Federal Aviation Administration

FAA / CAAs “Composite Meeting”

- Workforce Education Initiatives -

Level II Safety Awareness Courses

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Lester Cheng
FAA Composite Team

Singapore, Singapore
September 1-4, 2015

FAA / CAAs "Composite Meeting"
- WE & Safety Awareness Courses -

- Background - Workforce Education
  - ^ Composite Training Strategies (White Paper)
  - ^ Observations for Consideration
  - ^ FAA Workforce Education Plan
- Level II Safety Awareness Courses
  - ^ Composite Maintenance (CMT)
  - ^ Composite Structural Engineering (CSET)
  - ^ Composite Manufacturing (CMfgT)
- Courses Offering via NIAR/WSU (2015)
- Discussion

Level II Safety Awareness Courses

- Maintenance Safety Awareness (CMT)
  [International Standard: CACRC AIR5719]
  - FAA-led course development completed [9/2008]
  - FAA Audience: Flight Safety Inspectors [Content: 60 Hours]
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Technical Document - “Critical Technical Issues for Composite Maintenance & Repair”

- A document was developed to provide technical information on composite maintenance & repair [by SAD (Cheng & Ilcewicz), Sep/2006].
- Technical content includes -

  - Integral product development emphasis
  - Operational safety links with design & production
  - Regulatory maintenance/repair requirements
  - Technical Issues include: teamwork, disposition, damage detection & characterization, repair processes)
  - Safety essentials

- Constituted as technical basis for the “Composite Maintenance Technology (CMT) course.

SAE CACRC AIR 5719 - Checklist for Composite Maintenance Awareness Course

- Building on SAD Tech Document: SAE CACRC developed an Aerospace Information Report (AIR) 5719 as a checklist of creating safety awareness training covering the critical technical issues associated with the maintenance and repair of composite aircraft structures.
- This document describes terminal course objectives (TCOs) and teaching points, which in combinations serve as a course checklist for developing the awareness courses.
- TCOs indicate student learning expectations for each section of the course, while teaching points convey items that should be covered within each TCO.
- This document is a standardized checklist regarding critical issue awareness for composite structure maintenance/repair.

Composite Maintenance Training Reports

FAA Technical Document

Unofficial FAA document for informational purposes only

Written by FAA (L. Cheng & L. Ilcewicz)

Not a formal reference that is archived

FAA JAMS Technical Report

FAA document of JAMS R&D used for educational purposes to support course development

Written by Edmonds CC. (C. Seaton)

Formal reference that is archived

Import Key Content

SAE CACRC AIR 5719

International standard to describe essential course content

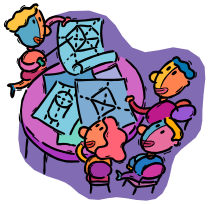
Drafted & approved by CACRC

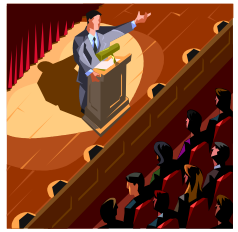
Formal reference that is archived

Industry Interface, CMH-17 Mtgs. and FAA Workshops

Basis for all reports & documents

Expert inputs and review of draft reports & course content



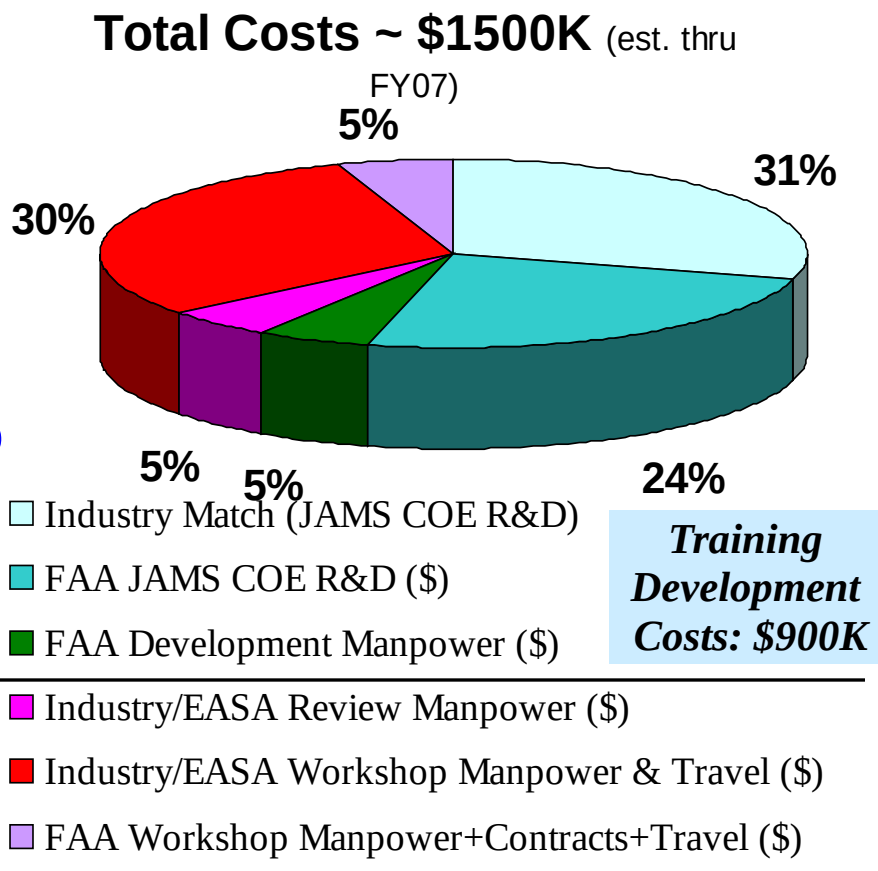


Testimonials, graphics, videos & other teaching aids

Edmonds CC. Beta courses

Joint Efforts by Industry & Regulatory Experts to Standardize a Course on *Critical Composite Maintenance & Repair Issues*

- 2004: Initial workshops to define framework (incl. course objectives on the key areas of awareness for engineers, technicians & inspectors)
- 2005: 11 course modules drafted for workshop review
- 2006: Update modules and develop course standards with SAE CACRC
- 2007: Coordinated FAA/industry release of course standards
- 2008: Make course available to FAA/industry designees



Composites Education
CMT Course Content

Prerequisite

- Overview of technology (awareness level of training)
- Students gain familiarity with terminology in preparation for safety awareness education
- 10 hours classroom or online training (self-paced, pass/fail assessment)

- Composite materials technology
- Maintenance and repair overview
- Regulatory requirements
- Metal bonding

Composites Education
CMT Course Content

CMT Course (60 hours on-line)

- Provides ‘meaning before content’
- Safety messages highlighting issues
  - Roles and responsibilities
  - Source documentation
  - Damage types, sources and disposition
  - Inspection procedures
  - Bonded and bolted repair

Composites Education
CMT Course Content

CMT Course (60 hours on-line)

- Involvement of subject matter experts in discussion forums
- Multimedia
  - Expert testimonials
  - Movie clips, including custom pulse echo (A & C scan)
- Sample Clip
  - Testimonial
  - Overview (Boeing/CACRC, Delta Rocket Explosion)
  - Pulse Echo inspection demonstration

Composites Education
CMT Course Content

CMT Course (60 hours on-line)

- Roles and responsibilities
  - Repair design, process planning, and approval
  - Damage detection, inspection and repair processes
  - Skills needed for engineers, technicians and inspectors
- Source documentation
  - Material and process specifications
  - Approved repair documentation, including Sims
  - Regulatory documents, including compliance documents and procedures

Composites Education
CMT Course Content

CMT Course (60 hours on-line)

- Composite damage types, sources and disposition
  - Sources and characteristics of damage
  - Damage significance to structural integrity
  - Structural analysis necessary for repair design
  - Damage disposition supported and not supported by source documentation, such as the SRM
- Inspection procedures
  - Techniques and comparisons among alternatives

Composites Education
CMT Course Content

CMT Course (60 hours on-line)

- Composite laminate fabrication and repair
  - Fabrication processing steps and relationship to repair
  - Processing parameters affecting repair quality
  - Metal bond repairs
  - Drying of composites prior to repair
- Composite laminate bolted repair
  - Issues to consider in selecting bolted versus bonded
  - Drilling and cutting, including differences from metals
  - Processing parameters affecting repair quality

Composites Education
CMT Online Discussion (with SMEs)

Week One: Skills	124	124

A new technician has been added to a maintenance and repair operation group. On the first day, his supervisor points out in the employee handbook the following statement:

"All aspects of composite maintenance and repair are interlinked such that each member of a repair team should understand his/her role and have the training needed to properly complete their tasks."

He is puzzled about what this means because he had the impression that he was there to repair secondary structure only, and needn't worry about 'interlinking'.

How do you respond to his reaction to the statement?

Week One: Slight Skin Damage	195	195

An aircraft shows a slight indentation on its skin, discovered during a routine walk-around of an aircraft. You note that the indent is observable up to 20 feet away, but looks, to the layman, to be minor. As a dedicated airline employee, you recognize the importance of getting the aircraft back into service quickly. Describe how you might react differently if the damage is on a metal versus composite material component.

Composites Education

CMT Online Discussion (with SMEs)

Week Four: Composite Repair	136	136

You read on an internet blog, the following statement;

Damage to composites are easier to repair (whoever has a boat knows that) and there is enough knowledge on composite fuselages in the last 20+ years to confirm this.

http://iaqblog.blogspot.com/2006/03/on-airbus-350-marketing-document-vs.html, dated March 11, 2006.

As a practitioner of composite maintenance and repair on commercial aircraft, you 'see red', and want to make a very brief, but insightful, comment that will enlighten the blogger's opinion without causing public hysteria about composite materials. What and how do you say this in less than 50 words?

Week Three: Underlying Damage	221	221

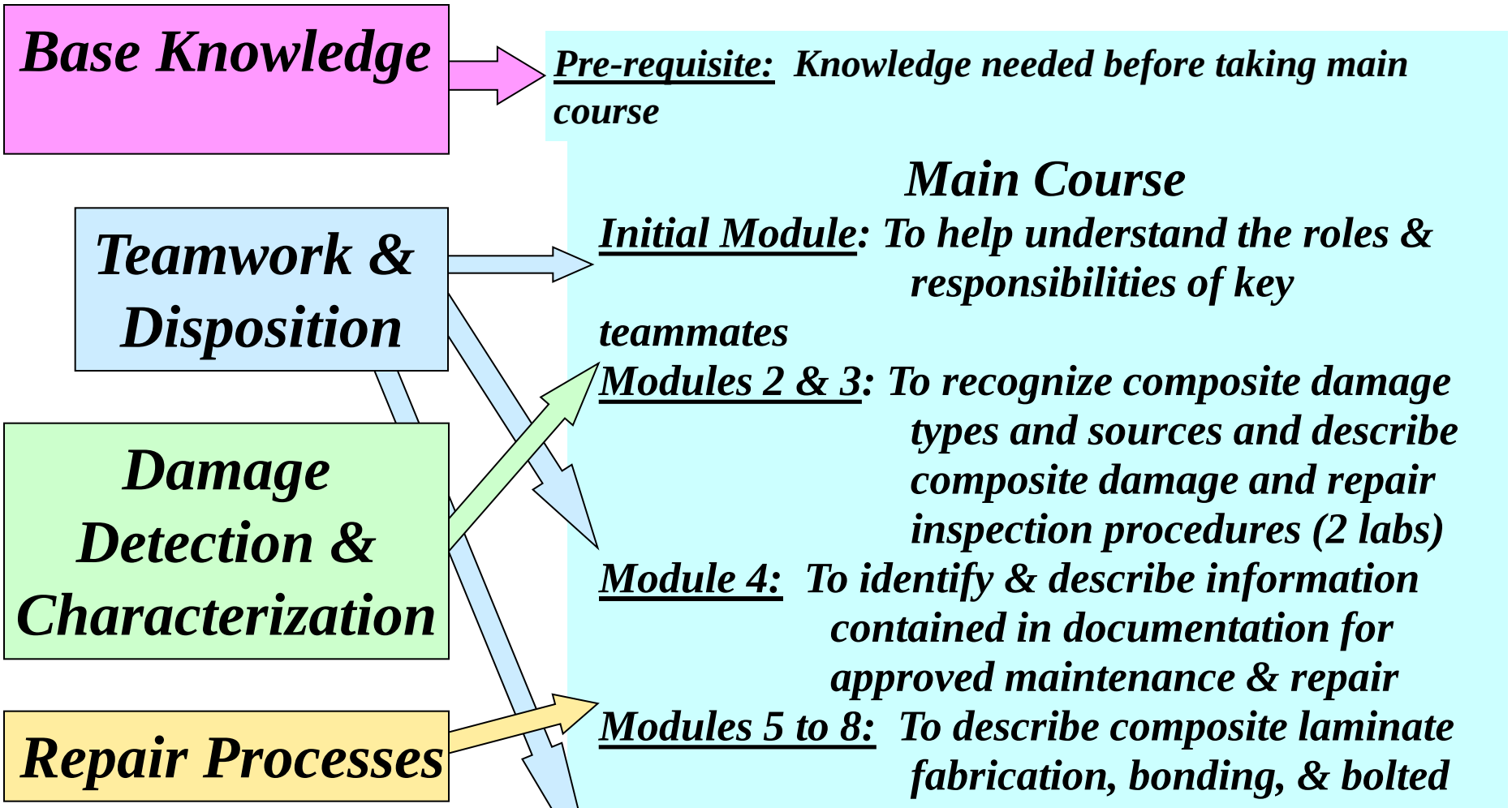
As someone very familiar with metal skin repair on airplanes as an inspector, you are confident that you will transition fairly easily into the practice of composite materials maintenance. However, your son ran across a disturbing article at the following link: https://www.flightsafety.org/asw/mar07/asw_mar07_p17-21.pdf

Within that article was the following graphic:

Composite Underlying Damage

Within that article, was the attached picture depicting types of damage. How does this awareness course adequately prepare you, or not prepare you, in your profession, and how should you respond as a result?

CMT Awareness Course Structure



Level II Safety Awareness Courses

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Structural Engineering Technology (CSET)

- Top-Level Course Objectives
  - Students will describe essential safety awareness issues associated with composite structural engineering important to safe composite aircraft product applications
  - Students will describe engineering principles of composite airframe substantiation during all stages of aircraft product certification
- Course Outline

1.0 Introduction
2.0 Challenges of Composite Applications
3.0 Design, Material and Fabrication Development
4.0 Proof of Structure
5.0 Quality Control of Composite Manufacturing Process
6.0 Maintenance Interface Issues
7.0 Additional Considerations
7.1 Proof of Structure – Flutter +
7.2 Crashworthiness
7.3 Fire safety and fuel tank issues
7.4 Lightning protection

Contributors - Level II CSET Course

- FAA Composite Team (led by Larry Ilcewicz, Lester Cheng & Charlie Seaton)
  - Structures Specialists: Dave Walen (Lightning Protection CSTA), Mark Freisthler (Transport Directorate Standards), Cindy Ashforth (Transport Directorate International Branch), Angie Kostopoulos (Chicago ACO), Allen Rauschendorfer, Melanie Violette and Nathan Weigand (Seattle ACO)
  - Cabin Safety Experts: Joseph Pellettiere (Crash Dynamics CSTA), Dick Hill, Robert Ochs & Alan Abramowitz (FAA Technical Center), Jeff Gardlin (Transport Directorate Standards),
- Key subject matter experts (SME)
  - Peter Smith (retired Boeing)
  - Keith Kedward & Steve Keifer, UCSB (incl. composite design/analysis textbook)
  - Steve Ward (M&P control, design/analysis and proof of structure)
  - Tom Walker and D.M. Hoyt, NSE Composites (fatigue & damage tolerance)
  - Wichita State University (Yeow Ng, Waruna Senevertine, Beth Clarkson, lab development)
  - Delft University (Christos Kassapoglou)
  - Other SME (contractors and volunteers)
    - Michael Niu (UCLA, composite design)
    - Max Davis (Adhesion Associates, metal-bonding)
    - Michael Borgman (Spirit Aero, repair substantiation)
    - FAA JAMS (Paolo Feraboli, Hyonny Kim, Dan Adams)
    - John Halpin (retired Air Force)
    - Will McCarvill (retired Hexcel)
    - John Adelmann (retired Sikorsky)
    - Dan Ruffner (Boeing, Mesa)
    - Convergent Manufacturing Technologies (Univ. of British Columbia composite manufacturing experts)
    - Heatcon (Field and Production repairs, including those performed on-airplane)
    - Workshop participants: presentations, discussions, testimonials (M&P control, fatigue & damage tolerance, crashworthiness)

Composite Structural Engineering Course Syllabus
(April to June, 2013)

Course Schedule

WEEK	TOPICS	DISCUSSION BOARD (20 topics) 400 points	EXAMS
First Week TCO A April 1-7	Basic Knowledge of Composite Materials and Structures Technology	Not Applicable (self-study)	Prereq. Exam (Score >= 80%)
ONE TCO 1, 2, 3, 4, 5 April 8-14	Introduction, Challenges, and Material and Fabrication Development	1: Top ten issues from the introduction module 2: Functional inter-relationships through Integrated Product Teams in support of safety management principles and ensuring the existence of stable materials	
TWO TCO 6, 7, 8, 9 April 15-21	Design, Material and Fabrication Development	1: Importance of establishing a stabilized manufacturing process, including schedule considerations 2: Structural design details and consideration of environmental effects, including sandwich moisture ingression	
THREE TCO 9, 10 April 22-28	Design, Material and Fabrication Development	1: Analysis methods and considerations for FEM 2: Material allowables and knockdown factors	
FOUR TCO 10, 11, 12, 13 April 29-May5	Design, Material and Fabrication Development	1: Bonded and bolted considerations for designing a front wing spar 2: Designing for ease of manufacture and maintenance	
FIVE TCO 14, 15, 16, 17, 18 May 6-12	Statistics and Proof of Structure	1: Contrasting environmental approaches for calculating A- and B- values 2: Damage in fatigue and static strength substantiation using analysis supported by test evidence	Mid-term (50 points)

Composite Structural Engineering Course Syllabus,
(April to June, 2013) *continued*

SIX TCO 19, 20, 21, 22, 23 May13-19	Proof of Structure	1: Implications of high energy, low velocity impact events 2: Reliability for composite fatigue and damage tolerance assessments	
SEVEN TCO 24, 25, 26, 27 May20-26	Proof of Structure	1: Reasons for more reliance on testing for composite structure 2: Managing 'significant changes' related to materials and processes	
EIGHT TCO 28 May28-June 2	Maintenance	1: Roles and responsibilities of the repair team 2: Issues associated with repairing composites having complex geometry with different thermal environments	
NINE TCO 33, 34, 35, 36 June 3-9	Laboratory (2.5 days)	Hands-on reinforcement of teaching points	
TEN TCO 29, 30, 31, 32 June 10-16	Additional Considerations	1: Evaluate the effect of large damage and environment on flutter, and repair to reestablish lightning protection 2: Evaluate design options for accommodating crashworthiness and fire safety	Final (50 points)

Structural Engineering Technology (CSET)
Illustration – Content for Flutter Section
[via a separate file]

- CSET Course Outline
  - 1.0 Introduction
  - 2.0 Challenges of Composite Applications
  - 3.0 Design, Material and Fabrication Development
  - 4.0 Proof of Structure
  - 5.0 Quality Control of Composite Manufacturing Process
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CMfgT Development Plan/Strategy

- Selected contractor (Convergent Manufacturing Technologies) qualified to create most of the course with FAA support
  - Involve FAA Manufacturing Inspection District Offices (MIDO @ SEA, ICT, MSP) focal from the start.
  - Work with FAA composite experts to refine content as needed for MIDO Aviation Safety Inspectors (ASI) and industry designees.
- Follow "near-ideal" approach to course development

  Detailed outline → TCO/teaching points → Course content → Beta review with industry → Course implementation
- Industry experts to be involved in Beta course review
- Course ready for Beta in Spring 2014

Overall Objective of CMfgT Course

- Students will describe the essential safety awareness issues associated with composite manufacturing technologies & processes important to conformity of type design.
- Students will describe deficiencies on the factory floor that have safety implications.

Configuration - Level II CMfgT Course

Composite Manufacturing Safety Awareness Course
[60 hours, incl. Labs, Excluding Prerequisite]

- Prerequisiste

  This will contain basic knowledge of composite materials and manufacturing technology. This is intended to be an independent study with assessment examination (Total 5 - 10 hours).

- Main Course
- Laboratory Sessions

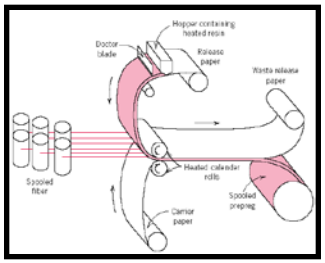
  Laboratory to illustrate course principals and consequences of process deviations. Lab sessions to be conducted in FAA designated regional laboratories.

- Job Aid

  A computer-based tool to access relevant class content.

CMfgT Followed a Logical Flow Understood by Safety Professionals Involved in Manufacturing Oversight

Prepreg Production

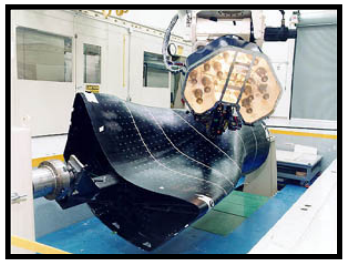


Transportation

Storage

Tooling Preparation

Layup



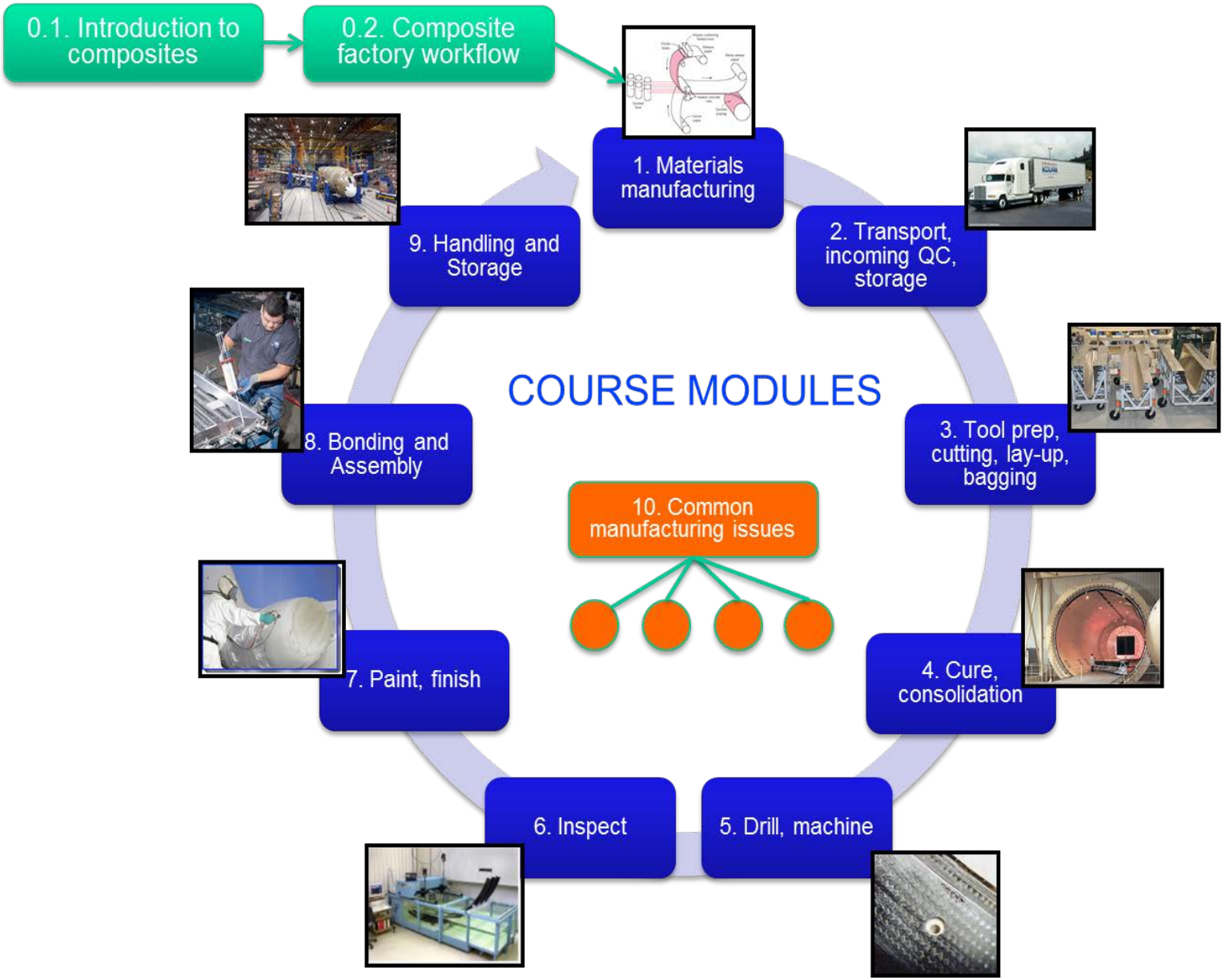
Debulking / Bagging

Cure

Inspection

Assembly

- ***Course presented from a factory perspective as would be experienced by a MIDO inspector***
- ***At each step, discuss deviations (and defects), root causes, in-process and post-process controls***
- ***Introduced information over a number of passes***


0.1. Introduction to composites
0.2. Composite factory workflow
1. Materials manufacturing
2. Transport, incoming QC, storage
3. Tool prep, cutting, lay-up, bagging
4. Cure, consolidation
5. Drill, machine
6. Inspect
7. Paint, finish
8. Bonding and Assembly
9. Handling and Storage
10. Common manufacturing issues
COURSE MODULES

Content Overview - Module 0.1
"Introduction"

- "Composites 101"
  - To ensure that the students' level of background knowledge in composite materials, composites manufacturing processes and composites structures is sufficient to successfully complete the course.
  - The emphasis is to bring all students up to a standard baseline level of knowledge.
- This module has three sub-sections:
  - Section 0.1.1 Composite material fundamentals
  - Section 0.1.2 Regulatory requirements
  - Section 0.1.3 The role of the ASI

Content Overview - Module 0.2
"Composites Factory Workflow"

- Class content is arranged to match the typical factory flow
- Objectives:
  - Introduce the variety of composites manufacturing facilities based on different material forms and manufacturing processes.
  - Introduce the fundamental processing steps that are common within various manufacturing processes.
- Emphasis is on the fundamental processing steps that are common within various manufacturing processes.

Content Overview - Module 1
"Materials Manufacturing"

- Objectives
  - Introduce the manufacturing processes of the individual constituents of composites as well as the composite forms.
  - The student should appreciate the relationship between the constituents manufacturing and the composite form on the resulting composite structure.
- Emphasis is on how the initial materials and their forms affect the subsequent composite properties and performance.

Content Overview - Module 2
"Transport, Incoming QC, Storage"

- Objectives
  - Understand the importance of managing environmental conditions (temperature, humidity, etc.) for the composite constituents from the time of raw material manufacture to production.
  - Understand the impacts of environmental conditions on the quality of the materials and final product/
- Emphasis is on how to control environmental conditions through specifications, testing, etc., to ensure the quality of the finished product

Content Overview - Module 3
"Tool Prep, Cutting, Layup, Bagging"

- Objectives
  - Introduce the importance of tool preparation, cutting, layup and bagging on the quality of manufactured parts.
  - Introduce methods to assure quality during the layup process, including environmental controls
- Emphasis is on the relationship between tool preparation, cutting, layup and bagging on the quality of manufactured parts.

Content Overview - Module 4
"Cure and Consolidation"

- Objectives
  - Introduce the various factors that affect how the material cures and consolidates (Temperature, Pressure, Time, Vacuum, etc.)
  - Explain the difference between thermosets and thermoplastics.
  - Demonstrate the importance of cure on the resulting structural properties
- Emphasis is on the nature of cure, how it is dependent on time and temperature, and the effect on final structural properties

Content Overview - Module 5
"Drill, Machine"

- Objectives
  - Understand the differences in machining composites versus metals, woods and plastics
  - Understand the effect of dull tools and improper machining procedures on local delamination, thermal degradation, etc.
- Emphasis is one the differences between machining composites versus metals, and the importance of proper techniques to avoid mechanical and heat damage in the composite.

Content Overview - Module 6
"Non Destructive Investigation (NDI)"

- Objectives
  - Introduce common NDI techniques for cured parts.
  - Understand the advantages and disadvantages with different NDI techniques, and select appropriate techniques for a given application.
- Emphasis is on the most common NDI techniques and how to assess the appropriateness of the technique and NDI setup for a given application.

Content Overview - Module 7
"Paint, Finish"

- Objectives
  - Introduce common painting and finishing techniques.
  - Describe typical control documents for finishing product application, storage and testing
- Emphasis is on ensuring that any finishing technique is properly tested and qualified against appropriate control documents

Content Overview - Module 8
"Bonding and Assembly"

- Objectives
  - Introduce common bonding and assembly techniques.
  - Describe the advantages and disadvantages between adhesive bonding and mechanical assemblies.
  - Discuss the challenges in inspecting and qualifying joints.
- Emphasis is to describe the importance of critical steps in bonding and assembly of composite components.

Content Overview - Module 9
"Handling and Storage"

- Objectives
  - Describe sources of potential damage during handling and storage and common preventive methods.
  - Understand appropriate environmental conditions for storage (e.g. moisture content, temperature fluctuations, UV protection).
  - Understand risk of undetected damage
- Emphasis is on the importance of safe handling and storage procedures.

Content Overview - Module 10
"Common Manufacturing Issues"

- This is a catch-all section for subjects that are common throughout the manufacturing process
  - MRB, Scaling Issues, Dimensional Deviations, etc.
- Present practical examples of common manufacturing issues, means of early detection and corrective measures.
- Emphasis is on understanding the root cause of defects and the appropriate corrective actions.

Overview - Laboratory Session

- Students will fabricate panels with intentional defects
  - They will use NDI inspection techniques
  - They will test the panels to show effects of defects
- Students will see various material forms and defects
- There will be optional tours of a prepreg manufacturing facility and composite structures manufacturing facility

Overview - Job Aid (Computer-Based Tool)

- The job aid will be a computer-based tool to access relevant class content
- May be available as an application for mobile devices
- Intended to provide ASI a handy tool of supporting job function

FAA Collaboration With NIAR/WSU

- FAA development budgets have many research projects through NIAR/WSU (incl. course developments, leading to WSU continuous education business opportunities)
- NIAR/WSU has derived strategies and working relationships for FAA continuous education coursework
  - Marketing should lead to sufficient numbers of students and class longevity once reputation is established and students realize benefits
  - Past CSET, CMfgT & CMT sessions have led to an understanding for future offerings (student needs, interests and background)
- FAA Instructor involvement benefits both the FAA (reduced student costs) and NIAR/WSU (regulatory presence)
- Current contracted instructors have long-standing NIAR/WSU & FAA relationships (research & training development initiatives)

Offering via Wichita State University (2015)

http://webs.wichita.edu/?u=CONTED&p=/PublicEngineeringCourses/

Composite Manufacturing Technology (CMfgT) Course

- **Course Description:** This course will provide students with a technical knowledge of composite manufacturing to a level that allows them to better and more proactively identify deficiencies on the factory floor that have safety implications. This course was developed by Wichita State University in collaboration with key industry experts and the Federal Aviation Administration. Students will study advanced topics during an on-line, interactive learning experience via Blackboard. Teaching methodology includes online discussions facilitated by subject matter experts, relevant documentation, and audio/visual aids. Depending on prior knowledge and experience, students will spend approximately eight hours per week reviewing materials, participating in online discussions, and testing their knowledge. Depending on the students skill set and back ground the time investment may fluctuate a bit. The course will conclude with a 2-day hands-on laboratory.
- **Intended Audience:**

  - MIO/MIDO inspectors participating in the certification of composite structures.
  - FAA designees, international civil aviation authorities and engineers responsible for quality system development, approval and oversight of manufacturing processes for composite structures.
- **Course Delivery Method**: Online with a hands on lab
- **Course Length**: Approximately 9 weeks
- **Course Start Dates**: March 2, 2015

Offering via Wichita State University (2015)

Composite Structural Engineering Technology (CSET) Course

- **Course Description:** This course will provide students with an awareness of safety issues related to engineering, manufacturing, maintenance, and certification of composite materials associated with civil aircraft structures, in accordance with AC 20-107B (Composite Aircraft Structure). This course was developed in collaboration with Wichita State University, key industry experts, and the Federal Aviation Administration. After finishing a 1-week period of self-study of fundamental composites and successfully completing an examination, students study more advanced topics during an on-line, interactive learning experience via Blackboard. Teaching methodology includes online discussions facilitated by subject matter experts, relevant documentation, and audio/visual aids. Depending on prior knowledge and experience, students will spend up to ten hours per week reviewing materials, participating in online discussions, and testing their knowledge. The course will include a 2.5-day hands-on laboratory, which is optional but highly recommended.
- **Intended Audience:**
  - FAA Directorate/ACO engineers & industry designees participating in the certification of composite structures.
  - Engineers at aerospace companies who are involved in designing and analyzing composite structures
  - International Civil Aviation Authorities and their designees responsible for certification of composite structures
- **Course Delivery Method:** Online with an optional hands on lab
- **Course Length:** Approximately 12 weeks
- **Course Start Dates:** May 18, 2015