIRs currently under review around TCO framework in order to facilitate creation of certification standards
- **Low – training group**
  - Design for reparability
  - Update SACMA video for ramp personnel
  - Develop ‘case studies’ based on actual events for encouraging student participation and improving retention
- **Other**
  - Develop a ‘how to use’ manual for CMH 17