NATIONAL INSTITUTE FOR AVIATION RESEARCH

WICHITA STATE UNIVERSITY

Qualification Framework for Oxide/Oxide and SiC/SiC Ceramic Matrix Composites

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CECAM center of excellence for composites and advanced materials

JAMS JOINT ADVANCED MATERIALS & STRUCTURES CENTER OF EXCELLENCE

Federal Aviation Administration

RESEARCH TEAM & OBJECTIVES

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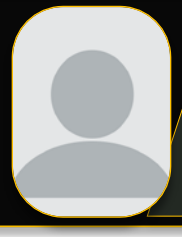


Ahmet Oztekin
Program Manager of FAA COE for Joint Advanced Materials and Structures (JAMS)

PROJECT OVERVIEW

INDUSTRY PARTNERS:

- Axiom Materials (ox/ox prepreg and test panels), AC&A (ox/ox test panels), 3M (ox fiber/fabric), IHI Corporation (SiC/SiC test panels), 20+ steering committee members

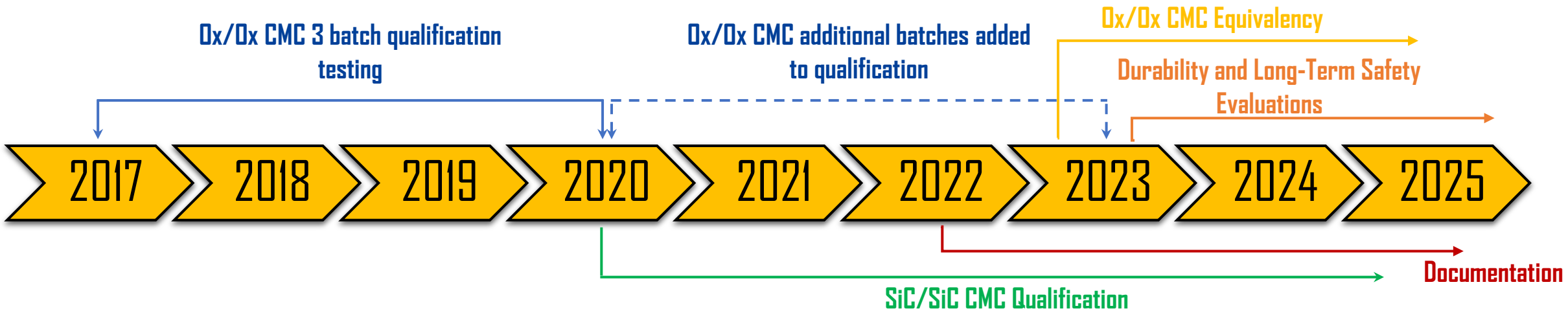
PROJECT OBJECTIVES

- Develop a framework for the qualification of CMCs, including guidelines and recommendations for their characterization, testing, design and utilization.
- Develop and execute a test plan to evaluate the durability and long-term safety of CMCs.
- Transition the CMC test data and guidelines generated in this program into shared databases, such as CMH-17.
- Coordinate with industry and government organizations, including CMH-17 CMC coordination and working groups and ASTM C28.

APPROACH

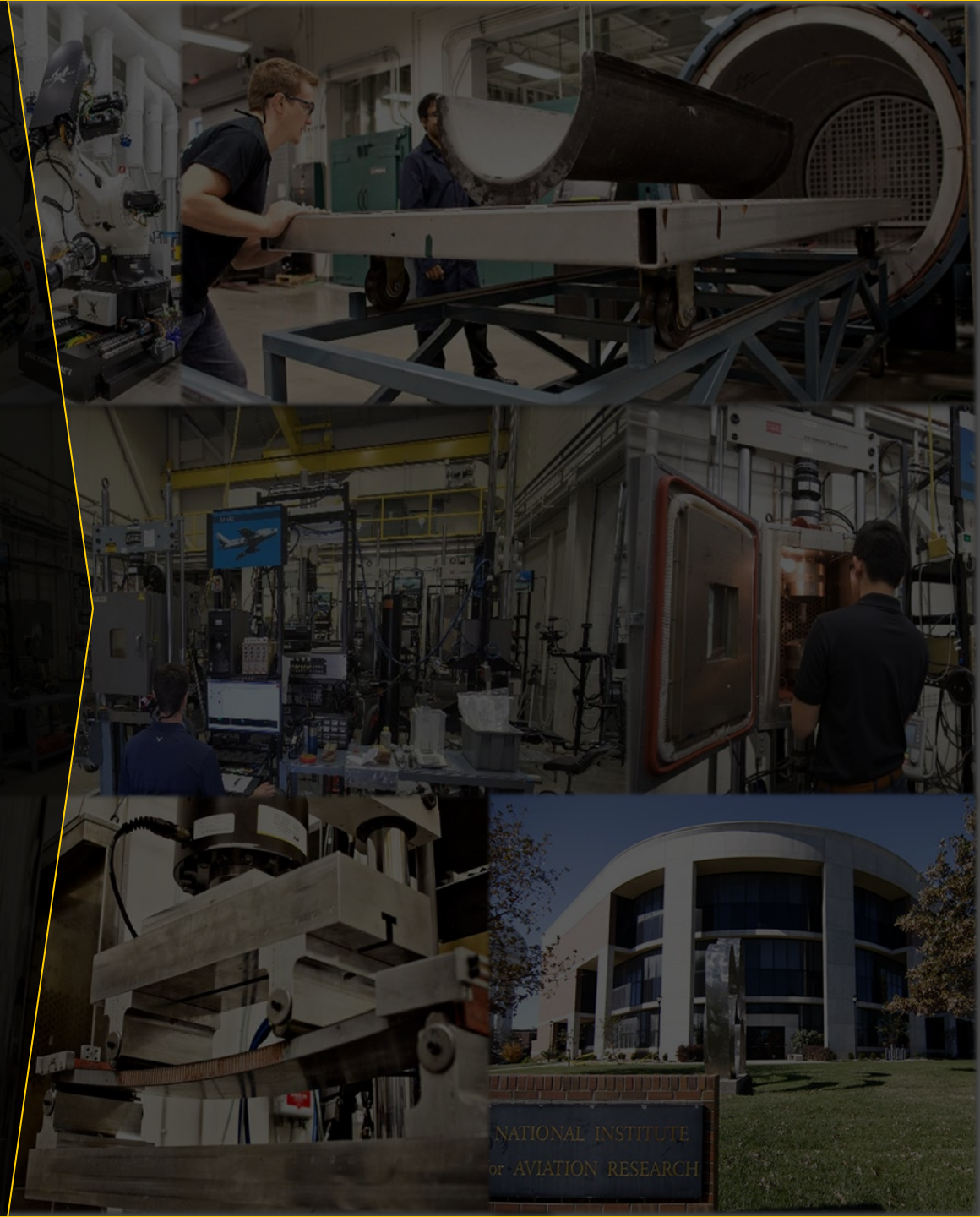
- **Generate Qualification Documents for CMCs and Perform Material Qualification to Establish Qualification Guidance**
  - Material and Process Specifications
  - Test Plan
  - Statistical Analysis Report with B-Basis Allowables or Estimates
- **Generate Equivalency Documents for CMCs and Perform Material Equivalency to Establish Equivalency Guidance**
  - Test Plan
  - Equivalency Analysis Report
- **Evaluate Durability and Long-Term Safety of CMCs**
  - Generate Test Plan
  - Perform fatigue, long term thermal exposure, and creep testing
- **Generate Technical Reports**
- **Generate Guidance Documents**

SCHEDULE



Task	Material Specification	Process Specification	Test Plan	Panel Fabrication	Testing
Ox/Ox CMC Qualification	✓	✓	✓	✓	In Progress
SiC/SiC CMC Qualification	✓	✓	✓	✓	✓
Ox/Ox CMC Equivalency	N/A	N/A	✓	• Received Prepreg • Pending Revisions to the Process Specification • Process Parameter Evaluations In Progress	
Durability and Long-Term Safety Evaluation	N/A	N/A	✓		

0x/0x Qualification



OX/OX QUALIFICATION

Fiber Source: 3M

Weaver: Textile Products Inc (TPI)

Prepreg Supplier: Axiom Materials

Panel Fabricator: AC&A & Axiom Materials

Nextel 610 Fibers
Alumina Fiber, 3K Denier, 5-Harness Satin Weave

AX-7800 Aluminum Silicate Slurry (Water Based)

Autoclave Cure and Sintering

3 Batches

- Documents Generated for Qualification Program:
  - Material Specification
  - Process Specification
  - Test Plan – including test matrix with physical, thermal, and mechanical test requirements
- Other Documents for Qualification Program:
  - Material Property Data Report
  - Statistical Analysis Report with Material Allowables

Knowledge gained from this program has aided in the completion of many sections of CMH-17 Volume 5

OX/OX QUALIFICATION

Material Specification: Revision Summer 2025

Process Specification: Revision Spring 2025

Test Plan: Complete

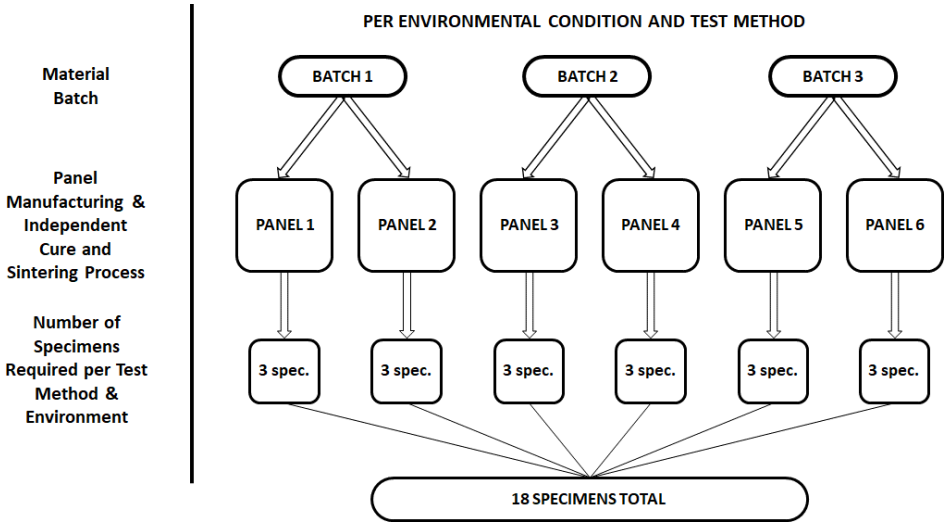
Panel Fabrication: Complete

Testing: Spring 2025

Statistical Analysis: Summer 2025

Test Reports: Summer 2025

Transition Data and Guidelines: Summer 2025



- Due to a high coefficient of variation observed for some properties, process-property data were evaluated and physical property acceptance limits were established – as a result, some data were excluded, requiring new data to be generated.
- Process parameter evaluations were performed and additional evaluations are planned to enable improved quality and reproducibility of test panels without changing material performance.
- More than five batches of prepreg and 100 panels have been produced, and more than 300 physical, 60 thermophysical, and 700 mechanical tests have been performed.

OX/OX MATERIAL AND PROCESS SPECIFICATIONS

Titles:

- NCAMP Material Specification NMS 780 Rev A: Autoclave Cure, Slurry Processed Axiom Oxide/Oxide Prepregs
- NCAMP Process Specification NPS 87800 Rev B: Fabrication of NMS 780 Qualification, Equivalency, and Acceptance Test Panels

Objectives:

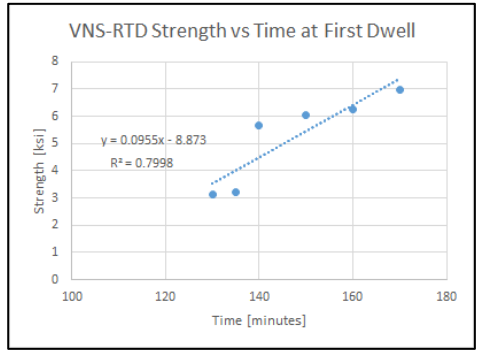
- Define technical requirements and quality assurance requirements for material procurement
- Define materials, test laminate fabrication, and quality assurance requirements for laminate fabrication

Status: Draft material and process specifications authored ahead of qualification activity. Specifications to be finalized at the conclusion of data analysis.

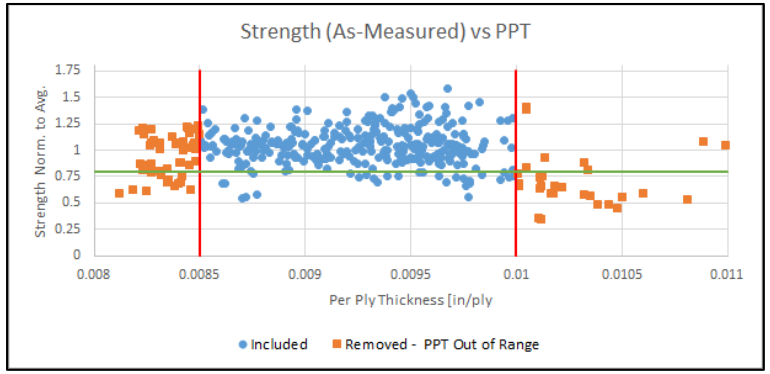
Key:
In-work
Planned

OX/OX QUALIFICATION – PROCESS ISSUES AND EVALUATIONS

- Performed linear and multivariate regression analysis on the qualification data to better understand process-property relationships to key-in on potential changes to the process specification.

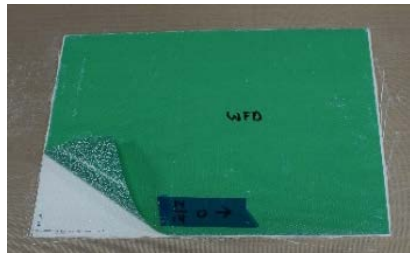


- Performed analysis to determine the appropriate physical property acceptance limits for which all the data was filtered.
  - Porosity Acceptance Limit: ≤ 29%
  - Density Acceptance Limit: 2.6 - 2.8 g/cm^3
  - Per Ply Thickness Acceptance Limit: 0.0085 - 0.0100 in/ply

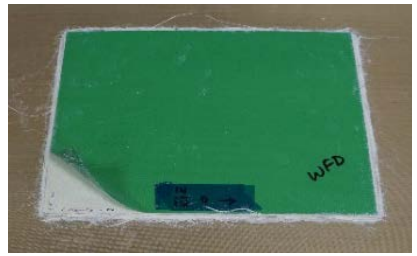


- Performed a limited number of process-parameter evaluations to understand process sensitivities and aid in revising the process specification by altering the following:
  - Frequency of Vacuum Debulks
  - Number of Bleeder Plies
  - Initial Dwell Temperature
  - Time Pressure Applied
  - Edge Dams

Before Debulk (Panel 2)



Debulks Complete (Panel 1)



OX/OX PROCESSING-PROPERTY RELATIONSHIP TECHNICAL REPORT

NIAR
Wichita State University

Title: Processing-Property Relationship of Oxide/Oxide Composites

Objectives:

- Understand the effects of processing variables and physical properties on the variability of mechanical properties
- Define physical property acceptance limits reducing the variability of mechanical property data

Status: Report drafted, reviewed by FAA personnel, revision in work

Test - RTD Strength	R2 Value							
	Density [g/cm^3]	Porosity [% Vol]	Fiber Volume [% Vol]	Matrix Volume [% Vol]	Per Ply Thickness [in]	Min Vacuum During AC Cure ["Hg]	Sintering Temperature [°F]	Sintering Hold Time [min]
Warp Tension	0.41	0.39	0.07	0.00	0.23	0.01	0.00	0.09
Warp Compression	0.72	0.70	0.35	0.00	0.43	0.00	0.25	0.00
Fill Tension	0.06	0.12	0.16	0.01	0.17	0.28	0.11	0.12
Fill Compression	0.29	0.56	0.67	0.52	0.10	0.62	0.17	0.01
In-Plane Shear (+/-45 Tension)	0.76	0.60	0.04	0.03	0.32	0.87	0.23	0.17
Unnotched Tension	0.23	0.16	0.01	0.09	0.04	0.13	0.34	0.05
Unnotched Compression	0.82	0.75	0.60	0.01	0.43	0.26	0.00	0.01
Open-Hole Tension	0.08	0.04	0.12	0.10	0.24	0.20	0.23	0.00
Open-Hole Compression	0.17	0.38	0.04	0.34	0.01	0.02	0.17	0.03
Filled-Hole Tension	0.56	0.49	0.17	0.01	0.20	0.01	0.04	0.23
Interlaminar Shear (Double Notch)	0.01	0.02	0.00	0.05	0.00	0.14	0.19	0.15
Single-Shear Bearing	0.73	0.80	0.29	0.01	0.31	0.29	0.33	0.11
Double-Shear Bearing	0.00	0.03	0.13	0.43	0.09	0.18	0.22	0.00
In-Plane Shear (V-Notch)	0.06	0.07	0.10	0.54	0.07	0.02	0.08	0.06
Interlaminar Shear (Short-Beam)	0.46	0.45	0.39	0.10	0.37	0.00	0.12	0.00
Interlaminar Tension	0.43	0.37	0.33	0.01	0.21	0.08	0.38	0.13
Flexure	0.13	0.16	0.02	0.35	0.47	0.00	0.00	0.05

Correlation Color Scale

0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9

Example correlation table for physical properties and mechanical strength properties used to generate acceptance limits

Key:
In-work
Planned

IMI3
INDUSTRIAL MODERNIZATION OF MATERIALS & MANUFACTURING

OX/OX QUAL. STATISTICS – MATERIAL ALLOWABLES GENERATION

- Material allowables were calculated in accordance with CMH-17 Volume 1 Chapter 8. Initial calculations were performed grouping the data by batch, which is typical for composites.
- For structured datasets, ANOVA must be used, which results in very low allowables because ANOVA doesn't handle less than 5 groups well.

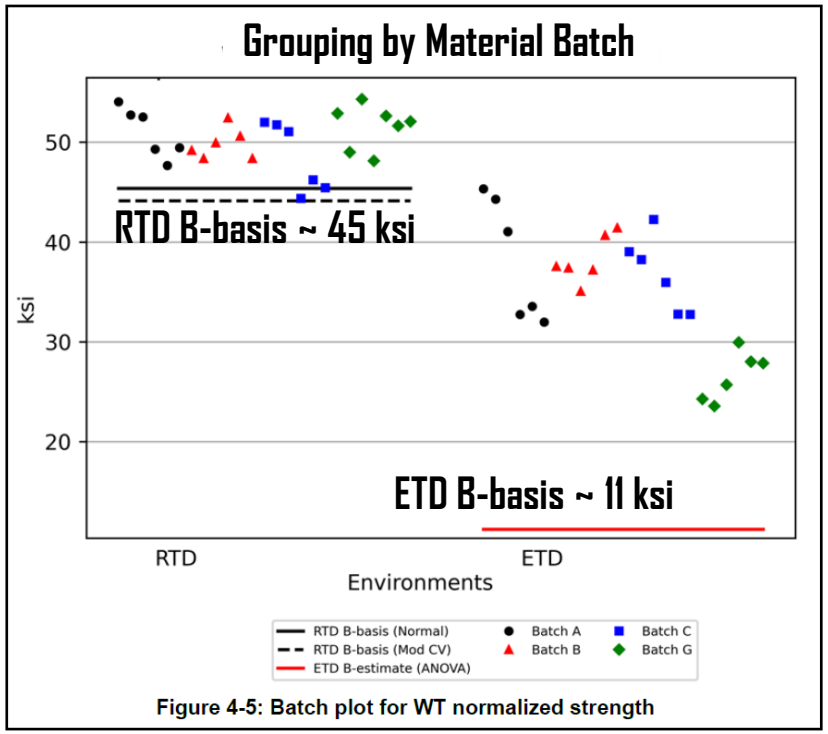


Figure 4-5: Batch plot for WT normalized strength

- Greater panel-to-panel variability has been observed than batch-to-batch variability. In this case, CMH-17 allows for the substitution of multiple panels within a batch for multiple batches when calculating basis values using the ANOVA method.
- Grouping by panel (6 groups) results in more reasonable material allowables when using ANOVA, but this could result in an overestimation of the b-basis value if batch-to-batch variability is not significantly smaller than panel-to-panel variability, so caution should be taken.

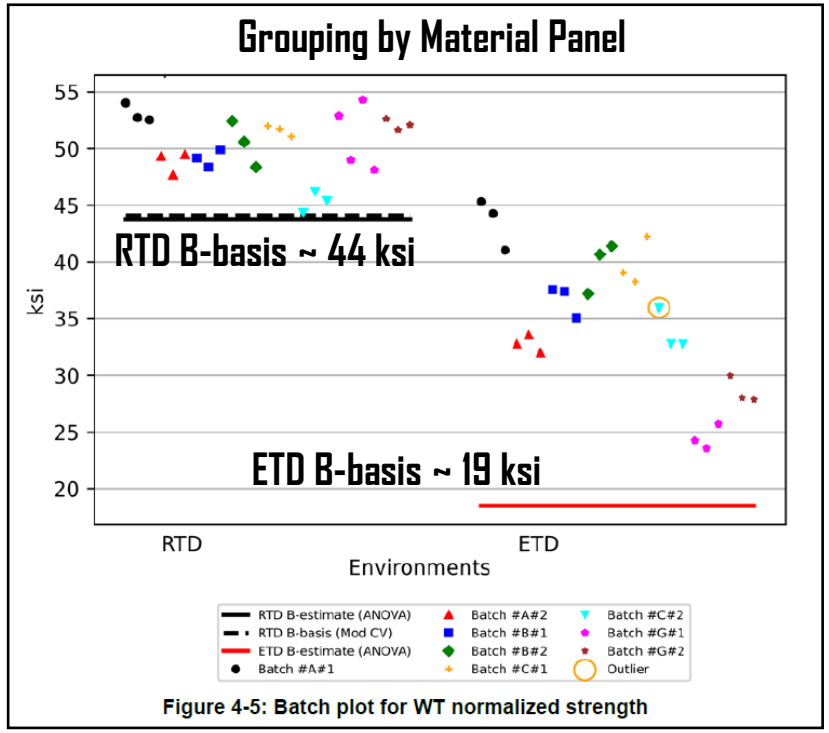


Figure 4-5: Batch plot for WT normalized strength

Properties – Structured vs Unstructured

Unstructured / Single-Point

- Warp Tension (WT) – RTD
- Warp Compression (WC) – RTD, ETD
- Fill Compression (FC) – RTD
- Interlaminar Shear (SBS) – RTD
- Filled-Hole Tension 1 (FHT1) – RTD, ETD (Mod CV)
- Double-Shear Bearing 1 (DSB1) – RTD (2% Offset)

Structured / ANOVA

- Warp Tension (WT) – ETD
- Fill Tension (FT) – RTD, ETD
- Fill Compression (FC) – ETD
- In-Plane Shear (45T) – RTD, ETD
- In-Plane Shear (VNS) – RTD (B-est. = 0)
- Interlaminar Shear (DNS) – RTD, ETD
- Interlaminar Tension (ILT) – RTD (B-est. = 0.09)
- Unnotched Tension 1 (UNT1) – RTD, ETD
- Unnotched Compression 1 (UNC1) – RTD, ETD
- Open-Hole Tension 1 (OHT1) – RTD, ETD
- Open-Hole Compression 1 (OHC1) – RTD, ETD
- Flexure – RTD
- Double-Shear Bearing 1 (DSB1) – RTD, ETD (Ult.)

B-estimate is less than 50% of the mean

B-estimate is greater than 50% of the mean

*The CMH-17 Statistics Working Group is looking at Bayesian Methods for determining allowables – expected to be better approach when multiple sources of variation are present.

0X/0X QUALIFICATION – PATH FORWARD

- **Data generated to date has mostly come from four batches of material for each property and condition.**
- **For structured datasets, ANOVA is being used.**
  - Allowables are unreasonably low in many cases because of significant panel-to-panel variability and only four material batches in the dataset.
- **The CMH-17 Joint Statistics and CMC Data Review Working Groups have been briefed on the qualification program and the datasets. They gave the following key recommendations:**
  - Only publish allowables for properties with reasonable allowables and classify the others a screening data. Don't publish unreasonable allowables. Engines with CMCs have been certified without allowables for every property.
  - Historical data may be useful in determining typical process variability, which can be helpful in making engineering judgements for allowables.
- **For datasets requiring ANOVA, "screening" values will be published. A fifth batch of material will not be tested.**

OX/OX DATA REPORTS AND STATISTICAL ANALYSIS

NIAR
Wichita State University

Titles:

- Axiom AX-7800-DF11-5HS3000D Qualification Material Property Data Report
- Axiom AX-7800-DF11-5HS3000D Qualification Statistical Analysis Report

NCAMP
NATIONAL CENTER FOR ADVANCED MATERIALS PERFORMANCE

Objectives:

- Publish material property data and statistical analysis results for oxide/oxide CMC qualification framework material

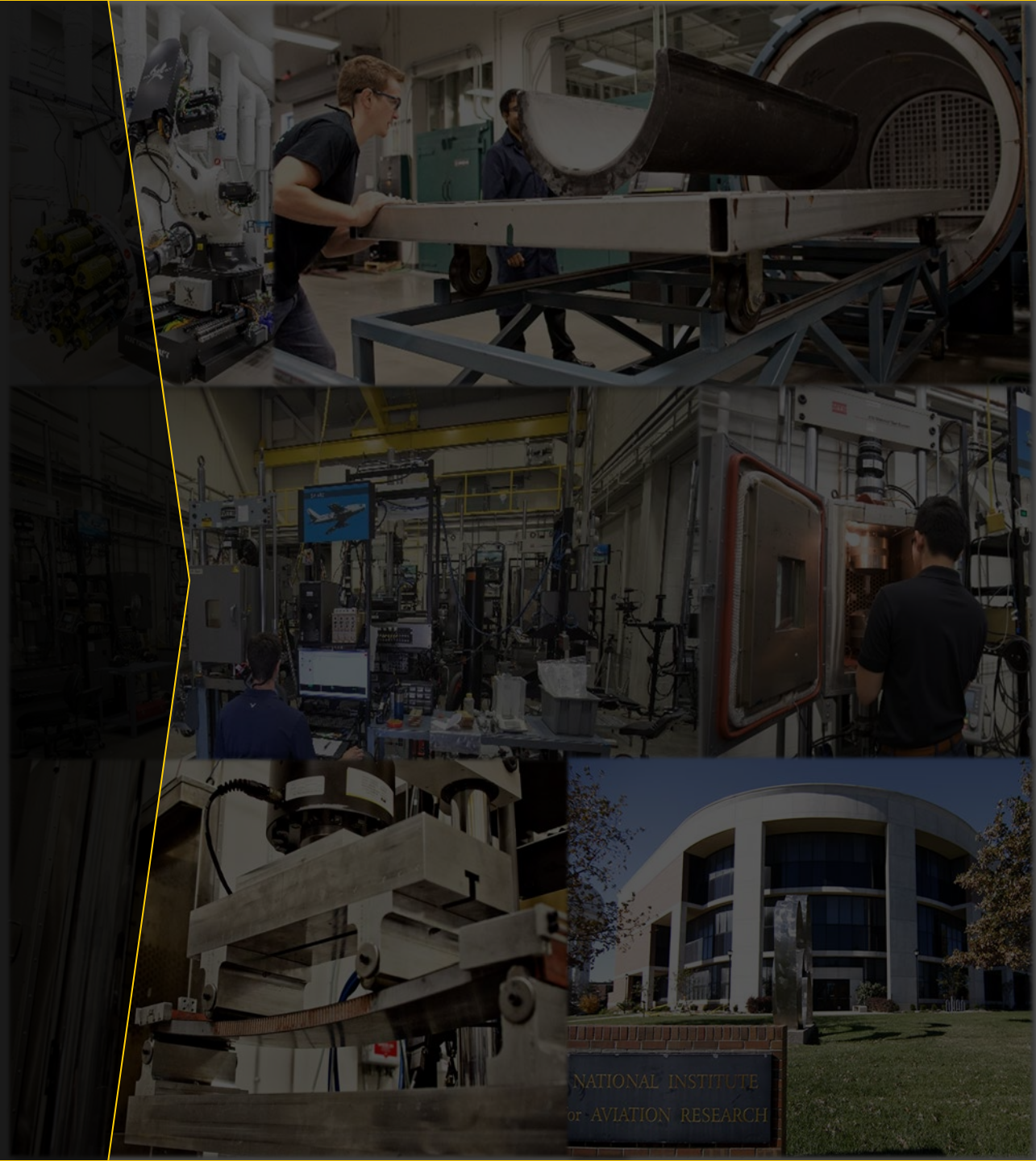
Status:

- Reports to be compiled at the conclusion of qualification testing and data analysis

Data generated as part of this qualification program is currently being balloted for inclusion into CMH-17 Volume 5 Rev. B

Key:
In-work
Planned

Ox/Ox Equivalency



OX/OX EQUIVALENCY

Fiber Source: 3M

Weaver: Textile Products Inc (TPI)

Prepreg Supplier: Axiom Materials

Panel Fabricator: NIAR

Nextel 610 Fibers
Alumina Fiber, 3K Denier, 5-Harness Satin Weave

AX-7800 Aluminum Silicate Slurry (Water Based)

Autoclave Cure and Sintering

1 Batch

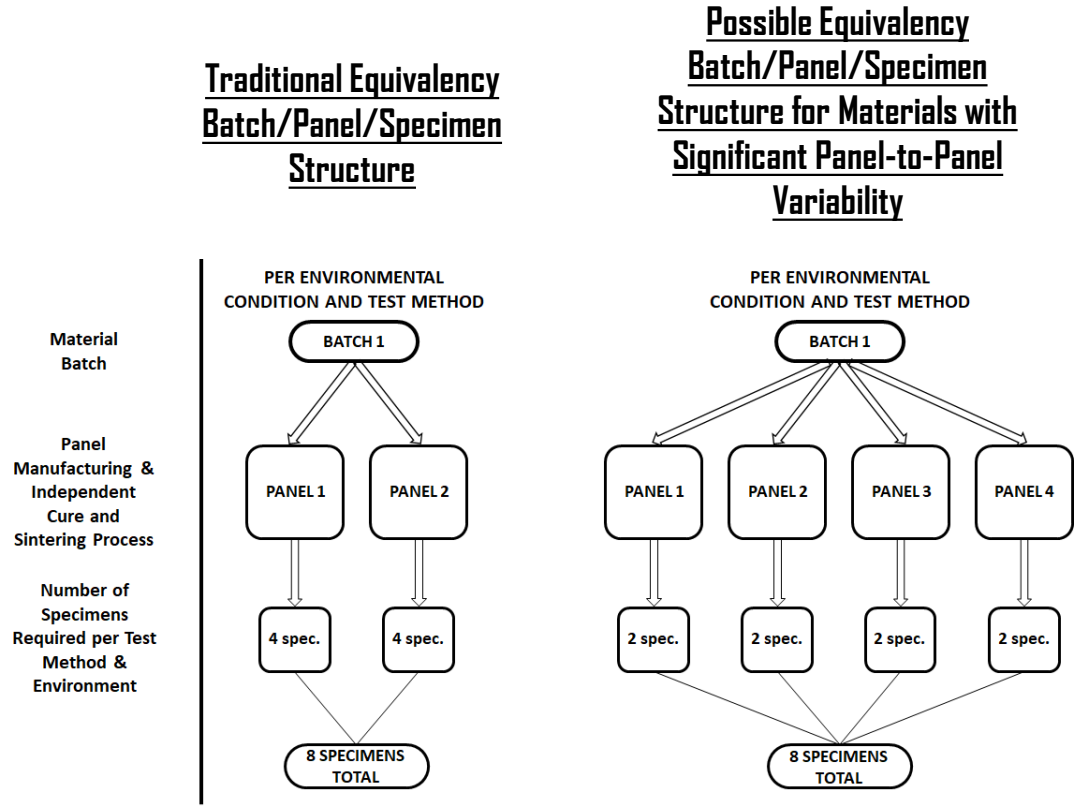
- Documents Generated for Equivalency Program:
  - Test Plan – including test matrix with physical, thermal, and mechanical test requirements
- Other Documents for Equivalency Program:
  - Material Property Data Report
  - Equivalency Statistical Analysis Report

Test Matrix: Complete → **Test Plan:** Complete → **Manufacture of Prepreg:** Complete → **Panel Fabrication:** Summer 2025 → **Testing:** Fall 2025

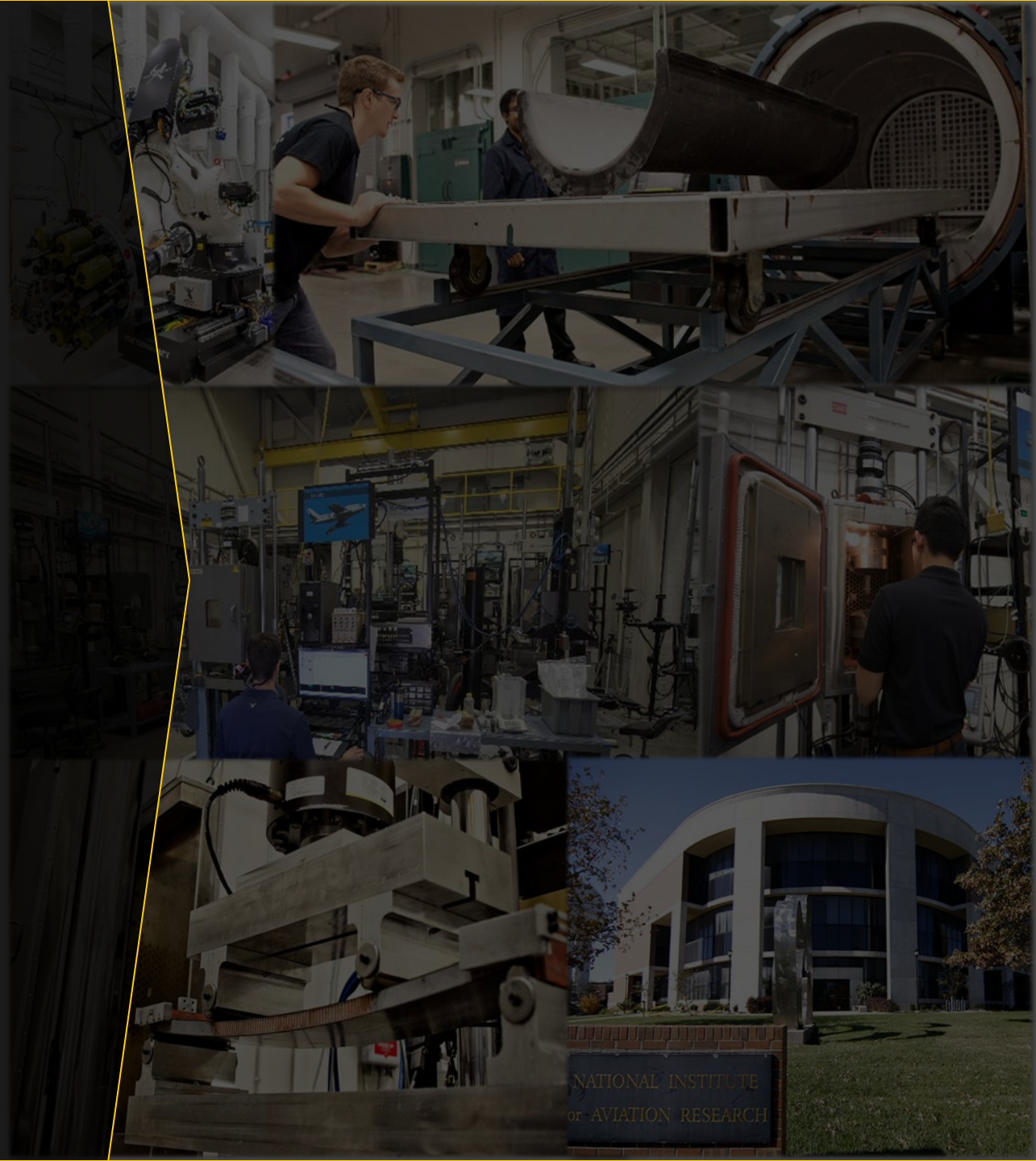
OX/OX EQUIVALENCY

- Equivalency panel fabrication work details have been written and will be update after the process specification is revised.
- Equivalency test matrices include physical, thermophysical, and mechanical tests.
  - Physical: NDE, Per Ply Thickness, Fiber and Matrix Volume, Bulk Density, and Open Porosity
  - Thermophysical: Specific Heat and Thermal Diffusivity, Conductivity, and Expansion in X, Y, an Z Directions
  - Mechanical:
    - Tension: In-Plane (RTD and ETD), Interlaminar, and Open-Hole (RTD and ETD)
    - Compression: In-Plane (RTD and ETD) and Open-Hole
    - Shear: In-Plane and Interlaminar (RTD and ETD)

More panels may be needed for equivalency if process variability is the key issue. Plans have been made to allow for specimens to be extracted from more than two panels for some properties where significant panel-to-panel variation has been observed.



Durability and Long-Term Safety



DURABILITY AND LONG-TERM SAFETY

Fiber Source: 3M

Weaver: Textile Products Inc (TPI)

Prepreg Supplier: Axiom Materials

Panel Fabricator: NIAR

Nextel 610 Fibers
Alumina Fiber, 3K Denier, 5-Harness Satin Weave

AX-7800 Aluminum Silicate Slurry (Water Based)

3 Batches

Autoclave Cure and Sintering

- Documents Generated for Durability and Long-Term Safety Program:
  - Test Plan – including test matrix with mechanical fatigue, long term thermal exposure, and high temperature creep test requirements
- Other Documents for Durability and Long-Term Safety Program:
  - Test Report

Test Matrix: Complete → **Test Plan:** Complete → **Manufacture of Prepreg:** Complete → **Panel Fabrication:** Winter 2025 → **Testing:** Spring – Fall 2026

Panel fabrication is pending outcome of the equivalency

DURABILITY AND LONG-TERM SAFETY: TEST PROGRAM AND REPORT

Title: Ceramic Matrix Composite (CMC) Materials Guidelines for Aircraft Design and Certification: Durability and Long-Term Safety of CMCs

Objectives:

- Perform testing to characterize durability and long-term safety of an oxide/oxide CMC
  - Room temperature fatigue
  - Thermal exposure
  - High temperature creep
- Report material properties and provide guidelines for future durability and long-term safety testing

Status: Test plan drafted, test program awaiting completion of base qualification framework activity

Fatigue

Layup (see Note 1)	Test Type (Test Environment)	Test Methods (see Note 2)	Number of Batches x No of Panels x No of Specimens Exposure Temperature and Duration (see Notes 2, 3)								
			1650F 500h	1800F 500h	1400F 1000h	1650F 1000h	1800F 1000h	1400F 5000h	1650F 5000h	1800F 5000h	1650F TBD
$[0]_{5S}$	Warp Tension (RTA)	ASTM C1275	1x2x3	1x2x3	1x2x3	1x2x3	1x2x3	1x2x3	1x2x3	1x2x3	1x2x3

Thermal Exposure

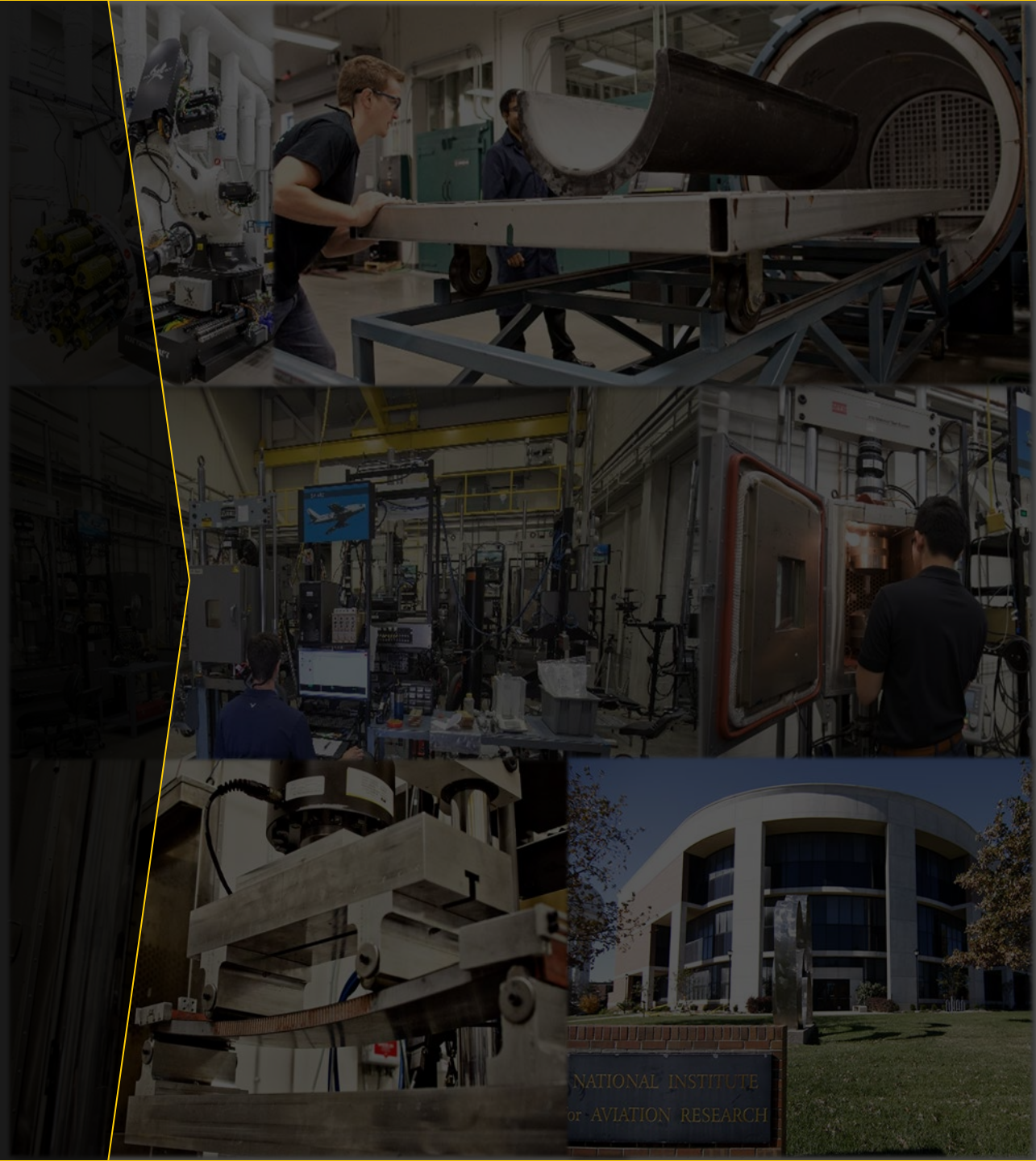
Layup (see Note 1)	Test Type	R-Value	Number of Batches x No of Panels x No of Specimens Targeted Cycle Count (see Note 2)			Relevant Test Methods (see Notes 3, 4)
			"Low"	"Mid"	"High"	
$[45/0/-45/90/-45/90]_S$	Unnotched Tension-Tension	0.1	1x3x3	1x3x3	1x3x3	ASTM C1360
$[45/0/-45/90/-45/90]_S$	Notched Tension-Tension	0.1	1x3x3	1x3x3	1x3x3	ASTM C1360 ASTM C1869
$[45/0/-45/90/-45/90]_S$	Notched Tension-Compression	-1	2x3x3	2x3x3	2x3x3	ASTM C1360 ASTM D6484
TBD (See Note 6)	Interlaminar Shear	TBD (See Note 6)	2x3x3	2x3x3	2x3x3	ASTM C1360 ASTM C1292
$[0]_{10}$	Interlaminar Tension (see Note 7)	0.1	2x3x3	2x3x3	2x3x3	ASTM C1360 ASTM D7291
$[45/0/-45/90/-45/90]_S$	Fatigue After Impact Tension-Tension (see	0.1	1x3x3	1x3x3	1x3x3	ASTM C1360 ASTM C1468

Creep

Layup (see Note 1)	Test Type (Test Environment)	Test Method (see Note 2)	Number of Batches x No of Panels x No of Specimens Relative Stress (see Notes 3, 4)					
			40%	50%	60%	70%	80%	TBD
$[0]_{5S}$	Warp Tension (ETA - 1650F)	ASTM C1359 ASTM C1337		1x2x3	1x2x3	1x2x3	1x2x3	1x2x3
$[45/-45]_{2S}$	In Plane Shear (ETA - 1650F)	ASTM D3518 ASTM C1337	1x2x3	1x2x3	1x2x3			1x2x3

Key:
In-work
Planned

SiC/SiC Qualification



SIC/SIC QUALIFICATION

Fiber Source: Ube Industries Ltd.

Tyranno ZMI SiC Fiber

Fiber Coating Source: IHI Corporation

Boron Nitride Coating

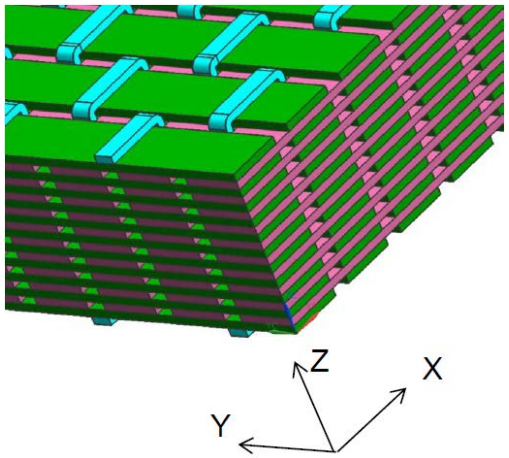
Weaver: Shikibo Ltd.

3D Orthogonal Woven Preform

Panel Fabricator: IHI Corporation

Chemical Vapor Infiltration (CVI) and Polymer Infiltration and Pyrolysis (PIP) Hybrid Process

2 Batches



SiC Fibers → BN Coating → 3D Woven → Trimming → Preforming → SiC Matrix Infiltration → Machining

Fabrication and machining performed by IHI

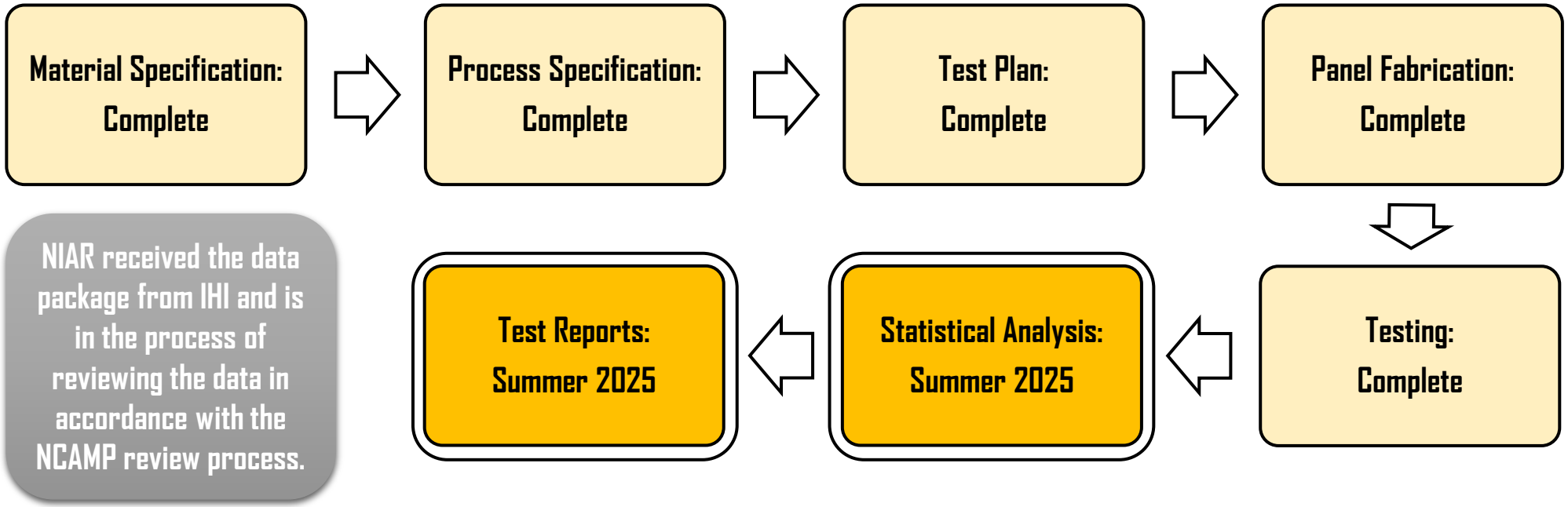
Thermophysical testing performed by JUTEM and mechanical testing performed by Kiguchi Technics in Japan

Vane – Possible Application

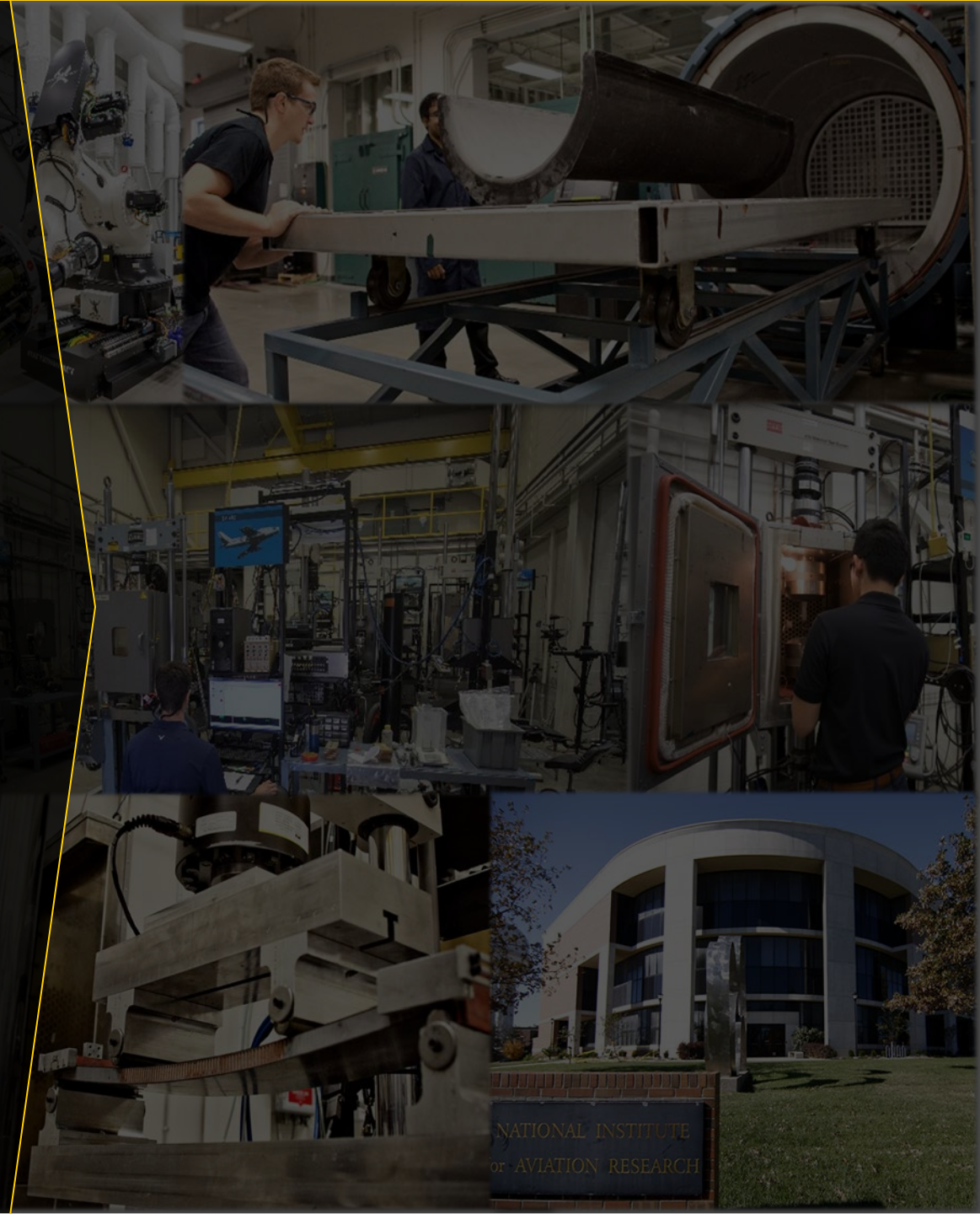
Watanabe, F., Manabe, T., "Engine Testing for the Demonstration of a 3D-Woven Based Ceramic Matrix Composite Turbine Vane Design Concept," ASME Turbo Expo 2018: Turbomachinery Technical Conference and Exposition, Oslo, Norway, June 11-15, 2018

SIC/SIC QUALIFICATION

- Documents Generated for Qualification Program:
  - Material Specification (Restricted Distribution)
  - Process Specification (Restricted Distribution)
  - Test plan – including test matrix with physical, thermal, and mechanical test requirements (Restricted Distribution)
- Other Documents for Qualification Program:
  - Material Property Data Report (Restricted Distribution)
  - Statistical Analysis Report with Material Allowables (Restricted Distribution)

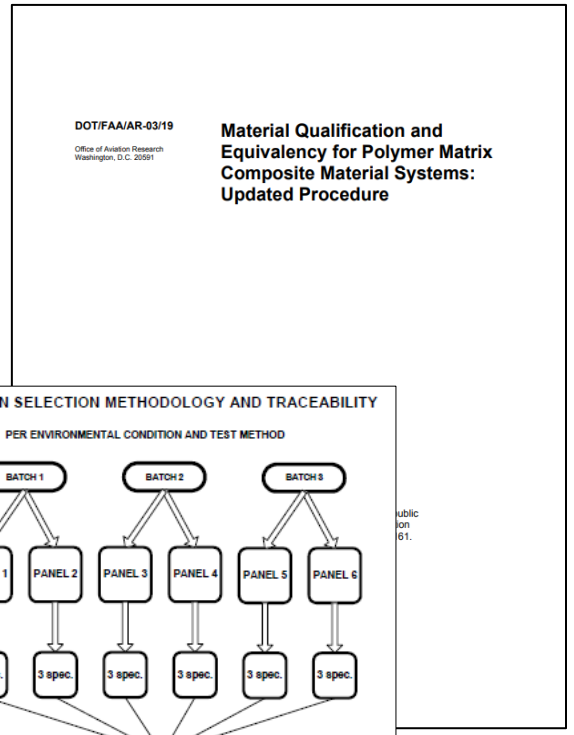


Guidance Documents



GUIDANCE ON QUALIFICATION PROCEDURE

Title: Material Qualification and Equivalency for Oxide/Oxide Ceramic Matrix Composite Material Systems


DOT/FAA/AR-03/19

Office of Aviation Research
Washington, D.C. 20591

Material Qualification and Equivalency for Polymer Matrix Composite Material Systems: Updated Procedure

Objectives:

- Provide guidance for performing oxide/oxide CMC material qualification and equivalency similar to DOT/FAA/AR-03/19
  - Applicable material forms and batch requirements
  - CMC-appropriate physical and mechanical test methods and environments
  - CMC laminate and specimen manufacturing, machining, inspection
  - Statistical analysis relevant for types of variability common in oxide/oxide CMCs

Example specimen selection methodology

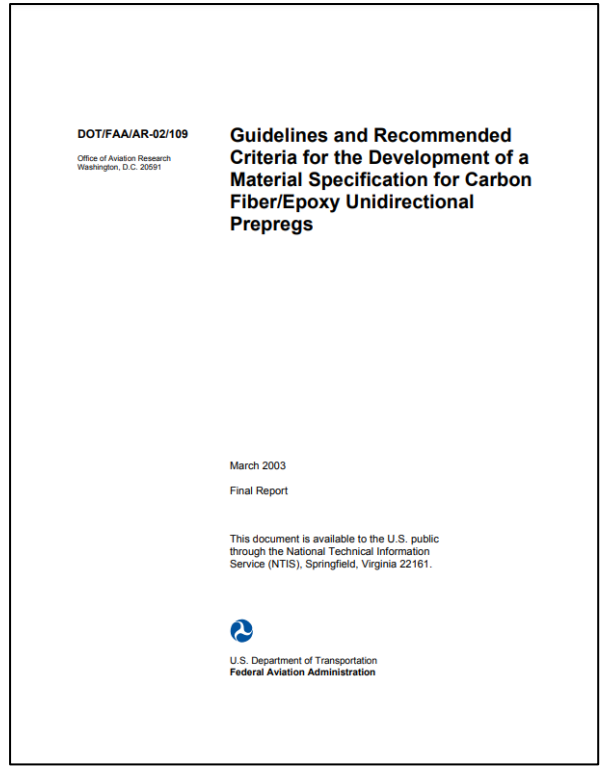
Status:

- Report has been revised to provide recommendations for qualification and equivalency with added content discussing topics for which the approach has not yet been validated in CMCs (e.g., equivalency and acceptance testing)
- Revised document with FAA for review

Key:
In-work
Planned

GUIDANCE ON WRITING MATERIAL SPECIFICATIONS

Title: Guidelines and Recommended Criteria for the Development of a Material Specification for Oxide/Oxide Ceramic Matrix Composite Prepregs


DOT/FAA/AR-02/109

Office of Aviation Research
Washington, D.C. 20591

Guidelines and Recommended Criteria for the Development of a Material Specification for Carbon Fiber/Epoxy Unidirectional Prepregs

March 2003

Final Report

This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161.

U.S. Department of Transportation
Federal Aviation Administration

Objectives:

- Provide guidance for writing specifications to control the procurement of oxide/oxide CMC pre-impregnated material similar to DOT/FAA/AR-02/109
  - Visual, physical, chemical, and mechanical property requirements
  - Storage and handling requirements, defect limit definition
  - Quality assurance and receiving inspection

Status:

- Initial draft completed and shared with the FAA. Report is now being revised based on discussions from Feb. 2025 meeting.
- Comments are welcome on either the initial draft or the revision, once completed.

Key:
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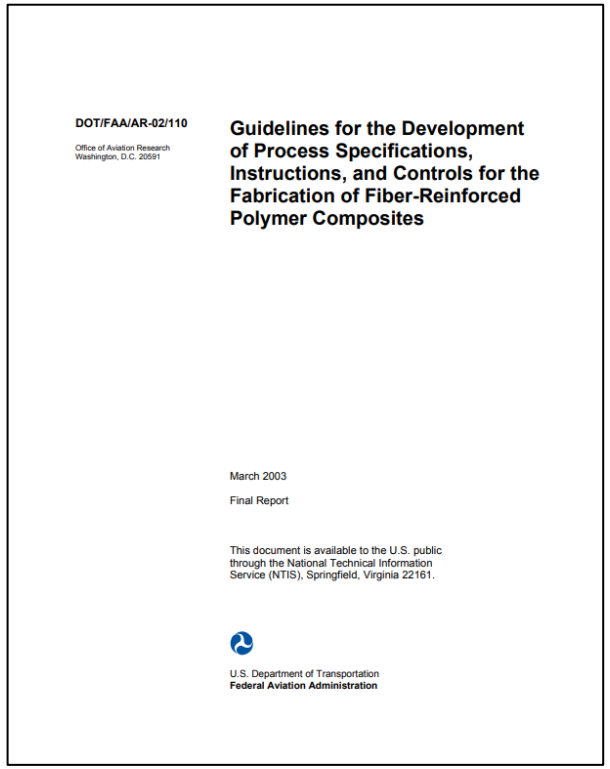
GUIDANCE ON WRITING PROCESS SPECIFICATIONS

Title: Guidelines for the Development of Process Specifications, Instructions, and Controls for the Fabrication of Oxide/Oxide Ceramic Matrix Composites


DOT/FAA/AR-02/110

Office of Aviation Research
Washington, D.C. 20591

Guidelines for the Development of Process Specifications, Instructions, and Controls for the Fabrication of Fiber-Reinforced Polymer Composites

March 2003

Final Report

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U.S. Department of Transportation
Federal Aviation Administration

Objectives:

- Provide guidance for writing specifications to control the processing of oxide/oxide CMCs similar to DOT/FAA/AR-02/110
  - Characterization and control of oxide/oxide CMC key material attributes
  - Oxide/oxide CMC material storage and handling
  - Defining procedures for control of tooling, equipment, layup, consolidation, sinter, machining, and heat cleaning
  - Process monitoring and inspection

Status:

- Initial draft completed and shared with the FAA. Report is now being revised based on discussions from Feb. 2025 meeting.
- Comments are welcome on either the initial draft or the revision, once completed.

Key:
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GUIDE FOR COUPON HEATING, GRIPPING, INSTRUMENTATION, AND TESTING

NIAR Wichita State University

Title: Standard Guide for Heating, Gripping, and Instrumentation of Oxide/Oxide Continuous Fiber Advanced Ceramics

Objectives:

- Provide guidance in the form of an industry-standard guide for heating, gripping, and instrumentation of oxide/oxide CMCs relevant to a range of test methods
  - Temperature methods, control, uniformity, and thermal surveys
  - Specimen gripping pressure, use of tabs, alignment tools
  - Temperature instrumentation: contact and non-contact methods
  - Strain instrumentation: appropriate use of extensometers, strain gages, visual techniques

Status: Many processes developed during material qualification framework activity. Additional testing and documentation needs to be identified after finalization of current guidance.

High temperature tension test with strain and temperature instrumentation

Key:
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Planned

NEW AND REVISED CMC-SPECIFIC TEST METHODS

NIAR
Wichita State University

Objectives:

- Leverage lessons learned from CMC qualification framework expansion activities to improve or author new CMC-specific test methods
- Revise current standardized test methods (tension, compression, fracture toughness) to:
  - Improve usability
  - Provide more specific configuration selection guidance
  - Reduce the frequency of unnecessary dispositioning
- Author new, CMC-specific standardized test methods for properties essential to CMC design
  - Interlaminar shear, interlaminar tension, open-hole compression, compression creep, flexure creep, bearing

Status:

- Initial effort focusing on one revision and one new standard
- Revision of the room temperature tension standard
- New standard for interlaminar tension
  - Using GE Aerospace standardized method as a foundation

Test Method	Type	Description of Effort
Tension (RT and ET are separate standards)	Revision	Separate different test options (round bar in a yoke, rectangular bar in grips, etc) into reportable Types Require reporting of test type Add US dimension and unit options throughout Revise specimen drawings to contain achievable tolerances, update drawing GD&T to state of the art Recommend strain ranges for modulus and require reporting of range, include guidance on using strain gages
Compression	Revision	Separate different test options (edge loaded vs face loaded) into reportable Types Require reporting of test type Add US dimensions and unit options throughout Revise specimen drawings to achievable tolerances, update drawing GD&T to state of the art Recommend strain ranges for modulus and require reporting of range, include guidance on using strain gages
Interlaminar Shear	New	Standardize an asymmetric four-point bend (4APB) ILS test method Currently standardized PMC test methods do not work well for CMCs or at elevated temperatures New standard to be applicable at RT and elevated temperature NASA LaRC and GE have internal test methods that can be used as a baseline
Interlaminar Tension	New	Standardize a thick-plate, 3-pt bend ILT test method Current PMC test method (flatwise tension) does not work at elevated temperature New standard to be applicable at RT and elevated temperature GE has an internal test method that can be used as a baseline
Open-Hole Compression	New	New standard that is an adaptation of a current PMC standard Specimen geometries will be obtainable for CMCs Will include guidance on gripping testing low strain to failure materials Will include guidance on elevated temperature testing
Compression Creep	New	New standard based on a framework of the tension creep standards (PMC and CMC) Defined specimen geometries based on load configuration (R-value) and meetable tolerances Guidance on fixturing and instrumenting Applicable to RT and elevated temperature
Flexure Creep	New	New standard based on a framework of the tension creep standards (PMC and CMC) Defined specimen geometries based on load configuration (R-value) and meetable tolerances Guidance on fixturing and instrumenting Applicable to RT and elevated temperature
Bearing	New	New standard that is an adaptation of a current PMC standard Specimen tolerances will be obtainable for CMCs Will include guidance on testing low strain to failure materials Will include guidance on elevated temperature testing
Fracture Toughness	Revision	Rewrite compliance equation used in data reduction to be accurate for thick mach Add load introduction method using a harness and through-width machined holes

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IMME
INDUSTRIAL MODERNIZATION OF MATERIALS & MANUFACTURING

QUESTIONS?

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