AMTAS
Composite Maintenance Workshop

November 30 – December 2, 2004

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Executive Summary

The goal for this workshop was to achieve consensus for composites maintenance and repair.

Objective: Specifically, the objective of the workshop was to provide terminal course objectives (TCOs) for a 5-day survey course and laboratory workshop regarding composites repair with the following vision:

Students at the end of the course will have a common foundation of understanding of the maintenance, repair and handling of composite materials, exposing them to simple repairs and preparing them for more advanced training. Students at the end of the course will be able to:

- Understand the basic art of composite maintenance and repair, including the design issues associated with airframe structure
- Describe the materials, processes and key quality controls used for bonded and bolted repair methods
- Understand the roles, responsibilities and relationship of technician, inspector and engineer in the composite repair process.
- Identify sources of technical data and regulatory requirements
- Produce composite laminate, damage it under controlled conditions, and make proper repair procedures. Identify differences in critical damage types, inspection methods and repair procedures for composite and metal structures
- Perform damage inspection on a composite part produced by student
- Assess effectiveness of the student-repaired composite part
- Distinguish between proper procedures for repairs that are and are not included in source documentation

Overview: Over 50 individuals, selected for invitation because of their extensive backgrounds in composites repair, attended the workshop. They represented academia, industry (OEMs, airlines and MROs), the FAA and U.S. Air Force, and professional training organizations, originating from a wide geographic spectrum. The workshop was sponsored by the FAA, AMTAS, and the Boeing Company. The workshop was sub-divided into three smaller work groups which represented Engineers, Technicians, and Inspectors – Each of the three work groups was facilitated by Boeing professionals who provided critical expertise to the workshop process.

Outcomes: Each of the three work groups provided vital information for the successful development of the curriculum: 1) draft Terminal Course Objectives (TCOs) and 2) a list of up to 150 essential skills. Equally important, the broad representation of personnel in the workshop provided a sense of ownership and responsibility to a broad spectrum of the industry for the resulting curriculum development. Educational resources were identified for potential incorporation into the class, and included, for example, videos on composites repair from the U.S. Air Force, Alteon and Heatcon, with the following video titles:

- Prevention and Reporting of Damage
- Basics of Composites
- Mishap and Post-Crash Handling
- Operation of Hot Bonder

Next Steps: The draft TCOs are being categorized and tested through the AMTAS advisory group for completeness and consistency, and this report will be made available to the workshop attendees for comment. Team coordination meetings within Edmonds and Everett Community Colleges are being initiated. TCOs will be finalized in the first quarter 2005. A progress update will be delivered to the Commercial Aircraft Composite Repair Committee (CACRC) in May, 2005, to be held in Bremen, Germany, where it is expected that additional European input will further refine the development. The initial course materials will be developed and the first class will be conducted at Edmonds Community College under an FAA grant. A final report for the project and a review of the curriculum will be delivered to FAA and industry personnel in Chicago for final comment and to support further training development directions. Coinciding with these activities, a review of major training resources that would either enhance the curriculum development or provide directions for students seeking more advanced training will be conducted. A database is being established which will provide a guide to aerospace regulations, information sheets, policies, and advisory circulars regarding the maintenance and repair of composite materials on commercial aircraft.

Terminal Course Objectives (TCOs) Outcomes

Inputs collected at the workshop are organized in the table below by Terminal Course Objectives (TCOs), and subordinate objectives to the TCOs. It is estimated that a course, which includes all of these objectives as currently worded, would exceed the current time available in a 5-day survey course. As a result, efforts are currently being applied to generalize TCO and reword subordinate objectives to ensure the most important points are included, while maintaining broad coverage. In addition, some objectives linked to a basic understanding of composite materials will be moved to prerequisites that are covered in self-study or through other basic knowledge held by students entering the course. Short, web-based learning modules, which include a basic entrance test, are envisioned for any prerequisite. Some TCOs, as identified in the workshop, will be identified as advanced topics, which require study beyond the 5-day survey course.

Terminal Course Objectives		Subordinate Objectives	
A	Understand the basic art of composite materials technology	**A1**	Describe various processing parameters and basic composite materials properties
		A2	Distinguish among resin, fiber, and core applications and uses.
		A3	Describe storage and handling requirements
		A4	Describe solid laminate and sandwich structure composite structures, including applications and properties
		A5	Describe ply and core orientation requirements and properties, including the sources of warp
B	Understand the basic art of composite materials maintenance and repair, including the design issues associated with airframe structure and materials, processes and key quality controls used for bonded and bolted repair methods	**B1**	Adhere to personal and equipment safety requirements
		B2	Describe basic steps in repair process, including the repair processes from damage assessment through repair completion
		B3	List the necessary tooling and equipment to accomplish a simple laminate structural repair
		B4	List the key composite and expendable materials needed for simple laminate structure repair including appropriate storage requirements
		B5	Describe the differences in critical damage types, inspection methods, and repair procedures between repairing composite and metal structures
C	Understand the roles, responsibilities and relationship of technician, inspector and engineer in the composite repair process.	**C1**	Identify and chart the steps involved in repair design and approval
		C2	List basic NDI methods with their limitations, including pre- and post NDI
D	Identify sources of technical data and regulatory requirements	**D1**	Identify the requirements for material and process specifications and specification approval requirements.

Terminal Course Objectives		Subordinate Objectives	
E	Produce composite laminate, damage it under controlled conditions, and make proper repair procedures	**E1**	Assess and Identify typical composite manufacturing and in-service defects
		E2	Demonstrate and apply common surface preparation and drying techniques and how to inspect them for acceptability
		E3	Demonstrate and apply material lay down [including orientation] and compaction process for a simple laminate structure repair
		E4	Demonstrate how to prepare and cure a simple laminated structural repair and explain the types of defects to be avoided
		E5	Know the different process parameters that affect repair quality (surface preparation, moisture ingression, contamination, cure parameters, storage & handling of materials, proper calibration & standards).
F	Perform damage inspection on a composite part produced by student	**F1**	Select and use manuals and publications to research repair processes, practices, parts, and materials.
		F2	Demonstrate critical steps needed in making a damage disposition, including drafting a QA plan for a typical repair (material selection/orientation, process parameters, and inspection requirements
		F3	Describe two different post-repair inspection procedures
G	Assess effectiveness of the student-repaired composite part	**G1**	Verify that the repair environment was correct, the surfaces were properly pretreated and cleaned, and that the part was properly dried.
		G2	Verify that a repair cure was done correctly, the plies were properly impregnated, the resin was properly mixed, the # and orientation of the plies was correct, and that the repair was properly thermocoupled.
		G3	Demonstrate an awareness of post-repair visual inspection and NDI techniques.
		G4	Verify that the correct materials were used and that they were handled and stored correctly.
H	Distinguish between proper procedures for repairs that are and are not included in source documentation		

Terminal Course Objectives		Subordinate Objectives	
I	Utilize and identify source documents (e.g. revision systems, effectivity, drawing numbering systems, ply charts, repair drawings, M&P specifications)		
J	Utilize and identify regulatory documents (e.g. FARs Advisory Circulars, Airworthiness Directives		
K	Verify correct fastener selection, that fastener holes were properly machined, inspected, and fasteners were properly installed.		
L	Explain the impact of processing variables on NDI, and fiber waviness.		
M	Describe various electrical requirements and effects, including prevention of corrosion, hazards of electromagnetic interference and electrostatic discharge		
N	Perform various damage and repair assessments, including visual inspection, tap test, and ultrasonic inspection.	**N1**	Discuss other advanced assessment techniques, such as bond testing, moisture meters, interferometer (3D characterization)
		N2	Evaluate and name types of damage and their significance, such as delamination and moisture/heat damage
O	Demonstrate bolted repairs	**O1**	Select between bonded and bolted repairs

Process Description

An outline of the workshop agenda is as follows:

1. Participants were first presented with the philosophy and approach of the workshop

Workshop Overview

Objective: Establish fundamental baseline training for composites maintenance and repair training course(s) to achieve a common level of understanding for the following workforce: Technicians, Engineers, Inspectors
Format: Three subgroups to consider unique requirements in separate breakout sessions and provide feedback & conclusions
Vision for Training Students at the end of the course will have a common foundation of understanding of the maintenance and repair of composite materials, preparing them for simple repairs and for more advanced training

Sample Terminal Objectives

Students will be able to:

- Use basic repair techniques (subordinate objectives TBD)
- Read and follow source documentation and procedures (subordinate objectives TBD)
- Determine selection criteria through assessment of damage for alternative repair solutions (subordinate objectives TBD)
- Mitigate technical risks (subordinate objectives TBD)

Overview: Workshop Goal

Inspector/Engineer/Technician groups: Each of the three work groups was to provide training objective recommendations from the group’s perspective and make presentations to the total audience for discussion and comment concerning the recommended desired state of training. Each group had an overall facilitator, supported by a technical facilitator and a ‘scribe’ to capture information being discussed. The process was designed to result in the following information at the end of the workshop:

- Course Objectives
- Obstacles to Overcome
- Alternative Approaches
- Parking Lot Issues (Out-of-scope issues)

2. Conduct of class: While a structured approach was provided to the facilitators, it was made clear that the facilitators, at their discretion, could deviate depending on the dynamics of the work group.

November 30

Session 1 Objective: After the welcome comments, participants were given an opportunity to describe current situation and why the workshop is needed. 6 groups were selected randomly to discuss composite repair scenarios from actual experience, and present one story to the total audience. Participants were requested to select one of the following, for example, and select a ‘favorite story’ for full session presentation, commenting on how the scenario could have been improved through training.

“How could a repair process be made more efficient by avoiding unnecessary rework?”
“Knowing what you don’t know: An instance where someone didn’t know when to ask for help”
“The Temptation of Shortcuts: An instance where shortcuts could have caused a bad situation”
“Understanding Roles: How one person didn’t understand the interdependence with other organizations and other roles in the process?”

A variety of scenarios were presented, including, for example, the following topics:

Repair of a hole in a leading edge
Metal overlay repairs
Structural Repair Manual issues
The difficulties of replacing metal structure with composites in a manufacturing line

Presentations were made from the representatives of the Commercial Aircraft Composite Repair Committee (CACRC), including Alteon and Abaris training organizations. A number of issues were identified, described under ‘Essential Issues’ later in this report.

Session 2 Objective: Workshop participants were broken into three equal-sized workgroups to address composite maintenance and repair for three types of composite construction. Groups were represented by three principal practitioners, engineers, technicians, and inspectors. Each workgroup outlined steps required in composites' maintenance and repair, and identified key people involved in the process. This laid the groundwork for discussing required skills in session 3. The three types of composite construction under consideration included thick laminate, laminate and honeycomb flight control surfaces, and honeycomb fairing panels.

Each group filled out a template reflecting the discussion and listing the repair steps.

<u>December 1</u>
Session 3 Objective: Identify skills of each work group (engineers, technicians, and inspectors) by addressing the question, “What basic skills do we use, what are the tools, source documentation, and techniques we use, and how did we learn them?”

Based on the repair steps identified in Session 2, each work group identified specific skills to perform the repair, including the tools, documentations, and techniques for each skill

Session 4 Objective: By comparing the current state of training for essential skills, and what the desired training ought to be, course objectives were to be decided by the work groups, addressing the question: “What should the training objectives be, considering improvements regarding current training?”

At this point in the process, it was clear that the number of ‘essential skills’ were numerous (up to 150 per work group), and that the process would have to be modified in order to meet the objectives of the workshop. By group consensus, the decision was to categorize each skill on a level of 1 to 3, with 1 identifying exposure of students to the skill, and 3 identifying more focus for the curriculum development. From the ‘level 3’ skills and considerations of the other desired skills, which would be covered to a lesser extent, each work group identified TCOs that are summarized in this report.

Session 5 Objective: Each group provided their conclusions, presented by their respective technical facilitators. Invitations were extended for final comments (see Essential Issues below) and solicitations were made for training resources. Educational resources were identified for potential incorporation into the class, and included, for example, videos on composites repair from the U.S. Air Force, Alteon, and Heatcon, with the following video titles:

- Prevention and Reporting of Damage
- Basics of Composites
- Mishap and Post-Crash Handling
- Operation of Hot Bonder

Essential Issues mentioned by Participants

1. Urgent request to have a sanctioned training standard by the FAA in composites' repair
2. Suggestion that composites repair training be mandatory (i.e., a regulatory requirement)
3. Composites' repair training exists – it is the implementation of training that is the concern
4. Course will be universally available – by reaching consensus on the course content, standards and regulations can be developed from this baseline
5. Logistics – distance, cost and time for students – Alternative is to use web-based training
6. Involve employers to create priority and importance of training for students
7. Advanced training: Certain aircraft have special paint requirements, possibly requiring advanced training
8. Five days may not be sufficient to meet the terminal course objectives
9. Perception by technicians is that this course is a 'final' course, rather than a survey course
10. Training location logistics – who pays for this?
11. Target audience for this course is not defined sufficiently
12. Teaching materials – availability may be an issue, especially manufacturers approved data
13. How will this course be integrated with the existing CACRC curricula?
14. Will the FAA recognize CACRC documents as acceptable/source data?

Compilation of Work Group Materials: Steps in the Composite Repair Process

Work Group (Technician Emphasis)

Steps in Repair Process & Key People

Flight Control Surfaces – Honeycomb and Thin Stiffened Laminate Construction

Steps	Description	Role of Key Person	Job Description of Key Person
A	**Overall Process Control**		**Inspector**
B	**Design Repair**		**Engineer/Technician**
C	**Locate Tooling**		**Technician**
D	**Materials**		**Technician**
E	**Moisture Detection/Removal**		**Technician/Inspector**
F	**Damage Evaluation**		**Technician/Inspector**
G	**Damage Removal**		**Technician**
H	**Core Installation**		**Technician**
I	**Scarf/Sand**		**Technician**
J	**Repair Layup**		**Technician**
K	**Cure**		**Technician**
L	**Surface Prep**		**Technician**
M	**Vacuum Bag**		**Technician**
N	**Balance**		**Technician/Inspector**
O	**Post Repair NDI**		**Inspector**
P	**Post Repair Surface Restoration**		**Technician**
Q	**Final Documentation**		**Technician/Inspector**

Work Group (Inspector Emphasis)

Steps in Repair Process & Key People

Fairing Panels – Light Honeycomb Construction

Steps	Description	Role of Key Person	Job Description of Key Person
A	Determine the extent of damage	Inspector	
B	Define Repair	Eng. / Tech	
C	Get access	Tech	
D	Surface prep	Tech / Insp	
E	Get tools; bagging, material, consumables	Tech	
F	Dry part	Tech / Insp	
G	Remove damage	Tech / Insp	
H	Obtain repair material	Tech	
I	Cut repair plies to size	Tech	
J	Layup repair material	Tech	
K	Replace core	Tech	
L	Get repair approval when required	Eng / Insp	
M	Bag repair	Tech	
N	Document materials used	Tech	
O	Cure repair	Tech	
P	Debag	Tech	
Q	Inspect completed repair	Inspector	
R	Complete repair area to finish requirement	Tech	

Work Group (Engineering Emphasis)

Thick Laminate Construction:
Steps F through J will differ significantly depending on bolted or bonded repair

Steps	Description	Role of Key Person(s)	Job Description of Key Person
A	**Initial damage/flaw detection (service damage or mfg/repair mistake)**	**Discover problem**	**Operations, Inspector, Technician**
B	**Damage assessment (inspect full damage extent, NDI, ID structure, document)**	**Define scope of problem**	**Inspector, Technician, Engineer**
C	**Disposition (Review source documents, engage OEM, ID repair, plan, ROM, ID team)**	**Identify solution path**	**Engineers (Maintenance & OEM)**
D	**Remove paint and other surfacing layers**	**Remove surface coatings**	**Technician**
E	**Remove damage**	**Remove damage**	**Technician**
F	**Repair Detail Design & Process Plan (ID/procure materials, OEM interface, define structural repair detail, tools, process steps, technician skills)**	**Define repair path**	**Engineers (Maintenance & OEM)**
G	**Obtain tooling, equipment and expendable materials**	**Obtain repair aids**	**Engineers, Technicians**
H	**Execute processes (bolted repair : machining, drilling, sealing, fastening or bonded repair: cleaning, scarfing, surface preparation, layup, bond assembly, cure)**	**Perform repair**	**Technicians**
I	**Perform in-process controls**	**In-process QC**	**Inspectors**
J	**Post-Repair Inspection**	**Inspect repair**	**Inspectors**
K	**Finishing (aero fairing, EM protection, surfacing, painting)**	**Finish surface**	**Technicians**
L			

Compilation of Work Group Materials: Required Composite Repair Skills

Work Group (Technician Emphasis)

This is oven focus with a touch on hot bonder

Primary Emphasis - 3;
Secondary Emphasis -1

	Essential	Current Training	Desired Training
Proper storage and handling techniques	Yes	3	
Determine material by visual recognition	Yes	3	
Know basic material characteristics	Yes	3	
Determine the type of initial materials	Yes	3	
Detail knowledge of the repair that is required	Yes	3	
Determine the initial part cure temp.	Yes	3	
Use of proper environment (cleanliness and ventilation)	Yes	3	
Identify Ply and orientation requirement	Yes	3	
Determine overlap	Yes	3	
Align ply sequence	Yes	3	
Use proper techniques	Yes	3	
Prepare plies	Yes	3	
Employ proper handling techniques	Yes	3	
Skills for wet lay-up versus pre-preg	Yes	3	
Cut and lay-up plies / adhesives	Yes	3	
Determine vacuum bag schedule	Yes	3	
Perform leak check	Yes	3	
Place of ports at correct location	Yes	3	
Determine cure cycle	Yes	3	
Debag the part	Yes	3	
Surface prep	Yes	3	
Skills in tool usage	Yes	3	
Determine scarf requirements (ratio, overlap)	Yes	3	
Figure the required dimension	Yes	3	
Select proper Personal Protective Equipment (PPE)	Yes	3	

	Essential	Current Training	Desired Training
Run the cure cycle	Yes	2	
Know types of cure and equipment	Yes	2	
Know NDI requirements	Yes	2	
Evaluate cure record	Yes	2	
Determine the appropriate removal process or tools	Yes	2	
Evaluation repair options	Yes	2	
Select adhesive	Yes	2	
Clean and prepare core	Yes	2	
Cure core	Yes	2	
Use MSDS	Yes	2	
Know of hazardous areas and environment	Yes	2	
Select the proper repair category (interim, time limited, permanent)	No		2
Gather technical data	Yes	1	2
Check allowable damage limits	Yes	1	2
Disposal requirements (all steps)	Yes	1	2
Ask or Do NDI	Yes	1	2
Identify steps or techniques (Moist)	Yes	1	2
Assess core condition	Yes	1	2
Follow steps	Yes	1	0
Use techniques	Yes	1	0
Determine accessibility	Yes	1	
Determine fixability	Yes	1	
Perform a NDI	Yes	1	
Knowledge of what you are fixing	Yes	1	
What is the inspection items	Yes	1	

Techniques to taper sand using assorted equipment	Yes	3	
Identify core type	Yes	3	
Identify orientation (ribbon direction)	Yes	3	
Cut adhesive	Yes	3	
Use of hand tools	Yes	3	
Use of potting	Yes	3	
Determine core dimensions	Yes	3	
Select bagging schedule	Yes	3	
Debag and sand	Yes	3	
Evaluate the surface cleanliness	Yes	3	
Use proper cleaning techniques	Yes	3	
Understand galvanic corrosion	Yes	3	
Protect surfaces	Yes	3	
Select and use proper PPE	Yes	3	
Follow HazMat requirements	Yes	3	
Protect electrical equipment from carbon dust	Yes	3	
Explain the reason for each step	Yes	3	
How to process repair material	Yes	3	
Ability to drill and machine materials	Yes	2	3
Identify and select fasteners	No		3
Prepare doublers	No		3
Determine fasteners spacing and edge margin requirements	No		3
What is the required paperwork	No		2
Select appropriate heat blankets	No		2
How to correct anomalies	No		2
Manage thermocouple variances	No		2
Evaluate substitution options (core)	No		2
Determine surface restoration requirements	No		2
Apply surfacer and sealant	No		2
Know when to do bolted repair	No		2
Know proper storage and handling	Yes	3	2
Be able to inspect for the extent of the damage	Yes	2	
Select type of material	Yes	2	
Select proper cleaning agents and material	Yes	2	
HazMat requirements	Yes	2	

Determine repair limits	Yes	1	
Determine substitutions	Yes	1	
Find and remove obstacles	Yes	1	
Document repair plan	Yes	1	
Identify required tools	Yes	1	
Identify required equipment	Yes	1	
Determine cure method	Yes	1	
Identify allowable removal processes	Yes	1	
Knowledge of part structure	Yes	1	
Identify moisture / contamination	Yes	1	
Determine when component is clean and dry	Yes	1	
Restore lightning strike / HIRF protection	Yes	1	
Determine if material in supply	No		1
Determine substitution allowable	No		1
Find out repair history	No		1
Be able to interpret Structure repair manual	No		1
Use calibrated equipment	No		1
Use of insulation	No		1
Techniques to step sand using assorted equipment	No		1
Stabilize the core	No		1
Use of septums	No		1
Select cure stages	No		1
Restore P Static coating	No		1
Reinstall removed item	No		1
Calculate weight and balance	No		1
Prepare all required documentation	No		1
Complete all required documentation	No		1
Evaluate for Group repairs	No		
Calculate the cost of the repair	No		
Determine availability of replacement part	No		
Determine time and schedule for type of repair	No		
Where is the data plate (control surfaces)	No		
Develop repair concept (suggested title)			
Be able to interpret technical manual	No		
Perform heat survey when required	No		

Ability to create and use templates	Yes	2		Identify the support tool requirement	No	
Determine vacuum bags types	Yes	2		Ability to Repaint	No	
Determine number of thermocouples	Yes	2		record results of w & b	No	
Determine placement of thermocouples	Yes	2		Ability to weigh and balance	No	
Follow vacuum requirements	Yes	2		Provide signature	No	

Work Group (Engineering Emphasis)

Thick Laminate Construction Skills and Knowledge	Essential Content for Intro Level (yes, no)	Relative scale of Content (1 to 3)
Skill A/Initial damage/flaw detection		
1) Inspection method used to first detect damage (capability and limits)	Yes	2
2) Description of damage (language/glossary that can be understood)	Yes	2
3) Source of damage if known	Yes	1
4) Description/function of damaged part (knowledge of a particular aircraft structure)	No	
4a) Part functional requirements (Aero, Operational)	"	
5) Realization that damage may be bigger than indications from inspection method (visual)	Yes	2
6) Knowledge damage types	Yes	2
7) Standard definitions for possible damage types	Yes	2
8) Knowledge of applicable NDI methods	Yes	2
10) Visual characterization criteria	Yes	2
11) Process parameter variation or other in-process check that indicates a problem	No	
12) Knowledge of lightning strike protection schemes and whether or not it is present	Yes	2
13) Remote visualization for engineers (OEM or MRO/Airline off-site)	No	
14) Realization that damage well away from visual indication may be important	Yes	2
14b) Particularly important as related to 3)	"	"
15) Knowledge of overall "Supportability"	No	
16) Modes of failure	Yes	2
17) Understanding of operational issues	No	
18) Knowledge of different material/design characteristics	Yes	2
20) How is damage usually found (operations, lost operational function, directed inspection)	No	
21) Basic knowledge of composites	Yes	3
22) Paint discoloration, fluid leaks, or other indications of composite part degradation/damage	Yes	1,2
23) Historical data on typical damages, degradations	Yes	1,2
Skill B/Damage Assessment		
9) How important is the damage, or defect noted to structural integrity	Yes	3
1) Understanding which NDE methods are needed to fully characterize damage	Yes	2
2) Whatever 3D descriptions of damage possible with different inspection schemes	No	
3) Knowledge of SRM damage descriptions/limits	Yes	2
4) Implications of damage for different structural configurations	Yes	2

1: mention
2: expand
3: get into details

5) Knowledge of the overall aircraft structure (e.g., reaction points for vehicle collisions)	Yes	1
6) Documentation of previous damage scenarios/part history	Yes	1
7) Knowledge of the extent of possible damage versus indications of the event	Yes	1,2
8) Knowledge of structural test programs to assess the effects of defects/damage	No	
9) Ability to read the NDI results and interpret structural-specific anomalies	Yes	1
9a) Ability to avoid "false positives"	"	
10) The effect of drifting repair process parameters and their effects on structural integrity	No	
11) Normal maintenance inspection schedule (MPD)	No	
12) Knowledge of the materials present in the damage component	Yes	2
13) Standard checklist to document/define damage for those you need to communicate with	Yes	2
14) Knowledge of the structure and what NDE method is appropriate	Yes	2

Skill C/Disposition

1) Knowledge of the allowable damage limits for that part	Yes	2
2) Knowledge of the service environment	Yes	2
3) Structural repair methods that are available and can be performed at location of airplane	Yes	2
4) Knowledge of available materials to make repair	Yes	2
5) Knowledge of available equipment, tooling and expendable ancillary materials	Yes	2
6) Understanding the limitations of facility and available personal	Yes	2
7) Knowledge of the cost and time to complete the repair	Yes	1
8) Awareness of flight restrictions for specific damage scenario	Yes	2
9) Knowledge of regulations (e.g., lightning, fire, structural integrity, aero)	Yes	2
10) Incorporation/knowledge of information in Flight/operations Manuals	Yes	1
11) Knowledge of regulations creating a disposition outside previously certified repairs	Yes	2
12) Phone number of the OEM/awareness of who was the OEM	No	
13) Knowledge of what your limits are/what you don't know	Yes	1,2
13a) Who do you go to when it is beyond your experience (resources)	"	"
14) Thorough understanding of the SRM and repair/damage size limits	Yes	3
14a) Is the SRM applicable? (clarification of existing source documentation)	"	
15) Documentation/planning/communication with the team (OEM, technicians, inspectors)	Yes	1,2
16) Is the structure removable from the aircraft (to properly consider repair options)	Yes	1
17) Is a temporary disposition an option	Yes	1
18) Does the damage/repair have implications to the airline maintenance program	Yes	1
19) Recognizing warranty or customer relations	No	
20) Team leader/player skills and ability to communicate the actions	Yes	1,2
21) Understanding of possible repair options	Yes	2

Skill D/Removal of paint and other surfacing layers

1) Health and safety PPE	Yes	2
2) Appreciate the risks of not following approved processes	Yes	2
3) EPA/OSHA regulations for the specific location	Yes	1
4) Knowledge of what should be there versus alternate that made their way onto airplane	No	
5) Approved processes and necessary technician skills	Yes	2
6) Limits on removal and possible related structural damage possible	Yes	2
7) Recognition of conductive coating and the restoration processes	Yes	1,2
8) What process is used to remove paint	Yes	2
9) Various coating schemes and their function	Yes	2

Skill E/Remove damage

1) NDI following damage removal and redisposition if necessary	Yes	2
2) Knowledge of methods, equipment, tools and shop aids used for damage removal	Yes	2
3) Health and safety issues different than paint removal	Yes	1
4) Access considerations (removal of systems, fluids, fuels, or aircraft parts as necessary)	Yes	1,2
5) Collect damage debris and waste for proper disposal	Yes	1
6) Knowledge of taper ratios if appropriate	Yes	2
7) Issues of square corners, sharp edges or other structural detail you may or may not want	Yes	2
8) Knowledge of bolt removal schemes	Yes	2

Skill F/Repair Design Detail & Process Plan

1) Knowledge of approved specifications and processes	Yes	2,3
2) Examples of good plans	Yes	2
3) Selection of appropriate design/limits from SRM	Yes	2
4) What tooling and equipment is needed	Yes	2
5) What technician skills are needed	Yes	2
6) What is the regulatory process for creating your own repair design substantiation (separate from OEM)	Yes	2
7) General knowledge of differences between metals and composites	Yes	2
8) Selection of bonded or bolted repairs	Yes	2
9) Realization of the limits of repair options (e.g., bond scarfing)	Yes	2
10) Statistics of composites versus metals	No	
11) Forgiveness for mfg variations	No	
12) Selection of proper repair materials, handling and qualification reqmts (often with OEM)	Yes	2
13) Knowledge of configuration control for specific design/OEM (regulatory aspects)	Yes	1
14) Knowledge of over curing/post-curing	Yes	2
15) Validation of alternative materials (knowledge of material compatibility issues)	Yes	2
16) Fixture requirements part handling/removal	Yes	1,2
17) Knowledge of machining, drilling and forming composites and titanium sheets	Yes	2
18) Knowledge of composite fasteners and installation methods	Yes	2
19) Knowledge of achieving uniform temperatures in the bonded repair (on-airplane/oven or autoclave)	Yes	2
20) Material compatibility (e.g., aluminum and carbon/epoxy composites)	Yes	2
21) Knowledge of EMI protection design/process details	Yes	2

22) Sequence of repair processes (skills, time of execution)	Yes	2
23) Ply orientation, symmetry and balance (patch layup guidelines)	Yes	2
24) Other aspects of repair design including knowledge of the parent part details	Yes	1,2
25) Realization of CG, resonance and balance/weight, functional, aero requirements	Yes	1,2
26) Knowledge of critical process steps (drying, surface prep, bond assembly, tolerance control)	Yes	2
27) Knowledge of cure pressure and temperature affect on structural properties	Yes	2
28) Plan & procedure to ensure temperature min/max tolerance is met	Yes	2
29) Other planning considerations for subsequent processing steps	No	
30) Addition of sacrificial plies	Yes	1
31) Basic insights on composite stress analysis and structural capabilities	Yes	2

Skill G/Obtain tooling, equipment and expendable materials

1) Tool fabrication	Yes	1,2
2) Recognize material shelf life	Yes	2
3) Tooling compatibility with selected repair	Yes	2
4) Systems approach to expendable materials/ guidelines for alternates (if any)	Yes	1
5) Knowledge of heating equipment and technicians have been certified for use	Yes	1
6) Environmental and cleanliness controls	Yes	1,2
7) Drill jigs for fastener location and structural backup as needed	Yes	1,2
8) One-sided repair considerations	Yes	2
9) Facility maintenance requirements	Yes	1
10) Loft considerations	Yes	1
11) Knowledge of specific material types	Yes	2
12) Storage requirements for tooling and equipment	Yes	1

Skill H/Execute processes and Skill I/In-Process controls

1) see Skill F list	Yes	
2) Determine whether a QA plan is needed and applied	Yes	2
3) Compacting issues for thick laminates	Yes	2
4) Is the plan consistent with technician behavior (breaks vs. surface prep, resin setup, cure)	Yes	1
5) Quantity and location of thermocouples	Yes	2
6) Detailed process planning and reactions to upsets that may occur	Yes	2
7) Knowledge of complexities of thick part cure	Yes	2
8) Integrated time management of QA and process steps	Yes	1
9) Understanding of curing mechanisms	Yes	2
10) Understanding of impregnation of dry cloth	Yes	1,2
11) Understanding of moisture diffusion as related to part details	Yes	1,2
12) Reaction to curing or other problems that occur in process	Yes	2
13) Bond surface prep techniques and related QA (environmental and cleanliness and surface activation)	Yes	3
14) Portability of the process between OEM (e.g., Boeing and Airbus similarities/differences)	Yes	1
15) Realization that expendable materials must be monitored and replaced	Yes	1
16) Risk mitigation through equipment and tooling inventory/maintenance	Yes	1

Skill J/ Post-repair Inspection

1) Understanding of approved inspection procedures	Yes	2
2) Disposition of defects and damage caused by repair (MRB? actions)	Yes	2
3) Understand porosity limits and make disposition	Yes	2
4) Realization of process dependence for mfg. defects	Yes	2
5) Interface with technicians and inspectors to minimize "defects"	Yes	1,2
6) Process documentation requirements and review	Yes	2
7) Witness or traveling coupon test reduction and assessment	Yes	1

Skill K/ Finishing

1) Understanding of the need for coatings and protective layers	Yes	2
2) Realization of the implications of peel plies and release fabrics	Yes	2
3) Functions of the different coatings used for specific structure on aircraft	Yes	2
4) Tedlar function/characteristics	Yes	1
5) Tolerances for thickness and processing	Yes	1,2
6) Restoration of conductivity	Yes	1,2
7) Sealants	Yes	1
All of the above for metal bond as appropriate.	Yes	2

Compilation of Work Group Materials: Terminal Course Objectives

Work Group (Technician Emphasis)

Summary of Terminal Course Objectives and Issues

Desired State of Training in Composites Repair and Maintenance

Course Objectives	1	TSW be able to describe the state of the art of composite technology
	2	TSW be able to identify sources of technical data and regulatory requirements.
	3	TSW be able to describe repair processes from damage assessment through repair completion
	4	TSW be able to describe the differences between repairing composite and metal structures
	5	TSW be able to follow personal and equipment safety requirements
	6	TSW be able to describe storage and handling requirements
Obstacles	1	**Is there enough time to meet the objectives in five days?**
	2	**Danger of being perceived as a final training course for tech.**
	3	**What is the appetite for this course in industry**
	4	**Lack of a regulatory requirement**
	5	**Available training location. Who provides and how much?**
	6	**What is the target audience? Clearly define the target audience.**
	7	**Available parts, equipment and material in the classroom (Manufacturer's approved data)**
Alternative Approaches	1	**Video tape for lecture portion**
	2	**Electronic delivery for lecture portion**
	3	**In house for interactive portion**
	4	**In house for skill or lab portion**
	5	**Lecture in the classroom and use real examples in a lab immediately**
Parking Lot Issues	1	**Getting agreement to provide MAD to delivery providers**
	2	**Creation of advanced courses**
	3	**Integration with existing basic curriculum (CACRC)**
	4	**FAA recognition of CACRC documents as acceptable data.**

Work Group (Inspector Emphasis)

Summary of Terminal Course Objectives and Issues

processes, practices, parts, and materials.

Course Objectives -- Inspectors

Introduction

1 **Know the basic composite terminology.**

2 **Identify different in-service damage scenarios.**

3 **List basic NDI methods with their limitations.**

4 **Describe basic steps in repair process.**

5 **Know the different process parameters that affect repair quality (surface preparation, moisture ingression, contamination, cure parameters, storage & handling of materials, proper calibration & standards).**

6 **Identify typical composite manufacturing defects**

7 **Identify important differences between pre- and post-repair NDI.**

8 **Lessons learned.**

Repair

1 **Be able to verify that a repair cure was done correctly, the plies were properly impregnated, the resin was properly mixed, the # and orientation of the plies was correct, and that the repair was properly thermocoupled.**

2 **Be able to verify that the repair environment was correct, the surfaces were properly pretreated and cleaned, and that the part was properly dried.**

3 **Be able to verify correct fastener selection, that fastener holes were properly machined, inspected, and fasteners were properly installed.**

4 **Be able to explain the impact of processing variables on NDI, and fiber waviness.**

5 **Be able to verify that the correct materials were used and that they were handled and stored correctly.**

Closure

1 **Be able to demonstrate an awareness of post-repair visual inspection and NDI techniques.**

		Documentation
	1	**Students will be able to select and use manuals and publications to research repair processes, practices, parts, and materials.**
		Materials & Tooling
	1	**Students will be able to identify the use, advantages and disadvantages of materials/tooling used in composite repairs.**
		Other
	1	**Students will be able to understand the roles, responsibilities and relationship of technician, inspector and engineer in the composite repair process.**
Obstacles	1	**Distance, cost and time for students**
	2	**No appreciation by students of need for training: Involve employers**
Alternative Approaches	1	**Web-based training for basic knowledge to complement OJT**
Parking Lot Issues	1	**Certain models (esp. German) have special paint requirements - need for advanced training**

Work Group (Engineering Emphasis)

Desired State of Training in Composites Repair and Maintenance

(A Basic knowledge of composites) At the end of this class the student will distinguish between the resin, fiber, and core used in composite parts.

(A Initial Damage/Flaw Detection) At the end of this class the student will perform damage inspection on a composite part.

(B. Damage Assessment) At the end of the class the student will list appropriate detection techniques to determine size and extent of damage

(B 10 Damage Assessment) At the end of the course the student will determine if the noted damage is within allowable damage limits per the SRM

(C Disposition) At the end of this class the student will list and describe the critical steps and skills needed in making a damage disposition

(F. Repair Design Detail & Process Plan) At the end of the course the student will identify and chart the steps involved in repair design and approval

(F.1) At the end of the course the student will be able to identify the requirement for material and process specifications and specification approval requirements.

(G Tooling, equipment and expendable materials) At the end of the course the student will list all the necessary equipment to accomplish a simple structure laminate

(G Tooling, equipment and expendable materials) At the end of the course the student will list the key composite and expend material needed for simple laminate structure repair including appropriate storage requirement

(H Execute process and I In-Process Controls) At the end of the course the student will describe and apply common surface preparation and drying techniques and how to inspect them for acceptability

(H Execute process and I In-Process Controls) At the end of the course the student will describe and apply material lay down [including orientation] in compaction process for laminate structure repair

(H Execute process and I In-Process Controls) At the end of the course the student will demonstrate how to prepare and cure a laminated structural repair and explain the types of defects to be avoided

(H Execute process and I In-Process Controls) At the end of the course the student will articulate and draft a QA plan for a typical repair to include material selection and orientation, process parameters, and inspection requirements

(J Post repair inspection) At the end of this class the student will describe two different post-repair inspection procedures

(J Post repair inspection) At the end of this class the student will describe the steps taken in post-repair inspection and the meaning of results as related to different types of processing defects

Attendee List

Name	Affiliation	Title	Location
Michael J. Hoke	Abaris Training Inc.	Owner	Reno, NV
Eric Le Nir	Airbus	Structure Training Instructor	Blagnac, France
Bart A. Bauer	Alteon, a Boeing Company	Customer Training Instructor	Renton, WA
Tim J. Harris	Alteon, a Boeing Company	Senior Engineer, Principle Instructor	Miami, FL
Mike D. Borgman	Boeing Commercial Wichita	Engineer - Composites DADT/Repair	Wichita, KS
Steven D. Blanchard	The Boeing Company	Materials Engineer	Seattle, WA
Steve L. Coe	The Boeing Company	Project Manager	Edgewood, WA
Rick A. Haughian	The Boeing Company	Training Analyst	Marysville, WA
Wenjin Jia	The Boeing Company	Process Engineer, 7E7 Vertical Emp. LCPT	Seattle, WA
Rusty L. Keller	The Boeing Company	Structural Engineer	Seattle, WA
Jeff Kollgaard	The Boeing Company	Associate Technical Fellow	Seattle, WA
Arne K. Lewis	The Boeing Company	7E7 Service Engineer	Seattle, WA
Jolynn M. Lucas	The Boeing Company	Training Consultant	Seattle, WA
Ram C. Madan	The Boeing Company	Associate Technical Fellow	Cerritos, CA
Russ G. Maguire	The Boeing Company	Tech Fellow	Seattle, WA
Al G. Miller	The Boeing Company	Director	Seattle, WA
David A. Noll	The Boeing Company		Seattle, WA
Michael C. Richey	The Boeing Company	Program Manager-Strategic Partnerships	Seattle, WA

Name	Affiliation	Title	Location
Bob F. Sterzinger	The Boeing Company		Seattle, WA
Bruce M. Wheeler	The Boeing Company		Seattle, WA
Aydin Akdeniz	The Boeing Company	Technical Fellow - CAS Structures	Seattle, WA
David W. Berg	The Boeing Company	Associate Technical Fellow - Structural Repair	Seattle, WA
Nikki Larson	Edmonds Community College	Instructor	Lynnwood.WA
Charles C. Seaton	Edmonds Community College	Director	Everett, WA
Curt Davies	FAA	Program Manager, JAMSCOE	Atlantic City Int'l Airport, NJ
Larry B. llcewicz	FAA	CS&TA, Composites	Renton, WA
Peter Shyprykevich	FAA	R&D Manager	Atlantic City Int'l Airport, NJ
David D. Swartz	FAA	Aerospace Engineer	Anchorage, AK
Steve Rogers	Goodrich Aviation Technical Services	Composites Lead Mechanic	Everett, WA
Howard V. Banasky	HEATCON Composite Systems	President	Seattle, WA
Eric R. Casterline	HEATCON Composite Systems	Vice President	Seattle, WA
Mike Anderson	Hexcel Composites	Technical Service Engineer	Redmond, WA
John C. Halpin	JCH Consultants Inc. & retired USAF	CEO & Chief Engineer, Aeronautical System Center Rt.	Dayton, OH
Keith B. Armstrong	Kingston University	Student Project Supervisor	Sunbury-on-Thames, Middx UK
John E. Ingram	Lockheed Martin Aeronautics	Technical Fellow - Structural Integrity	Marietta, GA
Carlos Blohm	Lufthansa Technik AG	Senior Engineer	D-22335 Hamburg, Germany
Hendrik Freese	Lufthansa Technik AG	Instructor	D-22335 Hamburg, Germany

Name	Affiliation	Title	Location
Detlef Neumann	Lufthansa Technik AG	Senior Technical Instructor	D-22335 Hamburg, Germany
Jim R. Epperson	Nordam Repair Division	Director of Engineering	Tulsa, OK
Bill H. Pearson	Northwest Airlines	Project Engineer - A319/A320 Structures	Duluth, MN
Peter J. Smith	Peter Smith & Associates	Proprietor	Issaquah, WA
Jeffrey C. Holle	Purdue University	Associate Professor	Indianapolis, IN
Joe DiMambro	Sandia National Laboratories	Mechanical Engineer	Albuquerque, NM
Lawrence L. Coulter	U.S. Air Force	Engineer	Hill AFB, UT
David B. Mitchell	U.S. Air Force	Instructor Supervisor	Pensacola, FL
David A. Castellar	United Airlines	Maintenance Instructor	San Francisco, CA
Gary M. Derheim	United Airlines	Maintenance Instructor	San Francisco, CA
Al Riffal	University College of the Fraser Valley	Instructor	Surrey, BC Canada
K. Bud Das	University of Washington	Affiliate Professor	Seattle, WA
Brian D. Flinn	University of Washington	Research Associate Professor	Seattle, WA
Kuen Y. Lin	University of Washington	Professor	Seattle, WA
Jim C. Seferis	University of Washington	Professor of Polymeric Composite Materials	Seattle, WA
Samra Sangari	University of Washington	Research Associate, Chemical Engineering	Seattle, WA
Ellen E. Barker	University of Washington/AMTAS	Assistant to the Director	Seattle, WA
Mark E. Tuttle	University of Washington/AMTAS	Professor & Chair	Seattle, WA
Lamia Salah	Wichita State University	Research Associate	Wichita, KS
Charles Yang	Wichita State University	Associate Professor	Wichita, KS