Composite Materials Overview for Engineers

An Open, Online Course Co-Developed by Academia and Industry

ASEE CIEC 2014, Savannah GA

Meet the Team

The Boeing Company

Barry McPherson
Education Programs Leader

Dr. Michael Richey
Associate Technical Fellow

David French
Training Specialist

Dr. Kathleen Chang
Program Manager

Fabian Zender
Program Integration Manager

UW Instructional Team

Dr. Kuen Lin
Professors

Luke Richard
Graduate TA

UW Professional & Continuing Education

Emily West
Program Manager

Jonathan Keib
Videographer

Chad Williams
Instructional Designer

Maggie Kramm
Instructional Designer

Mark Ellison-Taylor
Project Manager

BOEING

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What is the importance of composites?

767
~2.5%

737
~1%

787
~50%

747
~1%

757
~2.5%

777
~10%

Pictures Courtesy of The Boeing Company

Possibility for weight and fuel savings leads to an ever increased used of composites

What is the importance of composites?

- Boeing 787
  - 50% Composites
  - First civil aircraft to have majority of wing assembly built from composites
- Boeing 777X
  - launched in 11/2013 in Dubai
  - Composite wing assembly with folding tip

Picture Courtesy of The Boeing Company

Where did the program originate?

- UW and Boeing LTD collaboration originated in 2002
- 3 UW Composite certificate programs were developed to deliver academic rigor and practical applications
  - Aircraft Composite Materials & Manufacturing
  - Aircraft Composite Structural Analysis & Design
  - Modern Aircraft Structures

Pictures Courtesy of the University of Washington

What has been accomplished so far?

- By 2013,
  - ***543*** Boeing engineers graduated from the certificate programs
  - approximately ***200*** took single courses
- Faculty Instructors
  - Dr. Das, Department of Material Science & Engineering
  - Dr. Mamidala, Department of Material Science & Engineering
  - Dr. Flinn, Department of Material Science & Engineering
  - Dr. Lin, Department of Aeronautics & Astronautics
  - Gerald Mabson, The Boeing Company
  - Chris Eastland, The Boeing Company
  - Dr. Mohaghegh, The Boeing Company
  - Dr. Safarian, Federal Aviation Administration

Aircraft Composite Materials & Manufacturing (Dr. Das, Dr. Mamidala, Dr. Flinn)

Aircraft Composite Structural Analysis & Design (Dr. Lin, Gerald Mabson, Chris Eastland)

Modern Aircraft Structures (Dr. Mohaghegh, Dr. Safarian)

Award Winning Program

- **2011 ASEE CMC Collaboration Award**
  - *"This partnership represents a new mode of knowledge spillover between industry and academia, one that advances the way we think about continued learning in the evolving workplace through integrating the rigor expected from academia with the practical applications that are critical to Boeing and our partner companies."* Dr. Michael Richey
- ***2008 Boeing Human Resources Functional Excellence Award***
  - *Development and delivery of the Aircraft Composite Structural Analysis & Design (ACSAD) program and ROI model*
- ***2007 CorpU Excellence Award***
  - *Excellence Award for Corporate – College Partnerships*

http://www.aa.washington.edu/courses/compcert.html

Composites at UW

- William E. Boeing Dept. of Aeronautics & Astronautics Automobili Lamborghini Advanced Composite Structures Laboratory:

  Research & education solutions in the field of composite materials & structures of relevance to ensuring safety of current and future air & ground vehicles.

http://oneighturbo.com/events/lamborghini-unviels-the-automobili-lamborghini-advanced-composite-structures-laboratory-at-the-university-of-washington/

- Dept. of Mechanical Engineering FAA Joint Advanced Materials & Structures Center of Excellence:

  Seeking solutions to problems associated with existing, near- and long-term applications of composites & advanced materials for large transport commercial aircraft.

http://depts.washington.edu/amtas/about/COEs.html

Composites at UW

- William E. Boeing Dept. of Aeronautics & Astronautics Master of Aerospace Engineering:

  Multidisciplinary professional graduate degree emphasizing applied skills and experience needed in industry, launched in 2013. Offers Composites concentration.

- The UW – Boeing LTD Aircraft Composite Structural Analysis & Design Certificate Program by 2013 has ***320*** Graduates

http://commons.wikimedia.org/wiki/File:U_of_Washington_Guggenheim_Hall_01.jpg

Aircraft Composite Structural Analysis & Design Program provides basis for open, online composite course

Why make an open, online course?

Georgia Institute of Technology

BACHELOR OF SCIENCE IN AEROSPACE ENGINEERING
2013 - 2014 DEGREE REQUIREMENTS

REQUIREMENT	REQ HRS	COURSE(S)	NOTES
Wellness	2	HPS 1040 or APPH 1040 or APPH 1050	
Core A - Essential Skills	3	ENGL 1101	
	3	ENGL 1102	
	4	MATH 1501	c
Core B - Institutional Options	3	CS 1371	
Core C - Humanities	6	Any HUM	
Core D - Science, Math, & Technology	4	CHEM 1310	
	4	PHYS 2211	a
	4	MATH 1502	
Core E - Social Sciences	3	HIST 2111 or HIST 2112 or INTA 1200 or POL 1101 or PUBP 3000	
	3	ECON 2100 or ECON 2101 or ECON 2105 or ECON 2106	
	6	Any SS	
Core F - Courses Related to Major	4	MATH 2401	c
	4	MATH 2403	c
	3	MSE 2001	
	4	PHYS 2212	b, c
	3	Technical Elective	d, e
Major Requirements	2	AE 1350	
	2	COE 2001	
	3	AE 2020	
	3	AE 2220	
	3	COE 3001	
	3	AE 3021	
	2	AE 3051	
	4	AE 3125	
	1	AE 3140	
	3	AE 3330	
	3	AE 3450	
	4	AE 3515	

University of Washington

Undergraduate Degree Requirements

180 Credit Hours are required for graduation:

Mathematics (24 credits)

MATH 124, "Calculus with Analytic Geometry I" (5)
MATH 125, "Calculus with Analytic Geometry II" (5)
MATH 126, "Calculus with Analytic Geometry III" (5)
MATH 307, "Intro. to Differential Equations" *or* **AMATH 351** (3)
MATH 308, "Matrix Algebra with Applications" *or* **AMATH 352** (3)
MATH 324, "Advanced Multivariable Calculus I" (3)

For course descriptions, please see: Course Catalog (MATH)

Engineering Fundamentals (16 Credits)

AA 210, "Engineering Statics" (4)
CEE 220, "Intro. to Mechanics of Materials" (4)
ME 230, "Kinematics and Dynamics" (4)
AA 260, "Thermodynamics" (4)

For course descriptions, please see: Course Catalog (College of ENGINEERING)

Natural World (25 Credits)

CHEM 142 *or* **145** (5)
CHEM 152 *or* **155** (recommended) *or* NW approved alternative (5)
PHYS 121 (5)
PHYS 122 (5)
PHYS 123 (5)

Visual, Literary, & Performing Arts *and* Individuals & Societies (24 credits)

10 credits minimum in each area
plus
4 additional credits from either area

Written Communication (5 credits)

5 credits in Written Composition
from the University's Composition List
7 additional credits of required writing are built into the major core courses

Aeronautics & Astronautics 300-Level Required Courses (45 credits)

A A 301 (4)	**A A 312** (4)	**A A 331** (4)
A A 302 (4)	**A A 320** (3)	**A A 332** (4)
A A 310 (4)	**A A 321** (3)	**A A 360** (4)
A A 311 (4)	**A A 322** (3)	**AMATH 301** (4)

Massachusetts Institute of Technology

Subject & Units	Institute Requirement	Units Beyond GIRS
1. Freshman Year		
Fall Term		
3.091 Intro to Solid-State Chemistry (12)	CHEM	
8.01-Physics I (12)	PHYS	
18.01-Calculus I (12)	CALC	
HASS (12)	HASS	
Term Units = 48		
Spring Term		
1.00 Intro to Computers & Engineering Problem Solving (12)	REST	
8.02-Physics II (12)	PHYS	
18.02-Calculus II (12)	CALC	
HASS (12), CI-H	HASS	
Term Units = 48		
2. Sophomore Year		
Fall Term		
Elective (12)		12
18.03-Differential Equations (12)	REST	
Elective (6)		6
HASS (12)	HASS	
HASS-D (12)	HASS-D	
Term Units = 54		
Independent Activities Period		
A six-unit elective, i.e. UROP-for-credit		6
Spring Term		
7.012-Introductory Biology (12)	BIO	
Elective (12)		12
HASS (12)	HASS	
HASS (12), CI-H	HASS	
Term Units = 48		
3. Junior Year		
Fall Term		
16.001-Unified Engineering I (12)		12
16.002-Unified Engineering II (12)		12
HASS-D (12)	HASS-D	
HASS-D (12)	HASS-D	
Term Units = 48		
Spring Term		
16.003-Unified Engineering III (12)		12
16.004 Unified Engineering IV (12)		12
Elective (12)		12
Concentration Subject #1 (12)		12
Term Units = 48		
4. Senior Year		
Fall Term		
16.06-Principles of Automatic Control (12)		12
Concentration Subject #2 (12)		12
Concentration Subject #3 (12)		12
Concentration Subject #4 (12)		12
16.621-Experimental Projects I (6)		6

Stanford University

Undergraduate Degrees

- Interdisciplinary Major
- Minor
- Coterminal Degrees

INTERDISCIPLINARY MAJOR IN AERO/ASTRO

Undergraduates enter Stanford with their majors undeclared. Although Aero/Astro is primarily a graduate department, Stanford undergraduates may declare an Interdisciplinary Major in Aeronautics and Astronautics leading to the Bachelor of Science degree in General Engineering. The principal purpose of this degree is to prepare students who are strongly interested in aerospace for subsequent graduate study in the field.

Course requirements include:

Mathematics	24 units during freshman, sophomore, or junior years.
Science	19 units in freshman or sophomore years.
Technology in Science	1 course
Engineering Fundamentals	3 courses, including Engineering Thermodynamics (ENGR 30) and Programming Methodology (ENGR 70A).
Departmental Requirements	48 units, including Introduction to Aero/Astro (AA 100), and specified other courses in the School of Engineering. Students will select two depth areas from among Dynamics and Controls, Systems Design, Fluids and Computational Fluid Dynamics (CFD), and Structures and take two courses from both areas.

Details on the course requirements can be found in the School of Engineering's Handbook for Undergraduate Engineering Programs.

Freshmen and sophomores are welcome to come to our Student Services Office in Durand 250 to discuss the possibilities for future involvement in our programs.

MINOR IN AERO/ASTRO

Alternately, Stanford undergraduates may declare an **undergraduate minor** in Aero/Astro. The minor introduces students to the key elements of modern aerospace systems and their many spin-off technologies. Within the minor, students may focus on aircraft, spacecraft, or disciplines relevant to both. The course requirements include:

ENGR 14*	Applied Mechanics: Statics (3 units)
ENGR 15*	Dynamics (3 units)

None of these institutions require a single class on composites to receive a Bachelors degree in Aerospace Engineering

Not everybody has a college degree…

- Technical colleges are limited to specific degree programs
  - ➢Open, online course can help provide overview of composites prior to acquiring specific skills
  - ➢Open, online course provides baseline knowledge for those not focused on composites directly
- High Schools have limited resources
  - ➢Open, online course can help student gage interest in advanced manufacturing
  - ➢Open, online course can help student gage interest in post-secondary STEM career

An online course for industry

Certificate Program currently taught F2F in Everett, WA

Excludes: Renton, Auburn, South Park, King Field (~50,000)

Boeing has ~168,000 employees only ~30,000 work in Everett

Philadelphia, PA
Rotorcraft
~6,000 Employees

St. Louis, MO
Boeing Defense
~15,000 Employees

Long Beach, CA
Boeing Commercial
Boeing Defense
~18,700 Employees

Charleston, SC
Boeing 787, 2nd Assembly Line
~7,400 Employees

Courtesy of The Boeing Company

The impact of composites is not confined to the aerospace industry

Turbine Blades – Power Industry

Courtesy of General Electric, Co

Radiator Core Support - Automotive

Courtesy of Toray Industries, Inc

Roof - Architecture

http://www.allairports.net/airports/denver-airport-address.shtm

Fuel Cells – Power Industry

Courtesy of Toray Industries, Inc

Ski – Sporting Goods

http://www.skiessentials.com/browse.cfm/2012-rossignol-avenger-72-composite-skis-w-tpi2-axium-100s-bindings/4,5425.html

Table - Medical Devices

Courtesy of General Electric, Co

What are the benefits?

- Serving a broader audience with world-class composites training
- Guiding students toward further composites education
- Filling competency gaps through industry-academia collaboration
- Inspire, prepare, and recruit the next generation of materials innovators

http://www.arkadin.com/us/our-solutions/cloud-collaboration-platform/cloud-technology-and-partners

Where to start?

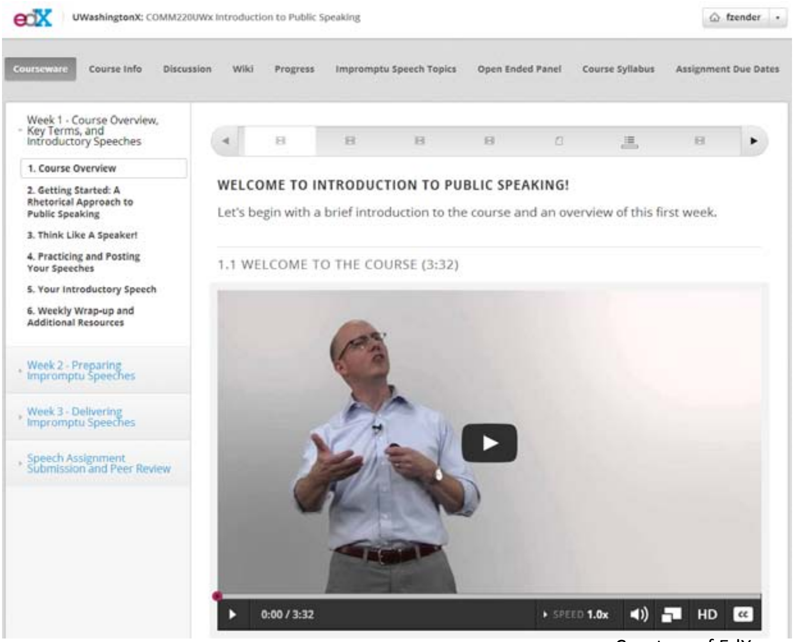
- An introductory course will reach the broadest audience
  - It has the largest effect size
  - It will provide critical lessons learned regarding online delivery of material for the transformation of the certificate programs
  - It can help UW and Boeing identify talent

Courtesy of Microsoft Office

What Course Platform to use?

- EdX has a collaboration with 30 universities internationally
  - Approximately 98 courses offered by January 2014
  - Enrollments typically range in the thousands
  - 1.6 million users thus far
- Ease of course implementation
- Data analytics
- Credentialed XSeries
  - Possible further development

Courtesy of EdX



Courtesy of EdX

What to teach in an introduction?

- Identify composite materials
- Why are they used?
- What are their advantages & benefits

Introduction

Differences between Metals and Composites

- Anisotropic vs. isotropic
- Tailoring of composites
- Service life and damage mode comparison

Properties of Fiber, Matrix, Composite

- Function of fiber and matrix
- Thermoplastic vs. Thermoset

Manufacturing of Polymeric Matrix Composites

- Identify available processes
- Typical defects
- Special Design considerations

Mechanics of Composites

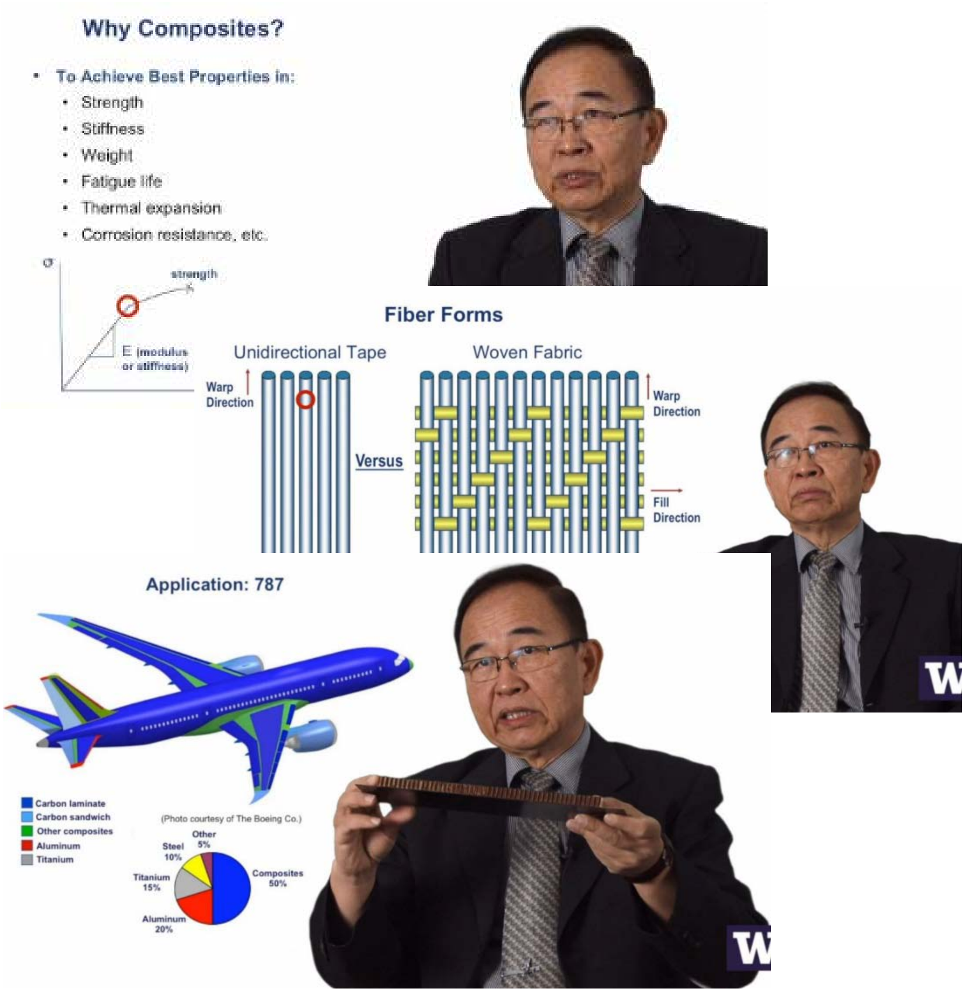
- Hooke's Law
- Stress-Strain Relations
- Lamination Theory

Design, Inspection, and Repair

- Composites in PLM
- Identification of damage
- Composite repair options

How to deliver this content?

- Expert Instructor
- Quality Lecture Material
  - Hands-On Displays
  - Industry Examples
  - Guest Instructors
  - Lab Demos
- Assignments
  - Quizzes
  - Forum
  - Formative & summative assessments
- Supplemental Material



How to deliver this content?

What can we learn from data analytics?

- Who is participating and how are they interacting?
  - Demographic survey of students (location, educational background, industry)
  - Who is interacting with who?
- How and what do people learn?
  - Formative assessment within each modules
  - Summative assessment at end of each module
  - Task behavior
    - Time on Task
    - Task Interactions (clickstream data)
    - Task Completion
  - Thought process and solution approach novice vs. expert

What does the future hold?

- Recruit students
- Start of the course
- Awarding Continuing Education Units from UW
- Development of online programs in related subject areas

Courtesy of Microsoft Office

http://commons.wikimedia.org/wiki/File:I_want_you.jpg

What questions do you have?

Industry:

Michael Richey, Ph.D.
Associate Technical Fellow
The Boeing Company
Michael.C.Richey@Boeing.com

Barry McPherson
Education Programs Leader
The Boeing Company
Kenneth.B.Mcpherson@Boeing.com

Dave French
Engineering, Learning Scientist
The Boeing Company
David.E.French@Boeing.com

Kathleen Chang, Ph.D.
Program Manager
The Boeing Company
Kathleen.Y.Chang@Boeing.com

Fabian Zender
Program Integration Manager
The Boeing Company
Fabian.Zender@Boeing.com

Academia:

Kuen Lin, Ph.D.
Professor
University of Washington
Lin@aa.washington.edu

Emily West
Program Manager
University of Washington
EWest@pce.uw.edu

Mark Ellison-Taylor
Project Manager
University of Washington
MTaylor@pce.uw.edu

Chad Williams
Program Management Director
University of Washington
CWilliams@pcd.uw.edu

Maggie Kramm
Instructional Designer
University of Washington
MKramm@pce.uw.edu