TCO C Module – Understand Roles and Responsibilities

C1: Identify the steps required in repair design, process planning, inspection and approval.

Repair design. Qualified engineering personnel must use approved information and data to design repairs. the intent of repairs to structural components is to restore the original strength and stiffness, regardless of whether the repair is to be bonded or bolted. This requires the use of the strength and stiffness data for the original material and the repair materials, and the strength, stiffness and bearing data for the repair fasteners. All original strength and stiffness data used for repair designs must be derived from the database used for the original type certificate. All data used for repair materials must be of an approved nature (i.e. DER approved). Repairs to moveable control surfaces must consider the effects on the overall part stiffness, weight, balance and flutter characteristics. The repair designs in approved documents, such a SRM, are not to be extended to components other than those specified.

Within Boeing SRMs there are two classifications of repairs:

a) Repairs that require an evaluation for damage tolerance capability. These are classified as Category A, B or C repairs. A Category A repair is a permanent repair for which the inspections given in the MPD are sufficient, and no other actions are necessary. A Category B repair is a permanent repair for which supplemental inspections are necessary at the specified threshold and repeat intervals. A Category C repair is a time-limited repair where supplemental inspections are necessary, followed by a replaced or reworked repair at the specified time limit.

b) Repairs which are not critical for the damage tolerance capability of the aircraft. These are classified as permanent, interim or time-limited, based on the expected durability of the repair.
Boeing SRM repairs which require a damage tolerance analysis have been evaluated, analyzed and categorized as A, B or C. All non-SRM repairs (see a) and b) below) to Principal Structural Elements (PSEs) are required to be evaluated for damage tolerance capability. PSEs are primary structural parts which are considered critical to flight safety. Examples of PSEs are wing main torque box spars, skins and stringers, fuselage skins, stringers and frames, horizontal and vertical main torque box spars, skins and stringers, and wing trailing edge flaps.

In the event that an approved repair design is not available, the maintenance engineer has several options;

a) Contact the OEM for an approved repair. In this case, the damage evaluation will be transmitted to the OEM, and a specific repair designed.
b) Prepare a specific repair for the damage not covered. In some instances, such as damage to a PSE not covered by the SRM, an adequate damage disposition or repair design will require evaluation by the OEM.

c) Replace the damaged part

Repair Process and Inspection Planning. The following are documents that are part of the maintenance and repair process, and must be either consulted for damage inspection or repair instructions, or filled out to maintain records of repaired components and repair materials:

Maintenance Planning Data document, SRM and Component Records. For planned maintenance events such as medium or heavy maintenance checks (e.g. "C" or "D" Checks), the maintenance planning data (MPD) document must be reviewed for directed inspections. For components with temporary, interim or time-limited repairs on them, the records must be reviewed for flight cycles since the temporary repairs in order to know if the repairs need to be replaced with permanent repairs. Many approved documents, such the SRM, have restrictions for proximity of repairs and damages, therefore when damages are found, the component records must be reviewed for previous repairs or previous allowed damages.

The SRM will contain inspection, allowable damage limits and repair instructions that are based on approved databases. If the damage and repair designs are available form this approved data, there is no need to communicate with the OEM or other DER for instructions.

Routine Work Documents. Routine work documents are used for planned maintenance tasks. The inspection and/or repair processes are predetermined, and instructions often are formally printed along with sign-offs for technicians, quality control and inspection personnel. The following are examples of documentation required by Federal Aviation Regulations (FAR 145 in the US), and Joint Airworthiness Requirements (JAR 145 in Europe):

Component Master Worksheet: this records the part number and description, description of the defect or damage, and the repair action taken.

Materials Record Sheet: This provides details of all materials used, including part and serial numbers, and batch numbers. The material batch numbers allow traceability of repair parts or materials used.

Component Record Card: This card records the part number, serial number and details of each component. This will enable future work on the same part to be related to previous repairs.

Inspection Record: This form provides for a report after a component has been inspected. The part may be new, damaged or repaired.

Technical Instruction, AB 110: This form is used to provide specific instructions for the performance of technical processes to ensure that adequate information is available to those performing the work.

These are other documents required such as: warranty/investigation reports, reject notes, stock record cards and unserviceable tags. A more comprehensible list of required documentation can be found in "Care and Repair of Advanced Composites" by Keith Armstrong and Richard Barrett.

When damages are detected during routine inspections in the maintenance depot, the instructions within the MPD and SRM must be strictly followed, and component and material records must be maintained.
When damage is found on the ramp during normal operations, the MDP and SRM may not be available, but the damage must be reported to a maintenance engineer for him or her to make a disposition. Also the above work documents may not be available on the ramp, but records of damages, inspection results, repair dispositions and materials used must be kept for entry into the above documents.
Because approved repair documentation is unlikely to be available on the ramp, it is essential that operations personnel have access to qualified maintenance engineers in order that proper damage or repair dispositions can be made. In the event the damage is beyond repair limits on the SRM, it is also essential, for expeditious repair dispositions, that the maintenance engineers have access to a DER or qualified OEM personnel. Some OEMs have service engineering personnel available on a 24 hour basis so as to be reactive to operator queries.

There may be situations where the damage was not discovered by ground personnel, but an incident occurred that may involve damage to aircraft structural components. Such incidents as bird impacts during flight, hard landings, engine or tire bursts, runway debris thrown up by the tires or vehicle collisions can cause severe damage to aircraft components. It is essential in the event of such incidents that the aircraft be inspected for any resulting damage at the earliest possibility.

C2: Describe the steps in the bonded and bolted repair processes, including details of damage discovery through repair completion and approval.

Steps 1 through 4 are common to any repair process, regardless of whether the repair is bonded or bolted.

Step 1: Visually discover the damage either by operations technician or by an inspector during a directed inspection per the MPD.

Step 2: Assess and map the extent of the damage. Use an instrumented NDI procedure. A tap test method may be used if it can be shown that a defect or damage that is less than or equal to the maximum allowable damage size can be found. If damage is found on the outside surface, inspect the inside surface if accessible.

Step 3: Review available documentation, e.g. the OEM's structural repair manual (SRM). If not available, consult with a qualified operator or MRO maintenance engineer.

a) Compare damage before clean-up to allowable damage limits (ADL) for the appropriate zone of the specific component (show example of a typical Boeing SRM ADLs, i.e. 777 SRM section 57-70-01 for CFRP sandwich wing spoilers)

b) If the damage is within the ADL, the damage is to be sealed per the instructions in the SRM and the component (or aircraft) can be returned to service. Before sealing the damage, all contaminates and water must be removed from the component (reference typical cleanup procedure per Boeing SRM section 51-70-04)
c) If the damage is beyond the ADL, then the damage is to be cleaned up i.e. any damaged materials are to be removed including damaged honeycomb core if present. Any loose or broken fibers are to be removed.
d) Compare the cleaned up damage to the SRM repair limits for the appropriate zone of the specific component. (Show example of typical Table 201 in section 57-70-01 of Boeing 777 SRM repair section)

Step 4: Choose a repair method from those listed in the SRM repair section for the specific component.

A) For a vacuum bag cure bonded repair of the outside face sheet and core of a sandwich component using prepreg material

Step 5: All contaminates and water must be removed from the component using vacuum and heat (reference typical cleanup procedure per Boeing SRM section 51-70-04). Water can be found using X-ray and thermographic procedures.

Step 6: Remove the protective coating (e.g. conductive coating if present, paint enamel and primer) using a prescribed method such as abrading or sanding. Remove the coatings over an area that will more than encompass the repair. Take care not to damage any composite fiber material. Use protective eye ware and a facemask and remove dust with a vacuum.

Step 7: Make the necessary taper to the damaged plies for the bonded scarfed repair, using a taper ration of 50 to 1. (Remove any damaged core, if present, to the same size as the cutout in the face sheet. Be careful not to damage the backside face sheet). Again use protective eye ware and a facemask and remove dust with a vacuum.

Step 8: Clean the abraded surface and tapered using area with soft cloth moistened with an approved solvent. Use further clean dry cloths to remove solvent.

Step 9: Prepare and clean a core plug the same size as the cutout in the face sheet. Allow foaming adhesive time to warm at room temperature before using to install core plug.

Step 10: Install core plug with foaming adhesive and cure using a vacuum bag, thermocouples and heat blanket. After cure, sand the core plug level with the original core. Again use protective eye ware and a facemask and remove dust with a vacuum.

Step 11: Prepare the repair ply material and film adhesive (i.e. remove from freezer and allow to warm up). Cut out the required number of replacement and additional repair plies and film adhesive.

Step 12: Place film adhesive down first, then each replacement repair ply, and finish with additional ply (or plies) over the tapered repair. Sweep each ply to remove any wrinkles

Step 13: If required by SRM or approved repair documentation, compact repair plies using a temporary vacuum bag.

Step 14: Place a parting film over entire repair and install vacuum system, a minimum of three thermocouples, required surface bleeder cloths and install the heat blanket. Apply the vacuum seal around the repair.

Step 15: Apply a vacuum of 22 inches of mercury, and cure the repair per the specified cure cycle. Monitor the heat up and cool down rates, dwell temperature and vacuum pressure throughout the cure cycle.

Step 16: After the repair has been cooled down to a prescribed temperature, remove the vacuum pressure.

Step 17: After cool down is completed, remove the heat blanket, breather cloths, thermocouples, vacuum seal and bag and parting film.

Step 18: Inspect the repair for voids and anomalies using approved inspection methods. Make sure to inspect the area around the bonded repair up to 6 inches away from the edge of the repair.

Step 19: If inspection proves the repair to be satisfactory, restore protective coatings over the repaired area per the approved documentation and return the component to service. Some composite components are protected from excessive damage from lightning strikes, by such systems as flame spray coatings or aluminum mesh or "picture framing". If damaged, or removed during a repair, these protection systems need to be restored per the SRM or other approved documentation. Some composite components that contact aluminum parts, are isolated by corrosion prevention systems such as a layer of glass epoxy. If these isolation systems have been damaged or removed during the repair, they must be restored per approved documentation.

B) For a bolted repair of a carbon fiber laminate stiffened component using titanium repair plates and fasteners

Step 5: Ensure that the damaged area and adjacent surface of the part are smooth and flat for the repair doubler.

Step 6: Clean the area with an approved solvent

Step 7: Seal the damage as applicable

Step 8: Select a repair doubler of the required thickness with a surface finish of 125 micro inches Ra or better.

Step 9: Mark the fastener pattern on the repair doubler, place doubler in a fixture if available and pilot drill all the fastener holes in the doubler.

Step 10: Put doubler in place on the component to be repaired, ensure that it does not move and pilot drill the fasteners holes in the composite part. Move to opposite sides of the fastener pattern for each hole to be drilled. Install a temporary fastener in each hole after drilling to ensure doubler and part do not move.

Step 11: Remove the doubler and place in a fixture. Drill all piloted holes to a diameter that is 1/16 inch smaller than final hole diameter, and remove all burrs.

Step 12: Drill all pilot holes in composite part to a diameter that is 1/16 inch smaller than the final fastener hole diameter, and remove all burrs.

Step 13: Place the doubler on the composite part, aligning the fastener holes, and install a temporary fastener in every other hole to ensure that opposite holes are clamped in each side of the symmetry line.

Step 14: Ream all holes to full size.

Step 15: Remove the doubler and deburr all the holes on both doubler and composite part. Chamfer edge of all holes on the fastener entrance side of the doubler to the same diameter as the radius on the underside of the fastener heads.

Step 16: Apply one coat of sealant to the mating surface of the doubler and composite part.

Step 16: Place the doubler over the composite part, aligning the holes in each part. Install temporary fasteners in each corner of the fastener pattern, and then install temporary fasteners in every other hole so that opposite holes are clamped on each side of the symmetry line.

Step 17: Select appropriate fasteners of the correct diameter and grip lengths.

Step 18: Install fasteners in the open holes through the squeezed out sealant.

Step 19: Remove all of the temporary fasteners and install the permanent fasteners in the open holes through the squeezed out sealant.

Step 20: Inspect the fasteners to see that they are correctly installed. Inspect the back side of the repair to see if the fastener sleeves are satisfactorily installed.

Step 21: Remove and replace any fasteners found to be incorrectly installed.

Step 22: Apply a fillet seal around the repair doubler.

Step 23: Restore protective coatings over the repaired area per the approved documentation and return the component to service.

C 3: List of basic NDI methods with their limitations for damage assessment and post-repair inspection.

Damage and repair assessment are important aspects of repair work. Several methods of damage and repair assessment are typically available and are discussed below:

1) Visual Inspection:

Damage detection: Visual inspection is the first and most obvious method for damage detection. Composite aircraft components are typically designed such that damage too small for visual detection is considered non-catastrophic, and component static and fatigue strengths and stiffnesses are sustainable for the life of the aircraft.
If surface damage is detected by visual means, however small, there is the likely potential for hidden damage that may exist, and other NDI methods are required for more complete damage assessment.

For components fabricated from composite materials, the smallest damage size likely to be found has been establishes experimentally by one OEM as follows:
"Using a number of experienced and inexperienced operators, viewing the surface from a distance of approximately 2 meters (6 feet) and using a flashlight to illuminate the area, surface damage of 1.4 mm^2 (0.002 in^2) and a depth of 0.3 mm (0.012 in) was reliably detected with a probability of 95%. This gives confidence that significant damage will not remain undetected." This particular standard for what is called "barely visible impact damage" (BVID) is some what different for the other major commercial aircraft manufacturer. This difference in interpretation of BVID has influenced each manufacturer's structural test database for the residual strength of damaged composite components.

Apart from directed NDI of specific components or specific areas of components, visual inspection is the cornerstone of airline maintenance of composite structural components. If any damage is discovered, however small, it must be investigated and the SRM (or equivalent documentation) must be consulted for appropriate action.

Post-repair inspection: Visual inspection is also the first and most obvious method for post-repair inspection. Repairs using some materials, such as GFRP, are more easily visually inspected for repair defects such as voids and delaminations. However, CFRP repairs are not easily inspected visually, apart from adhesive bleed-out and fillets. Unlike for damage detection, if no defects or anomalies are discovered in post-repair visual inspection, the repair must still be inspected by either a tap method, or by using pulse-echo equipment. For most repairs visual inspection is the precursor to the more reliable NDI inspection.

Advantages of Visual Inspection:

No expensive equipment is needed

Airworthiness design philosophy is such that most damage that is of concern is capable of being found visually

Disadvantages of Visual Inspection:

Inspectors have difficulty in maintaining concentration over large areas

Composite parts with apparently small visual damage may have extensive non-visible damage. This is particularly important in the case of non-visible delaminations. A critical failure mode of structures fabricated from composites is compression, and any delaminations present can reduce compression strength and stiffness.

2) Tap Test

Most commercial and military aircraft operators use the tap test for damage detection in composite components. Tap testers range from a simple coin, to a tap hammer, to more complicated automated tap hammers.

The basic tap coin or hammer relies on the human ear to detect changes in frequency. For example, a good bond or non-damaged part will emit a clear, high frequency sound when gently tapped, while a disbonded or damaged part will emit a dull, lower frequency sound.

The automated tap hammers do not rely on the efficiency of the human ear, which deteriorates with age and varies from person to person. The method may be described as audio sonic because it operates in the human hearing range. The advantage of the automated tap tester is that a change in frequency at which a defect is considered to exist can be set and the area mapped accordingly. The automated tap tester is considered more accurate because of the lessened reliance on the human eye.

Damage Detection: In general, the tap test works well for detection of damages in thin skins of any type. The method is especially useful on sandwich structure with composite face sheets and honeycomb core. It can work on solid composite laminate structure if the first few plies are delaminated, but it cannot detect defects deeper in the laminate. Similarly metal-bond parts (metal skinned honeycomb parts or bonded metal doublers) above a certain thickness of approximately 1 mm (0.04 in.) do not respond with a change in frequency if disbonded.

Post-Repair Inspection: As for damage detection, most aircraft operators use the tap test for post-repair inspection of repairs to sandwich parts. It's is simple, cheap and quite reliable when used by experienced inspectors. The method has the same limitations for post-repair inspection as for damage detection. Changes of frequency are not obvious for deep delaminations within the repair or for anomalies in the bond line if the repair patch if more than a few plies thick.

Advantages of the Tap Test:

It is simple and cheap

A tap test provides a quick initial method of investigating the extent or existence of a defect.

A tap test can be used to reliably detect delaminations and disbonds in thin composite skins, and severe moisture within sandwich parts.

Disadvantages of the Tap Test:

It is impractical to cover large areas because it is difficult for an inspector to maintain concentration

The tap test can be highly subjective, although the automated tap testers significantly reduce this subjectivity

A tap test cannot locate small defects such as voids or minor moisture ingression

It is not effective on thick skins and its effectiveness may be reduced when inspecting parts covered by protective coatings (e.g. lightning protection systems)

3) Ultrasonic Inspection

This type of inspection uses an ultrasonic signal and measures the attenuation of that signal. Ultrasonic inspection is the study of materials or structures using ultrasonic or stress waves. These stress waves are mechanical waves or vibrations, and they follow the formula:

Wavelength $\lambda = c/f$

where c = the velocity of ultrasound

and f = frequency

The velocity varies with the elastic properties of the material under test or inspection. Thus, for a given frequency, the wavelength will vary with the material being investigated. For composites a frequency of 1 to 10 MHz is normally used. These frequencies are way outside the audible range for humans (up to 20 kHz).

Two modes of operation are normally used:

A Through-transmission mode, using two transducers

B Pulse-echo, using a single transducer

In either mode, currently the transducer(s) must be coupled to the structure via a liquid or solid medium because of the severe impedance mismatch between air and solid materials.

Through-transmission (TTU) mode is typically used in the factory for **post-fabrication inspection,** and the medium is achieved with water jets for large components or immersion for smaller parts. This method can not only detect small (down to 0.5 in dia) defects, but the depth of the defect can also be determined. Large components can be inspected at decent speeds (e.g. X ft^2 per minute), and a "C" scan can be produced as a permanent record.
TTU can easily detect delaminations in laminates, disbonds in adhesive joints and between the face sheets and core of sandwich structure. Foreign inclusions that have significantly different acoustic impedance from that of the composite can also be found. Ultrasonic testing requires calibration on known standards.
This type of testing is basically comparing the trace of a good standard with the part being inspected, and interpreting the meaning of any differences found. This means that the TTU inspector must have a thorough knowledge of the structure being inspected.

Based on the complexity of this method and the need for accurate interpretation, ultrasonic inspection is a job for well-trained, experience personnel.

Pulse-echo (P/E) utilizes a liquid gel as the couplant and is particularly suitable for field work, **i.e. damage detection and post-repair inspections.** Similar to TTU, pulse-echo inspection can detect small defects through the thickness of a laminate and disbonds between face sheets and honeycomb core. Compared with factory TTU inspection, P/E is quite a lot slower and is not as useful for large components. It is more useful for inspecting areas that have yielded visual damage indications. Most commercial aircraft operators will have pulse-echo equipment available in their maintenance bases. In order to obtain accurate readings and correctly interpret the results, the inspectors must be carefully trained in the use of the equipment.

Advantages of Ultrasonic Inspection:

This method can detect many types of anomalies; defects within the plane of laminates, delaminations, voids, foreign objects, moisture, disbonding and some cracks.

This technique can detect the depth of defects in thick laminates

In the case of P/E, it is very portable and flexible

In the case of TTU, large areas can be inspected

Also, in the case of TTU, a 3-D image can be generated if necessary

Disadvantages of Ultrasonic Inspection:

A couplant is necessary between the transceiver and the component. This is usually in the form of a gel for P/E or water for TTU. However new technology transducers, such as air-coupled ones, are becoming available, and may eliminate these needs.

TTU typically requires removal of the component from the aircraft.

P/E allows detections of damage from only one side of the component

TTU requires access to both surfaces of the part

Calibration standards are required for each material and thickness

4) X-Ray

Conventional x-radiography (x-ray) of CFRP is difficult because the absorption characteristics of the fibers and resin are similar and the overall absorption is low. The properties of glass and boron fibers are more suited to the use of x-ray as an inspection method for composites.
Detection of delaminations by x-ray is difficult because delaminations tend to be normal to the x-ray beam and thus make little difference to overall absorption. However, if a surface crack is present, delaminations can be detected by x-ray, if a radio opaque penetrant is introduced to reach the delaminated layers. The use of penetrants is usually restricted to the laboratory due to potential contamination.

X-ray can detect foreign inclusions and voids if they are sufficiently large, and water can be detected in the honeycomb cells of sandwich core.

X-ray is often used as a complement to ultrasonic inspection because it provides indications of defects (e.g. cracks) in planes perpendicular to defects detected using ultrasonic methods.

Advantages of X-Ray

X-ray inspection may be used to detect transverse cracks, inclusions, honeycomb core damage, moisture ingression, voids and porosity.

Disadvantages of X-Ray

Considerable safety measures are necessary with this technique.
The equipment is not easily portable
Usefulness is limited by accessibility
The use of penetrants contaminates the composite. Organic penetrants are affected by moisture, which may alter the recorded results, and halogen-based penetrants may result in stress corrosion.

5) Eddy Current Inspection

Eddy current inspection is typically used to detect cracks emanating from fastener holes in metal structures without removing the fasteners.
Eddy current is of very limited use for detecting damages within composite structures and for inspecting repairs for integrity. It is limited to composites with a conducing phase, and the measurements obtained are sensitive to the volume fraction and integrity of that phase. Eddy current can be useful for checking volume fraction in a carbon composite, although this is not always easy for cross-plied laminates.
Its optimum use is for detecting fractures in substructure beneath a laminated skin. This capability is particularly useful for detecting crack propagation in metal structures that have been repaired with a bonded composite patch.
This method of inspection is complementary to ultrasonic inspection in materials such as CFRP because it is sensitive to those defects that are difficult to find using ultrasonic

inspection. The resistivity of carbon fibers is much greater than that of metals; thus, lack of penetration depth is usually not a problem.

Advantages of Eddy Current Inspection

Eddy current inspection can be used for detecting fractures in substructure beneath a laminated skin.

The equipment is easily portable

Eddy current can be used for checking volume fraction in CFRP composites

Disadvantages of Eddy Current Inspection

Cannot be used for detection of defects in GFRP composites due to a lack of a conducting phase in glass fibers

Eddy current is relatively insensitive to porosity, non-conducting inclusions and delaminations

6) Thermography

Two forms of thermographic inspection methods are currently available:

Passive: The response of the structure being inspected to an applied heating transient is monitored.

Active: Heating is produced by applying cyclic stress to the structure either in a fatigue test machine or in a resonant vibration system.

In both forms, the surface temperature of the structure in monitored, usually with an infrared camera, and anomalies in the temperature distribution can reveal the presence of defects. The passive technique is more widely used than the active method, and its performance depends strongly on the heat source used. The conductivity and anisotropy of the composite are also important parameters. For example, in CFRP laminates, the conductivity in the laminate plane is approximately 9 times that in the through-thickness direction. This tends to obscure defects that are not close to the surface.

Advantages of Thermography

Thermography is a quick method for inspecting large areas.

Thermography is more convenient than x-ray in that other personnel do not have to leave the area while the process occurs.

It can be used to find disbonds in adhesive joints, delaminations and inclusions whose conductivity differs significantly from the base material.

Thermography is often used by airline operators for detecting moisture in the form of ice in honeycomb core of sandwich structures.

Disadvantages of Thermography

Equipment costs are high

The method is not as sensitive as ultrasonic inspection for detecting delaminations and disbands.

The aircraft must accessed soon after landing in order to detect moisture in the form of ice in sandwich structure.

Thermography cannot be used with thermally conductive materials such as metals

Climatic conditions may not be suitable for effective inspections.

Skilled interpretation and knowledge of the aircraft structure and systems are required to determine which heat sources and sinks are real defects.

7) Bond Testers

Bond testers are instruments that use the mechanical impedance method. They measure the change in local impedance produced by a defect when the structure is excited in the frequency range of 1 to 10 kHz. They can be used to detect defects such as delaminations and adhesive disbonds.

These vibration techniques work at low frequencies, so coupling mediums are unnecessary.

Bond testers are readily portable; thus, they are attractive for field service. They are well suited to the inspection of sandwich structures for face sheet separation from the core. Gross defects such as wide-spread environmental degradation and face sheet disbonds in sandwich structure produce readily measurable changes in resonant frequencies. Large areas can be inspected for gross defects in a very short time. This makes the technique attractive if small, localized defects are unimportant.

Advantages of Bond Testers

They are simple to use and can produce quick results

They are very portable and relatively inexpensive

No coupling fluids are required

Disadvantages of Bond Testers

These instruments measure changes in resonant frequencies of whole components, and can only detect large degradation or disbonds.

They cannot detect small, localized defects

8) Moisture Meters

Moisture meters are used to detect the presence of moisture when making repairs to GFRP or aramid materials. They can detect moisture within aramid honeycomb core. The usual type of moisture meters relies on radio frequency dielectric power loss. This power loss is attributed to an increase in the conductivity of the composite due to moisture absorption. Therefore, the techniques cannot be used with carbon or any other conductive material such metal, or with antistatic coatings that contain carbon.

Advantages of Moisture Meters

Very useful for checking for the presence of moisture when drying GFRP and aramid sandwich structures prior to bonded repairs. Moisture meters can readily detect moisture within GFRP and aramid laminates.

Disadvantages of Moisture Meters
Current models cannot be used on carbon structure, Glass or aramid parts having an antistatic coating must be inspected for moisture from the back side. The presence of any metal inserts or doublers can give false indications and may cause panels to be removed needlessly.

9) Interferometry

Holographic Interferometry provides an object image from the properties of reflected light, using their intensity, wavelength and phase. Phase provides the 3-D effect. Lasers are used as the light source, and interference occurs when an object changes its relative position and, after double exposure to the laser light, the light's phase has changed. The double exposure occurs before and after the object moves. This can be produced by lightly loading the component mechanically or by the use of localized heating. Interferometry can be used on both metals and composites.
Interferometry can detect loose fasteners, cracks under fastener heads, and weak adhesive bonds in metalbond parts. In composite parts, it can be used to detect impact damage, heat damage, weak bonds, and delaminations.

Advantages of Interferometry
It can be used to detect defects in metal parts, metalbond and composite components. Interferometry can detect weak bonds, and will very useful for post-manufacture inspection, post-repair inspection, and in-service inspections.

Disadvantages of Interferometry
The equipment is currently bulking and not very portable. Interferometry equipment is currently very expensive

C 4: Distinguish between skills needed for structures engineers, inspectors and technicians dealing with composite maintenance and repair.

Structures engineers, inspectors and technicians all have vital roles to play in the proper maintenance and repair of composite structures. The skills needed by each discipline may differ, but each member of the repair team must be well versed in the requirements of his or her role, or else a wrongly assessed damage, a poor repair design or a improperly processed repair may ensue.

Structures Engineer
The structures engineer, at the OEM, operator or MRO, will need a minimum of a Bachelor of Science degree in engineering at a credited academic institution, and some formal training in aircraft structural analysis.

In order to design an appropriate repair for a damaged component, the structures engineer will need to have a detailed knowledge of the aircraft composite structural components, and have access to and understand the loads and material design values used to certify the aircraft structure. He or she will also need access to the design values for the repair materials so as to be able to design a repair that restores the component original strength and stiffness. For repairs to moveable control surfaces, the structures engineer must also consider the effects of a repair on the overall part stiffness, weight, balance and flutter characteristics.
The structures engineer responsible for providing repair designs and repair size limits, must have a good knowledge of the capabilities and limitations of repair technicians and their ability to process the repairs. He or she must also have knowledge of the workability and limitations of the specific materials that are approved for use in repair. At the OEM, manufacturing and process (M&P) engineers usually provide details of material workability and limitations and repair processing requirements. These details are provided in the SRM for specific repair materials and processing methods.

For most composite components, a typical SRM will contain allowable damage limits (ADLs) and repair designs for damages that exceed the ADLs. The OEM structures engineer is responsible for providing this information, and a structures Designated Engineering Representative (DER) will be needed to approve all data used for the ADLs and repair designs. A structures DER can reside at the OEM, an operator or an MRO, but all data used for ADLs and repair designs must be approved by a structures DER. Structures engineers responsible for providing ADLs must have the ability to analyse the component for residual strength and stiffness with various forms and degrees of damages. In order to calculate accurate ADLs, he or she must have access to the certification loads for each specific component. In addition to the strength and stiffness databases used for the original component design, the structural analyst will need the residual strength database for various types of damage to that component. These damages will typically range from a dent, or a crack and any associated delaminations, to a through penetration or hole. The ADLs that he or she will calculate typically require knowledge of damage parameters such as dent depth and diameter and any associated cracks and known delaminations. The presence and location of other damages or repairs will affect the ADLs for a specific component.
He or she must have an intimate knowledge of in-service inspection methods and their limitations in order to provide ADLs that qualified maintenance personnel can reliably detect.

Inspector

The inspector is responsible for assessing and mapping any damage that may be discovered by maintenance personnel during operations or during a scheduled maintenance event such as a ‘C’ or ‘D’ check. He or she is also responsible for inspecting and approving any repair that may have been performed as a result of the damage assessment.

For planned maintenance events such as a “C” or “D” checks, the maintenance planning document (MPD) must be reviewed for directed inspections. Inspectors of composite

components in the maintenance depot will have a variety of inspection techniques available to him. He or she must have good eyesight and hearing, and be trained and qualified in the use of these inspection techniques. An MPD may require the use of specific inspection techniques to adequately inspect critical component zones (e.g. areas around fittings). Inspection equipment commonly available in the maintenance depot are: the tap hammer or coin, ultrasonic equipment such as P/E, bond testers, eddy current and x-ray equipment, and moisture meters. Some of the more sophisticated MROs and operator maintenance depots may have thermographic equipment on hand, and in the future may invest in interferometry to more accurately discover hidden flaws such as loose fasteners and weak bondlines.
All of these different inspection techniques each require extensive training and re-training in order that the inspector is competent in the use of them, including application to specific structural details.

For damages discovered on the ramp during routine walk-arounds, the damage must be mapped as accurately as possible with the available inspection equipment. In many cases, a qualified inspector may not be on hand; therefore many repair dispositions on the ramp will be of a temporary nature (i.e. a repair that covers the assessed damage and allows the operator to fly the aircraft to a maintenance base for a permanent repair). In the case of damage discovered on the ramp; in order to make an adequate damage disposition, the damage must be mapped by a person qualified in the use of basic inspection techniques such as the tap hammer and P/E.

Many materials, such as prepregs, may be qualified for use beyond the shelf live expiration dates. A number of simple tests must be performed, and if the tests results are acceptable, the material is recertified for a further period. The inspector, in many facilities, is responsible for material re-testing and recertification.

In some cases, an inspector monitors the in-process controls during a bonded repair, but in most situations, the repair technician is responsible for monitoring his own in-process controls, and the inspector examines and either approves or rejects the in-process control records. This is also usually the case at the OEM during any composite bonding process.

Repair Technician

It is essential that the repair technician be familiar with the specific aircraft structure drawing system and the approved maintenance methods for the particular component in question. He or she must be able to follow the repair procedure explicitly and understand the ramifications of taking short cuts or guessing. Repair technicians need to be trained and qualified in all of the types of repair for which he or she is responsible for, be they bonded or bolted repairs. In some large MROs and operator maintenance depots, there may be specialists for bonded composite repairs, bolted repairs to composite components and metalbond repairs. In most small maintenance organizations, technicians will be responsible for processing all kinds of repairs.

The technician’s duties are varied and in addition to performing the actual repairs, they include the following:

a) Initial inspections of composite components during ‘C’ and ‘D’ checks. While not specifically qualified in the use of specific inspection techniques (see Inspector above), a technician will need to be sufficiently trained to be able to perform initial damage assessments using visual and basic tap inspection techniques.
b) Monitoring repair materials, such as resins, adhesives, prepregs, potting compounds and sealants, which are all perishable. Their shelf lives must be carefully monitored and correct storage conditions must be maintained. Or is an inspector’s job?
c) For components with temporary, interim or time-limited repairs on them, the technician must review the component records for flight cycles since the temporary repairs in order to know if the repairs need to be replaced with permanent repairs. Many authorized documents, such the SRM, have restrictions for proximity of repairs and damages, therefore when damages are found, the technician must review the component records for previous repairs or previous allowed damages.
d) The technician is also responsible for maintaining the following worksheets: the component master worksheet, the materials record sheet, and the component record card. These records must be kept up to date for good aircraft maintenance.

The repair technician must have an intimate knowledge of approved sources of repair information contained in such documents as the SRM and MPD. He or she must be able to follow the repair procedure explicitly and understand the ramifications of taking short cuts or guessing. Repair technicians need to be trained and qualified in all of the types of repair for which he or she is responsible for, be they bonded or bolted repairs. In some large MROs and operator maintenance depots, there may be specialists for bonded composite repairs, bolted composite repairs and metalbond repairs. In most small maintenance organizations, technicians will be responsible for processing all kinds of repairs.

J 8: Know your skill limits and who to go to for help.

While it is important that each member of the repair team has an understanding of the roles of the others, it is not possible, nor recommended, that any one team member be capable of carrying out all roles.

The following scenarios are presented so as to map the process for a damage/repair disposition:

a) If damage is detected during a routine maintenance event, qualified personnel should be on hand to perform his or her part of the damage/repair disposition. After the damage has been mapped by a qualified inspector, the technician will consult the approved documentation for the specific ADL. If the damage is within the ADL, he will prepare the part for sealing and restoration to service. If the damage is larger than the ADL, and the documentation contains an approved repair, he will perform the repair using approved repair materials, adhering strictly to the approved repair process. The repair will be inspected by a qualified inspector, and if found satisfactory, the component will be finished for restoration to service.

b) In the event that the damage is discovered during operations, the ramp technician may need to consult with the appropriate maintenance depot engineer for help with the disposition. If the ramp technician is not qualified to make an inspection, a qualified inspector will have to be dispatched to the site. After the damage has been mapped, the maintenance engineer will compare the mapped damage with the ADLs for the specific component in the approved documentation. If the damage is within limits, he will relay his damage/repair disposition to the ramp technician, and the ramp technician will seal the part and restore it to service. If the damage is larger than the ADL, an approved repair is contained within the SRM, and the ramp technician is qualified to perform the repair, the ramp technician will perform the repair per the approved process with approved materials. The repair will be inspected, and if found satisfactory, the component will be finished for restoration to service. If the ramp technician is not qualified to perform the repair or an qualified inspector is not available, a repair technician and/or inspector will need to be dispatched to the site.

In the case of a repair not being available in the approved documentation, the maintenance engineer will need to either communicate with the OEM for an approved repair, or request a repair from a DER which will restore the strength and stiffness of the component in question.

In any damage scenario, it is essential that only qualified personnel perform each task. If this protocol is not followed, any or all of the following may ensue:

1) A repair design that is not approved may not properly restore component strength and stiffness.
2) An incorrectly mapped damage may result in a component either being restored to operations with a critical damage, or with an inadequate repair.
3) A repair incorrectly processed may result in either; the repair being found unsatisfactory, removed and a new repair made, or the part may be returned to service with an inadequate repair.
4) An incorrectly inspected repair may result in a component being returned for service with an inadequate repair.