- Goals & Objectives
- Methods and Approaches to Material Quals and Production Control

John Tomblin, Director

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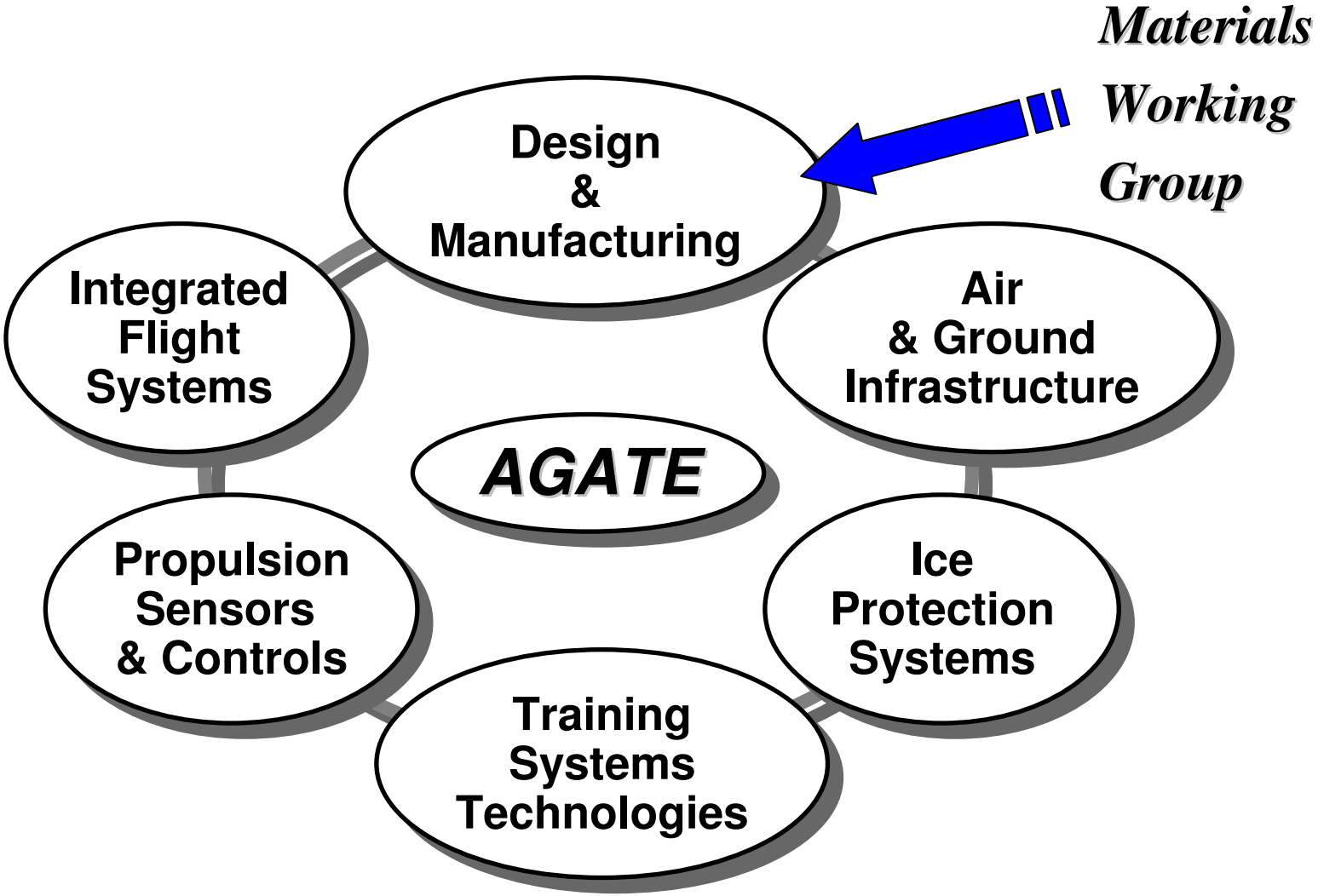
Kristin Marlett, Coordinator

Michelle Man, Research Associate

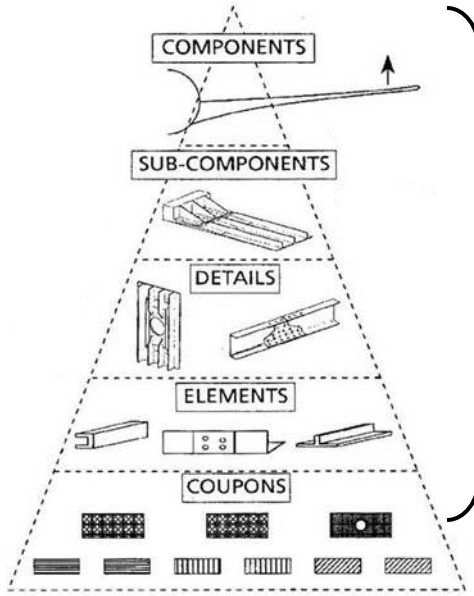
HISTORY: Advanced General Aviation Transport Experiments (AGATE)

- **GOAL: To revitalize U.S. general aviation through development and deployment of advanced technologies in support of retrofit markets and a general aviation transportation system**
- **1995-2002**

WHAT WAS AGATE ?



- **AGATE Materials Working Group was tasked to make composite material property data "shareable"**
  - **like aluminum through MIL-HDBK-5**
  - **to reduce time and cost**
  - **to standardize material property data acquisition**
  - **MIL-HDBK-17 data does not have the necessary pedigree (no M&P specs)**



"Proprietary" at these levels

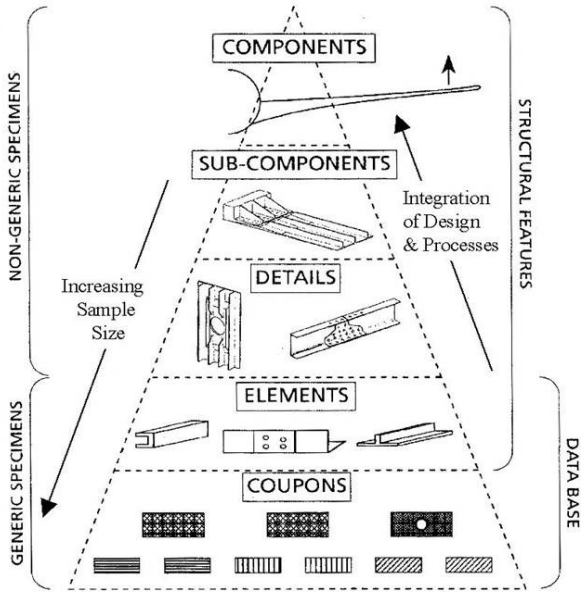
"Shared" at this level

AGATE
NASA — INDUSTRY — FAA

Timeline of Activity

- **1995** — **AGATE started with GA industry's desire to share databases and standardize procedures used in material characterization**
- **1998** — **First AGATE document release – MIL-17 presentation**
- **1998 - 2002** — **AGATE databases produced**
- **1998 - 2002** — **MIL-17 engagement and revision of qualification and equivalency guidelines (3 revisions) – statistical procedures**
- **2000** — **FAA Small Airplane Directorate policy memorandum (Policy Statement Number ACE-00-23.613-01; Volume 65, Number 114)**
- **2002** — **FAA Material & Process Specification Guidelines (unidirectional prepreg) – DOT/FAA/AR-02/109 & 110**
- **2003** — **FAA updated release of qualification and equivalency guidelines DOT/FAA/AR-03/19 (5th revision)**
- **2003** — **FAA issued AC 23-20 Material Acceptance Guidance**
- **2005** — **NCAMP Initiative Announced by NASA**
- **2006 - 2008** — **AFRL and Industry Funded Qualification Programs Began**
- **2009** — **NCAMP Standard Operating Procedures (modeled after FAA process)**

The NCAMP Logo

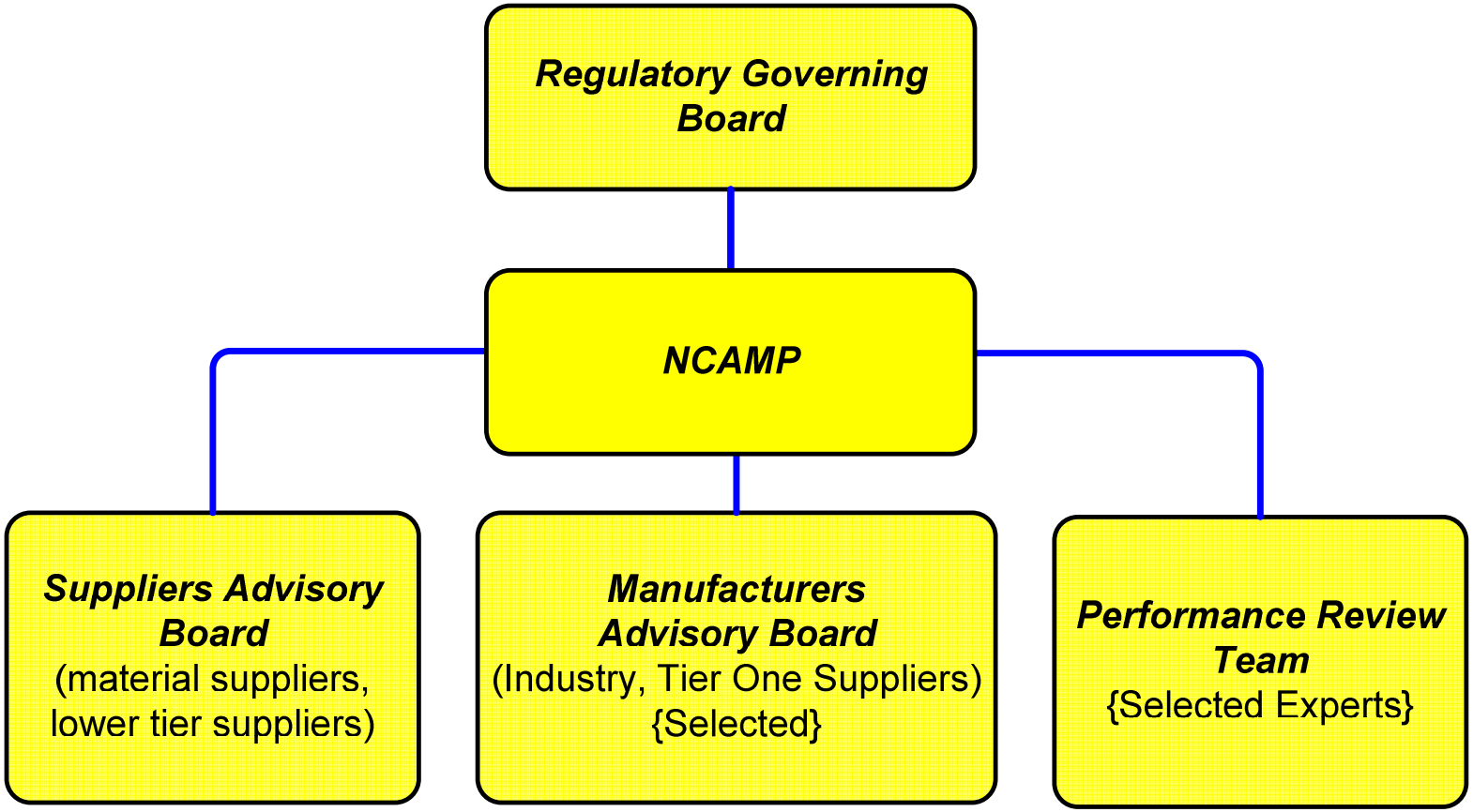


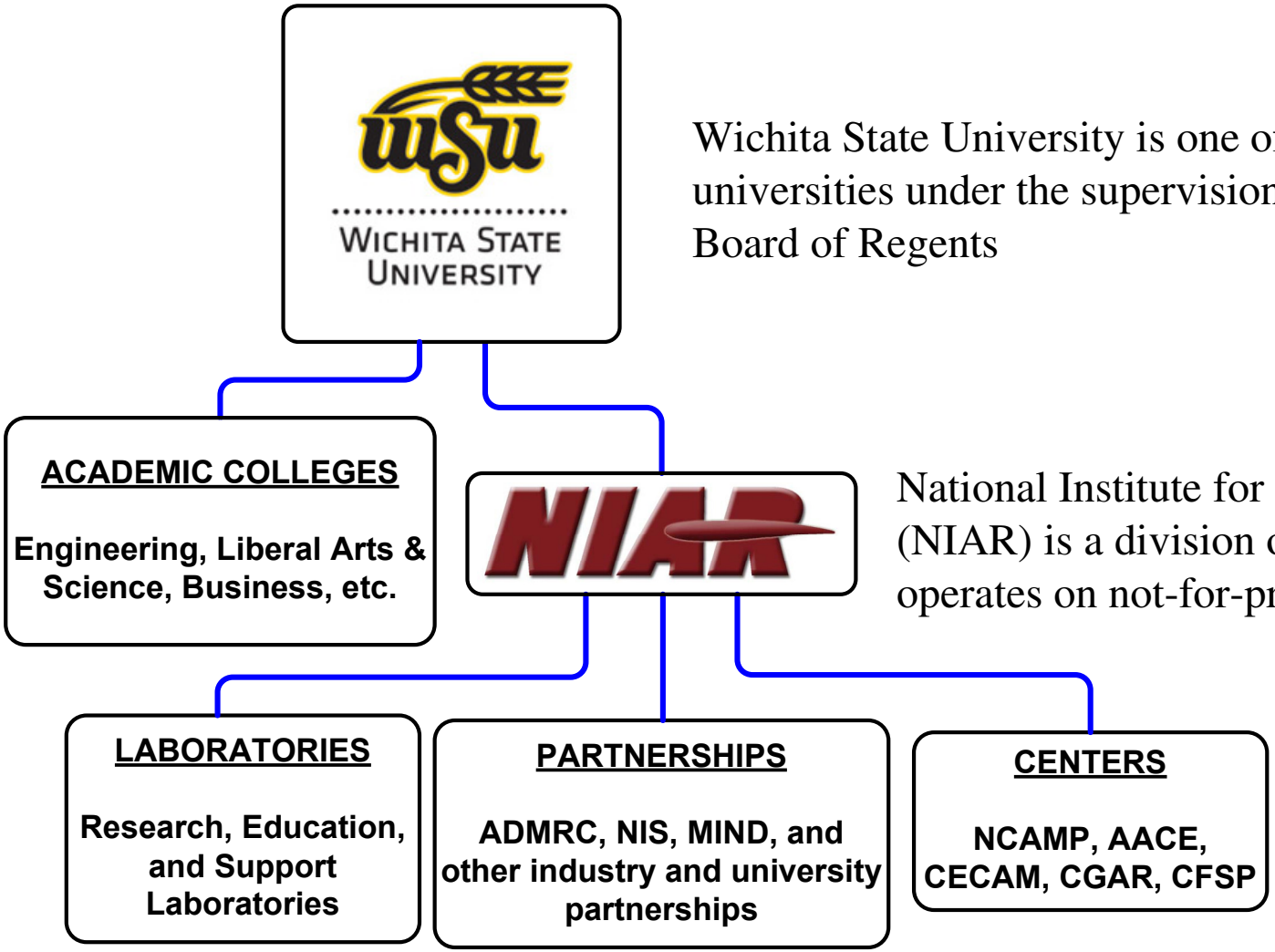
- The goal of NCAMP is to continue the work started with AGATE and expand its application to a broader range of products.

→ NCAMP
NATIONAL CENTER for ADVANCED MATERIALS PERFORMANCE

Focuses on lamina & laminate properties in support on higher level building blocks

NCAMP Organizational Structure





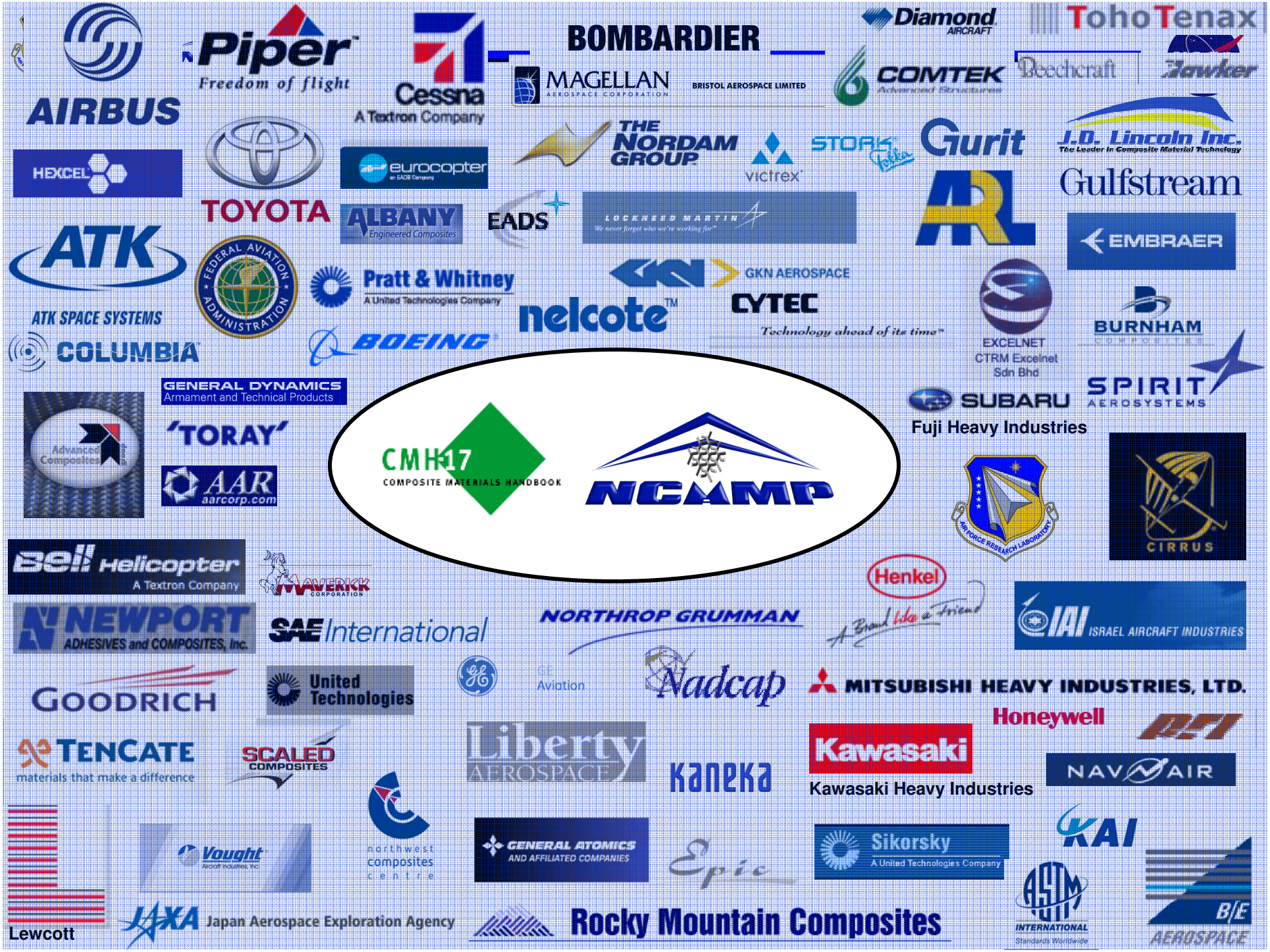
Wichita State University is one of several universities under the supervision of Kansas Board of Regents

National Institute for Aviation Research (NIAR) is a division of WSU which operates on not-for-profit basis

NCAMP is a center within NIAR which operates independently of other centers, partnerships, and laboratories.

Not-For-Profit Business Model

- Utilizing federal and commercial funding to build procedures to generate industry-shared composite material property databases and specifications
- Self-sufficiency
  - 15 year history of generating and maintaining industry-shared composite material property databases
  - Continual transition from federally-funded to industry-funded
- Sources of Revenue
  - Primarily from services rendered
  - No annual membership fee
  - No fee to access data or specifications
- NCAMP staff are not limited to industry-shared material property database and specification work; may perform proprietary work for industry and research projects for government

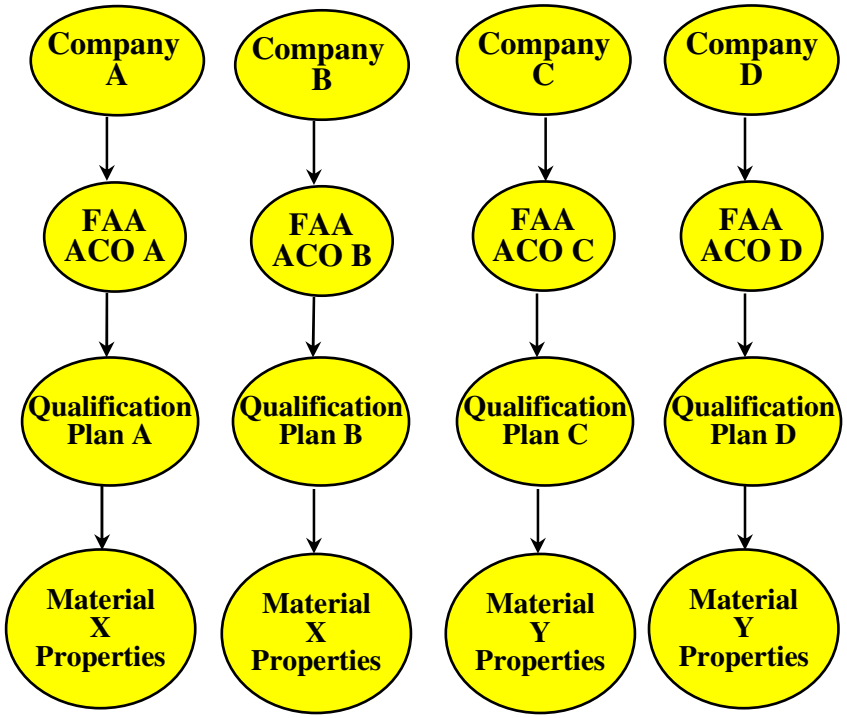

Piper
Freedom of flight
Cessna
A Textron Company
BOMBARDIER
Diamond AIRCRAFT
TohoTenax
AIRBUS
MAGELLAN
AEROSPACE CORPORATION
BRISTOL AEROSPACE LIMITED
COMTEK
Advanced Structures
Beechcraft
Jawker
HEXCEL
THE NORDAM GROUP
victrex
STORK
Gurit
J.D. Lincoln Inc.
The Leader In Composite Material Technology
eurocopter
an EADS Company
TOYOTA
ALBANY
Engineered Composites
EADS
LOCKHEED MARTIN
We never forget who we're working for™
Gulfstream
ATK
FEDERAL AVIATION ADMINISTRATION
Pratt & Whitney
A United Technologies Company
EMBRAER
GKN AEROSPACE
ATK SPACE SYSTEMS
COLUMBIA
nelcote™
CYTEC
Technology ahead of its time™
EXCELNET
CTRM Excelnet Sdn Bhd
BURNHAM
BOEING
GENERAL DYNAMICS
Armament and Technical Products
SUBARU
SPIRIT AEROSYSTEMS
Fuji Heavy Industries
'TORAY'
CMH-17
COMPOSITE MATERIALS HANDBOOK
NCAMP
AAR
aarcorp.com
AIR FORCE RESEARCH LABORATORY
CIRRUS
Bell Helicopter
A Textron Company
MAVERICK CORPORATION
Henkel
A Brand like a Friend
NEWPORT
ADHESIVES and COMPOSITES, Inc.
SAE International
NORTHROP GRUMMAN
IAI
ISRAEL AIRCRAFT INDUSTRIES
GE
Aviation
Nadcap
GOODRICH
United Technologies
MITSUBISHI HEAVY INDUSTRIES, LTD.
Honeywell
TENCATE
materials that make a difference
SCALED COMPOSITES
Liberty AEROSPACE
kaneka
Kawasaki
Kawasaki Heavy Industries
NAVAIR
Vought
Aircraft Industries, Inc.
northwest composites centre
GENERAL ATOMICS
AND AFFILIATED COMPANIES
Epic
Sikorsky
A United Technologies Company
KAI
ASTM
INTERNATIONAL
Standards Worldwide
B/E
AEROSPACE
Lewcott
JAXA
Japan Aerospace Exploration Agency
Rocky Mountain Composites

Collaborating Partners

- CMH-17: Technical resource & data depository
- SAE: Converts NMS to AMS
- PRI, Nadcap & QPL
- ASTM D30: Develop/Revise Test Method Standards

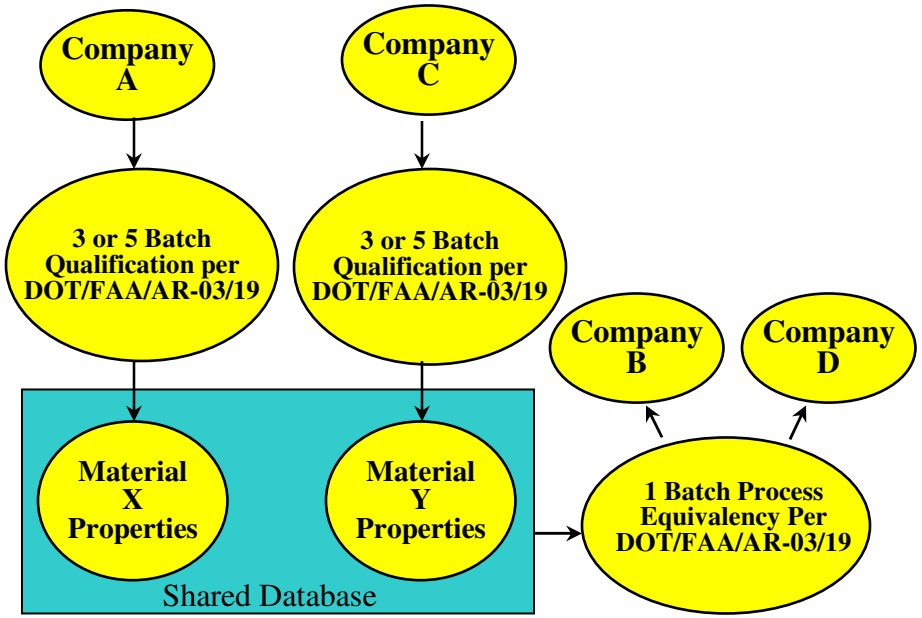
Material Qualification Processes

Traditional Process



MATERIAL PROPERTIES DO NOT IMPROVE THROUGH MULTIPLE QUALS !

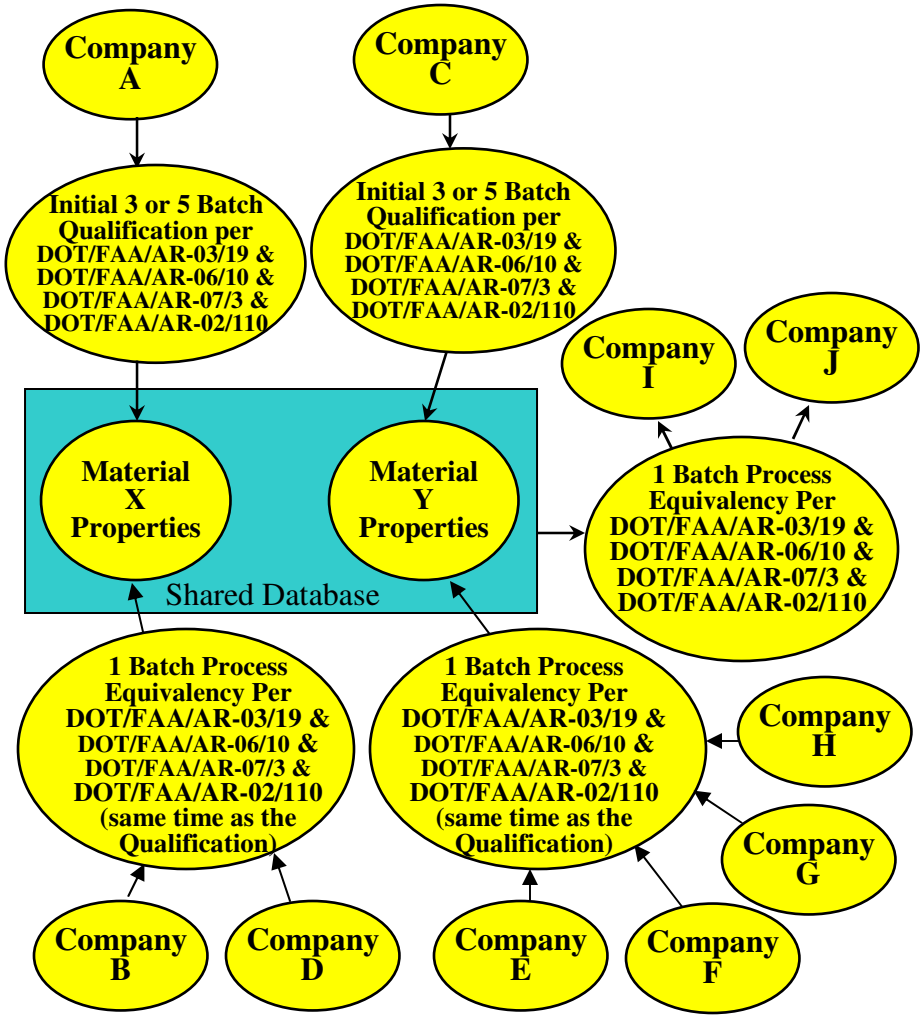
AGATE Shared Database Process



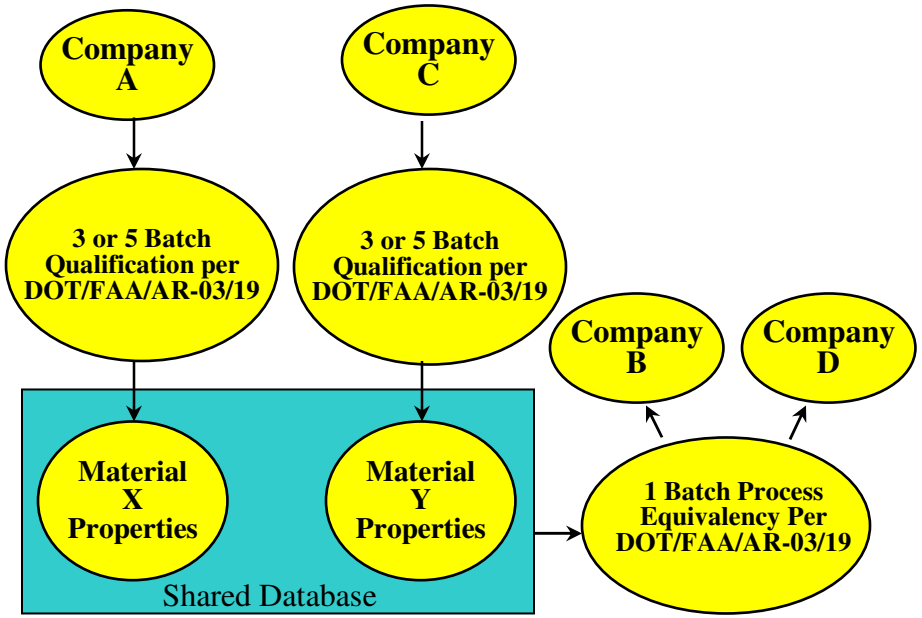
Note: Specification limits and allowables are derived from the same data

Material Qualification Processes

NCAMP Shared Database Process



AGATE Shared Database Process



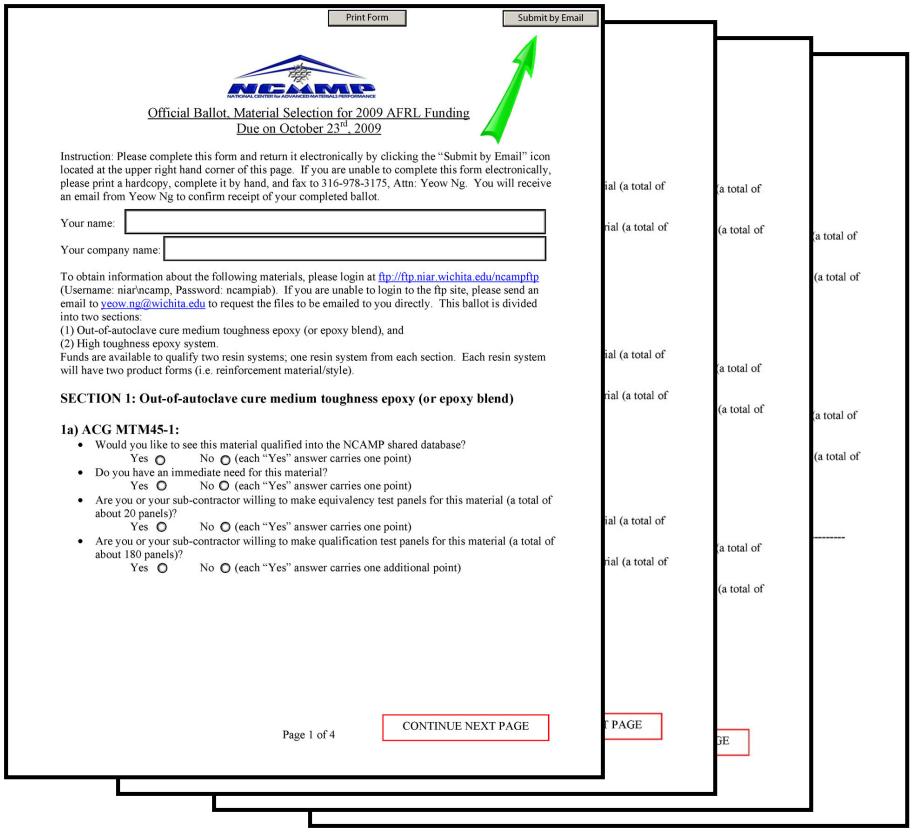
Who Contributes What?
(in government-funded programs)

- Material suppliers provide materials
- Aircraft companies generally provide labor to fabricate and inspect panels
  - May fulfill *coupon* level building block requirement
- FAA/NCAMP provides oversight and creates pedigree through inspection verification and test witnessing
  - No guarantee on any program application; subject to approval by certification agency on case-by-case basis
- NASA/DoD provide funding for coordination and material testing (limited time only)

Material Selection Process for Government-funded Programs

(when the government agencies do not specify the material)

1. Government/NCAMP may define categories of materials or processes
2. Material suppliers propose materials for inclusion in ballot
3. NCAMP creates the official ballot; government approval of the ballot is required
4. Material users (OEM/Tier-1) vote for the most desirable material
5. NCAMP counts the votes; government approval of the result is required



Material Quals w/ Govt Matching Funds

- NASA Funded Cytec Cycom 5215
  - T40-800 12K Unitape Gr 145 RC 33%
  - 6K 5HS fabric with T650-36% RC, CPT approx. 14.9 mils
  - 3K70PW fabric with T650-38% RC, CPT approx. 8.0 mils
- NASA Funded Cytec Cycom 5250-5
  - T650 6K Unitape Gr 145 RC 32%
  - 6K 5HS fabric with T650-35% RC, CPT approx. 14.6 mils
  - 3K70PW fabric with T650-36% RC, CPT approx. 7.8 mils
- NASA Funded Hexcel 8552
  - AS4 12K tape at 190 gsm 35% RC, CPT approx. 7.4 mils
  - IM7 12K tape at 190 gsm 35% RC, CPT approx. 7.3 mils
  - AS4 plain weave fabric at 193 gsm 38% RC, CPT approx. 7.95 mils
- NASA Funded ACG MTM 45-1
  - G30-500 193 gsm 3K plain weave fabric 36% RC
  - HTS 5631 12K 145 gsm uni 32% RC
  - 6781 S-2 glass 35% RC
- AFRL Funded Renegade MVK-14 FreeForm Polyimide Qualification
  - T650 3K 8HS 370 gsm Fabric 36% Resin Content
- AFRL Funded Cytec 5320 (2 product forms)
- AFRL Funded Cytec 5276-1 (2 product forms)

Benefits of NCAMP

- To Material Suppliers
  - Publication of key material properties
  - Non-proprietary industry material and process specifications
- To Material Users
  - Availability of published material properties suitable for:
    - Material selection
    - Initial sizing of structure
    - With minimal internal testing may be used as part of product certification
  - To get access to draft reports/specifications, contact kmarlett@niar.wichita.edu
- To Government
  - Reduced workload by leveraging industry experts
  - Reduced cost by eliminating multiple/redundant programs

Benefits of Fabricating the Test Panels

- If fabricating 3-batch qualification panels,
  - the data, basis values, and allowables may be used in certified aircrafts(1)
- If fabricating 1-batch equivalency panels,
  - the data, basis values, and allowables may be used in certified aircrafts if equivalency is demonstrated(1). Refer to MIL-HDBK-17 rev F section 8.4.1. or DOT/FAA/AR-03/19 section 6.0.
- **Testing costs fully funded by NASA/DoD, <u>for a limited time only (i.e. concurrent with initial qualification programs only)</u>**
- **Prepreg cost paid by the material suppliers, <u>for a limited time only (i.e. concurrent with initial qualification programs only)</u>**
- In 1-batch equivalency process, you will only need to fabricate about 18 panels per resin system per product form
  - Panel fabrication cost includes prepreg cutting and layup labor, some bagging materials, cure cycle, DAR conformity, and postage to send the cured panels to NCAMP only
- You have access to the data
- You will learn about composite material shared-database approach

(1) Subject to approval by certification agency

100% Industry Funded Programs

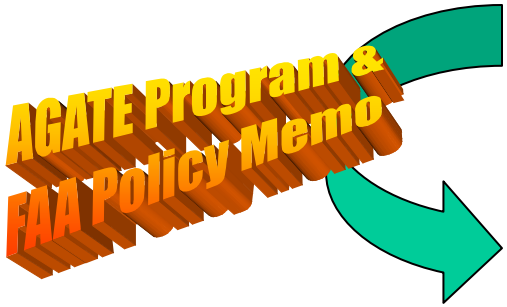
- Tencate TC250 (265ºF oven cure)
  - HTS40 F13 150gsm/TC250 uni-directional prepreg
  - 12 k HTS40 F13 SFP OSI (193 gsm)/TC250 prepreg
- Newport NCT4708 (265ºF oven cure)
  - NCT4708 MR60H 300gsm Tape
  - NCT4708 MR40 150gsm Tape
- Nelcote E-752 (350ºF oven cure)
  - 193 gsm 3k PW G30-500 E752 Fabric
  - 145 gsm AS7 E752 Unidirectional Tape

Companies that are fabricating test panels (participating in quals & process equivalency)

1. Gulfstream Aerospace
2. AdamWorks
3. Albany Engineered Composites
4. ATK Space Systems
5. Boeing Helicopters
6. Scaled Composites
7. Goodrich Aerostructures
8. Bombardier Aerospace
9. AAR Composites
10. Cirrus Design Corporation
11. Hawker Beechcraft
12. Spirit AeroSystems, Inc.
13. Cessna Aircraft Company
14. Canyon Composites, Inc.
15. Bell Helicopter Textron, Inc.
16. General Dynamics (GDATP)
17. Northrop Grumman Corporation
18. Israel Aircraft Industries, Ltd.
19. General Atomics Aeronautical Systems, Inc.
20. Lockheed Martin Aero
21. Comtek Advanced Structures
22. Burnham Composite Structures
23. Quickstep
24. Radius Engineering
25. Canyon Composites, Inc.
26. Advanced Composites Technologies
27. Composites Horizons Inc
28. BAE Systems Composite Structures Inc.
29. GE Aviation
30. Pratt & Whitney

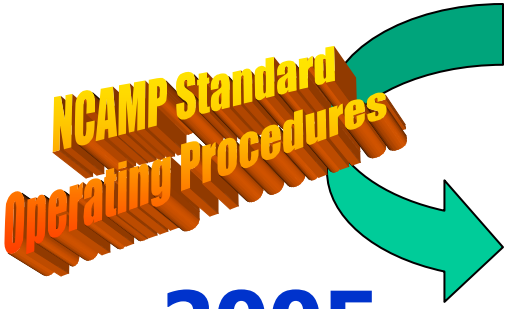
PAST
(Inefficient)

OEMs QUALIFY THEIR OWN MATERIALS
- same materials are qualified by different OEMs
- heavy workload on the FAA
- material properties not usable by others
- many years delay in data submission to CMH-17 (if ever) with no M&P spec



1996-2005

AGATE SHARED DATABASE APPROACH
- Primarily applied to General Aviation Products
- FAA accepting the role of CMH-17 and SAE
- each material is qualified one time only
- reduced workload on the FAA (but still higher than for metals)
- FAA-accepted shared material property databases



2005-FUTURE

In cooperation with CMH-17, NCAMP seeks to expand use of shared database
- FAA-accepted shared material property databases
- industry self regulate with minimal FAA oversight
  - supervised and reviewed by OEMs (similar to the “PAST”)
  - facilitated by CMH-17/SAE/NCAMP
- each material is qualified one time only
- no delay in availability of data to CMH-17

NCAMP SOP: Uses and Limitations

- Each material qualification and material property data acquisition program uses unique sets of test plan and material & process specifications. Since composite material properties are dependent on the raw material (e.g. prepreg) properties as well as the composite fabrication process, material users should use the same material & process specifications. Deviation from the original material specification may change the composite material properties and render the material property data and allowables invalid. The material specification along with its process control document (PCD) may be revised over time so material users should use the same material specification and participate in material/PCD change management activities. However, minor deviation from the original process specification is quite common, especially in fabricating complex aerospace parts, but the deviation must be justified by analysis and/or test, as required by certifying agency.

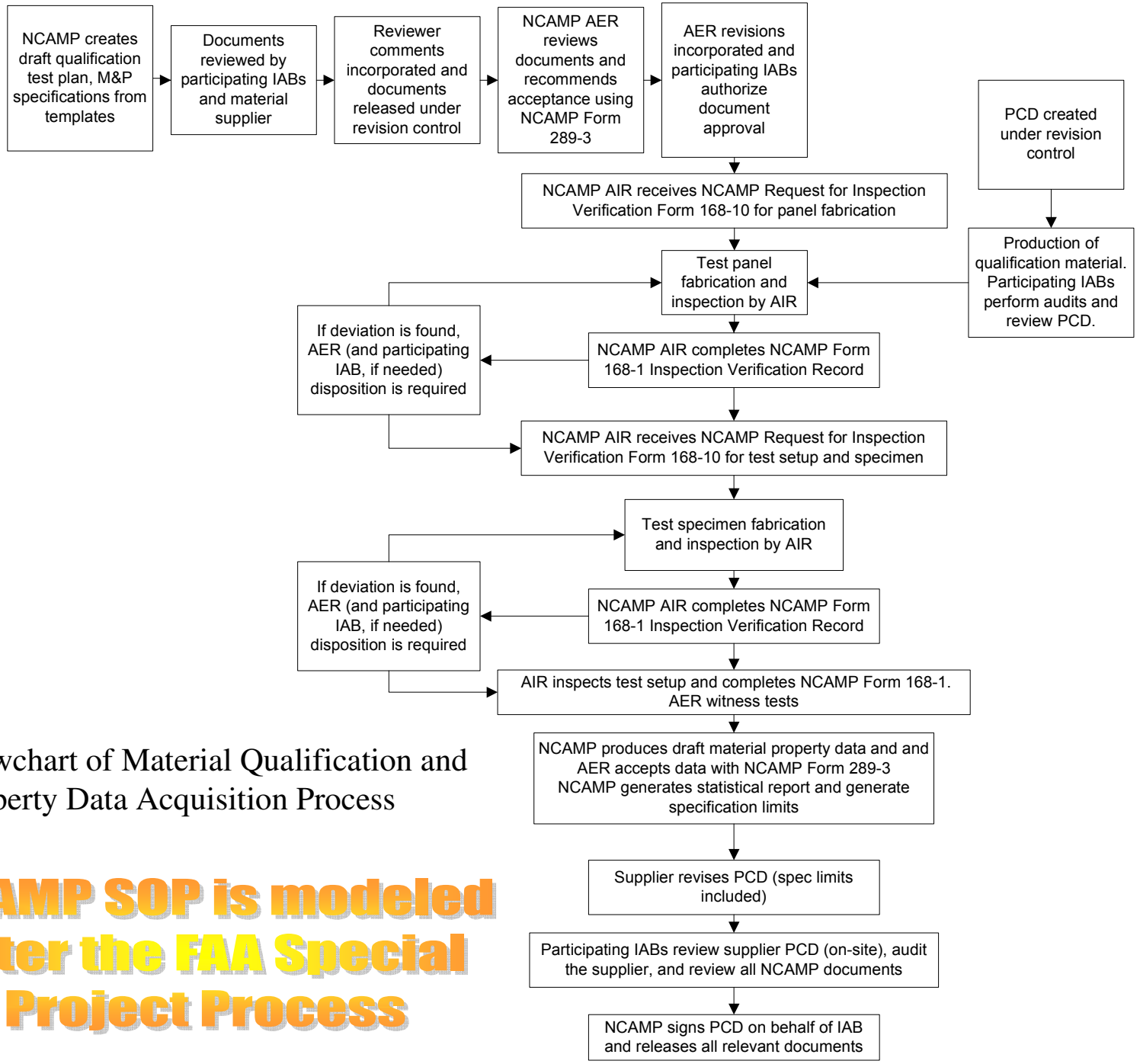
- The use of NCAMP material and process specifications do not guarantee material or structural performance. Material users must institute required quality control including, but not limited to, performing regular purchaser quality control tests, performing periodic equivalency/additional testing, participating in material change management activities, conducting statistical process control, and conducting regular supplier audits in order to properly utilize NCAMP design data.

- NCAMP does not guarantee that all the data necessary to design and certify a composite structure is provided by the data defined within the NCAMP database. The applicability of NCAMP material property data, material allowables, and specifications must be evaluated on case-by-case basis by aircraft companies and certifying agencies. Each user of the data must conduct validation tests as described by the NCAMP procedures to verify that the data is applicable to the materials and processes being used. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables, and specifications.

Scope of NCAMP SOP

- Material Qualification and Property Data Acquisition Process
- Equivalency Process for Part Fabricators
- Pre-existing Material Property Datasets
- Maintenance of Existing Shared Material Properties Database
- Provide processes to assure quality of data being provided

NCAMP and CMH-17 will work to publish these guidance in Vol. 1 of CMH-17



Flowchart of Material Qualification and Property Data Acquisition Process

NCAMP SOP is modeled after the FAA Special Project Process

The Approach - Completing the M&P Puzzle

Material Properties
NCAMP Basis Values → CMH-17 vol. 2

Material Specification
NCAMP NMS XXXX/XX → SAE AMS XXXX/XX

Process Control Documents (PCD)
NCAMP Guides → User Reviewed Supplier PCDs

Material & Process Limitation Information
UBC/CMT Process Maps → User Process Specs

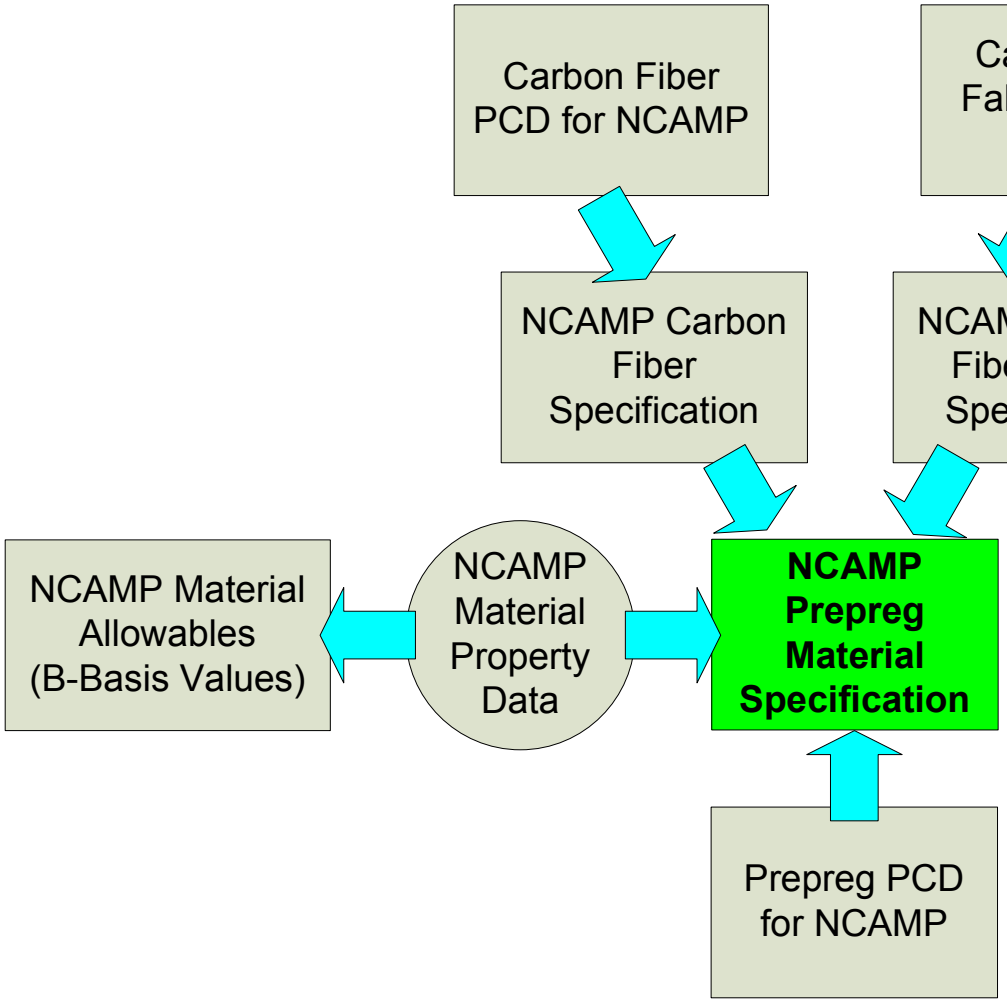
Material Design Guidance
NCAMP Recommendations → User Design Manual

Material Specification Callouts

- Recommended:
  - Option 1: For smaller applications, call out NMS directly in engineering drawings
  - Option 2: If an aircraft company desires more control, an equivalent material specification may be created with linkage to NCAMP prepreg specification through a material substitution table, or equivalent. This is a standard industry practice for many fasteners and metals.

- Not recommended:
  - An aircraft company creates a separate prepreg material specifications with no linkage to NMS

Linkages to NCAMP Material Specification



Material Property Control May be Lost If Any of These Linkages Is Severed

Must Maintain Direct Linkage to NCAMP Prepreg Material Specification

- NCAMP prepreg specification, which helps ensure NCAMP allowables, is linked to
  - Prepreg PCD
  - Fiber specification and PCD
  - Fabric specification and PCD

- When an aircraft company creates a separate standalone prepreg material specification
  - The linkages to all other controlling specifications and PCDs are lost
  - Loss of material property control
  - May render material allowables invalid
  - Material properties may diverge because material go through changes over time
  - Results in multiple specifications for the same material

OTHERWISE, DO NOT USE NCAMP ALLOWABLES

M&P Controls

Material Name	Process Spec	Prepreg Spec	Prepreg Change Control	Prepreg PCD	Fiber Spec	Fiber Change Control	Fiber PCD	Fabric Spec	Fabric Change COntrol	Fabric PCD
A	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
B	yes	yes	yes	yes	yes	yes	no	yes	yes	no
C	yes	yes	yes	yes	no*	yes	no	no*	yes	no

* fiber and fabric spec control via prepreg PCD and/or prepreg spec

"A" is most common; "C" is the minimum NCAMP requirement

Process Specification Callouts

- NPS are designed to produce test panels only for the purpose of material qualification, equivalency, and acceptance
- Aircraft companies should create their internal process specifications using NPS as the baseline to include
  - Compatible film adhesives, syntactic core, honeycomb, etc.
  - Ply splicing, temperature uniformity requirement, first part qualification, discrepancy acceptance/rework criteria, etc.
  - Some additional R&D and testing may be required to create robust (proprietary) process specifications.

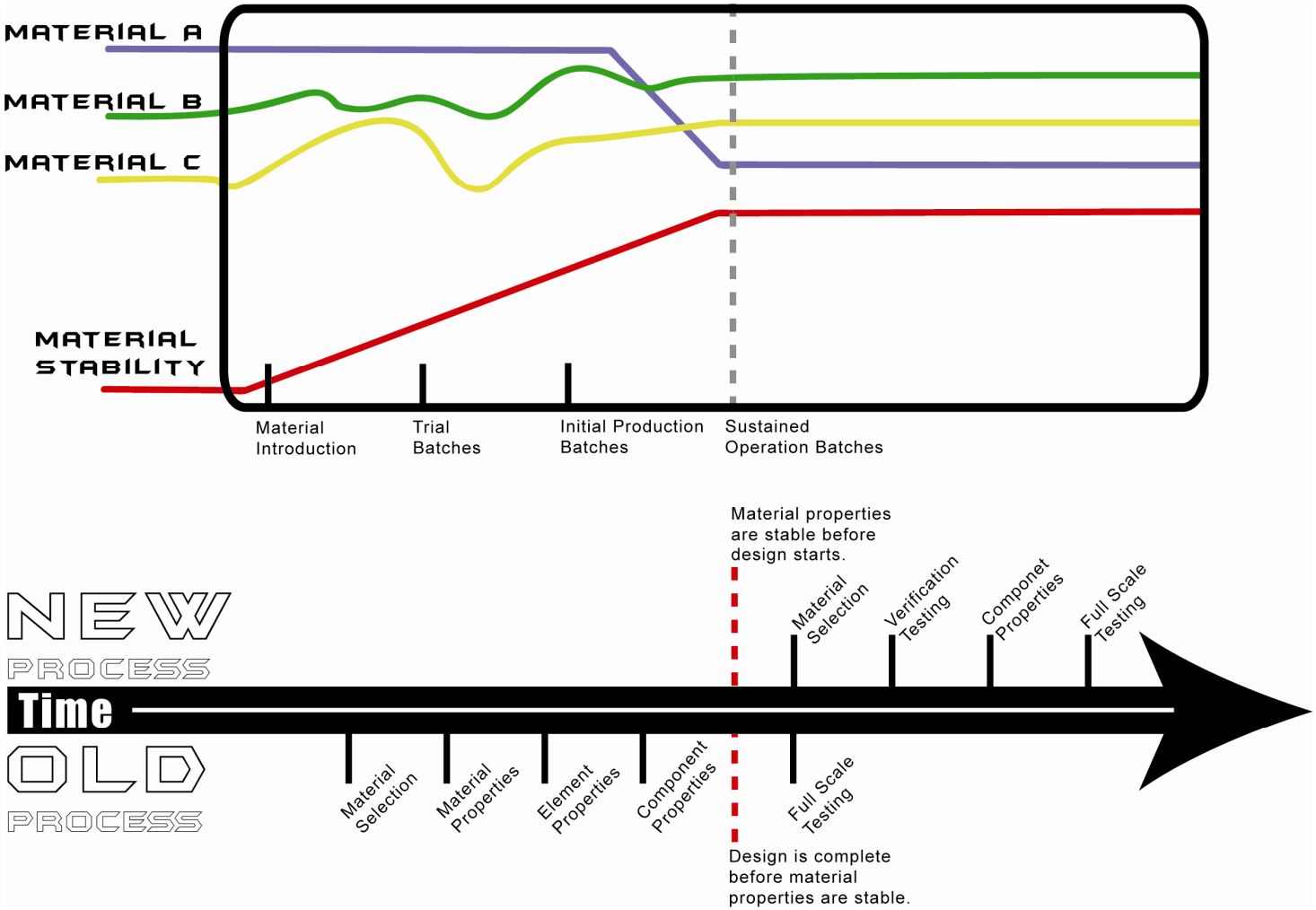
AFRL Funded Renegade FreeForm-14 (Non-MDA) Polyimide Qualification

- Industry selected
- Cure cycle may require a total of 15 hours and involve 200psi & 600ºF
- 500ºF wet, 550ºF dry operating condition
- Product form:
  - T650 3K 8HS 376 gsm Fabric 36 % Resin Content

AFRL Film Adhesive Screening Programs

- Screen for compatible film adhesives for cocure and cobond applications with the prepregs currently undergoing NCAMP qualifications
  - ACG MTM45-1, Cytec 5215, Cytec 5250-5, Cytec 977-2, Hexcel 8552, Newport 4708, Nelcote E752, Tencate TC250
- Two film adhesives per prepreg resin system will be chosen by material users
- As a screening program, there will be no FAA involvement
- Material allowables will not be generated
- Adhesive material specifications will not be created since they are not qualification programs.
- A detailed adhesive information data sheet will be included in the final report. The final report will only contain test results and observations.

Qualify Matured Materials Only



Material qualification and property data acquisition should be independent of aircraft certification program

The Future of Shared Database

- Government funding will not continue forever – need to become self-sufficient
  - Database must continue to grow and be maintained
  - Material specifications & PCD maintained by industry with *minimal* FAA & DoD oversight
- Material suppliers develop *PUBLICLY AVAILABLE* **basic** lamina and laminate material properties
  - Several variants of AGATE/NCAMP test matrices available to suit the budget and application
  - NCAMP test matrix is designed for multi-purpose use, although incomplete for many applications, is a significant cost and time savings for the material users
- Material users develop *PROPRIETARY* more detailed laminate and higher level building block properties

Desired Impact of Shared Database

- More material choices = more efficient designs
- One material = one qualification (cost savings)
- One material = one material specification (standardization)
- Improved availability: purchase "over-the-counter"
- Reduced price: you buy a quasi-commodity material
- Preferred by Tier 1 suppliers (when materials are not defined by OEMs) and small to midsize OEMs
- Designed by anyone, built by those who have proven equivalency (simple parts)
- Material properties are available before design begins
- Qualify only matured materials → more accurate data → improved structural efficiency & safety
- More resources are available to validate detail, sub-component, and component levels
- Leverage experts from all companies = improved safety
- **Promotes the use of composites through standardization and availability of material property data**
- **More use of lightweight materials such as advanced composites will lead to more fuel efficient transportation system which will minimize the impact on the environment and reduce fuel prices**

NCAMP Test Plans

- Based heavily on DOT/FAA/AR-03/19, DOT/FAA/AR-02/110, DOT/FAA/AR-06/10
  - Generic across commercial, military, space, rotorcraft, and general aviation
  - FAA helps create data pedigree (conformity & witnessing)
  - With process specification and material specification
  - Prepreg physical, chemical, and thermal properties
  - Lamina static, thermal, and fluid sensitivity
  - Laminate static (soft, quasi, hard): 3 environments, 3 batches
  - Subjected to rigorous industry and government review
- To establish material specification limits for material control
- To generate most basic material basis values (a.k.a material allowables), which is *not* to be confused with design values
- Provides some usable data; additional testing and analysis will be required (see CMH-17 vol.3)

NCAMP Lamina Test Matrix for unidirectional

Layup	Test Type and Direction	Property	Number of Batches x No. of Panels x No. of Specimens			
			Test Temperature/Moisture Condition			
			CTD	RTD	ETD	ETW
$[0]_8$	ASTM D3039 0° Tension	Strength, Modulus and Poisson's Ratio	3x2x3	3x2x3		3x2x3
$[0]_{20}$	ASTM D6641 0° Compression	Modulus	3x2x3	3x2x3	3x2x3	3x2x3
$[90]_{16}$	ASTM D3039 90° Tension	Strength and Modulus	3x2x3	3x2x3		3x2x3
$[90]_{20}$	ASTM D6641 90° Compression	Strength and Modulus	3x2x3	3x2x3		3x2x3
$[0/90]_{3S}$	ASTM D3039 0° Tension	Strength and Modulus	3x2x3	3x2x3		3x2x3
$[90/0/90]_7$	ASTM D6641 0° Compression	Strength and Modulus	3x2x3	3x2x3	3x2x3	3x2x3
$[45/-45]_{4S}$	ASTM D3518 In-Plane Shear	Strength and Modulus	3x2x3	3x2x3		3x2x3
$[0]_{45}$	ASTM D2344 Short Beam	Strength	3x2x3	3x2x3	3x2x3	3x2x3

NCAMP Laminate Test Matrix for unidirectional (continue next page)

(%0°/%±45°/%90°) Actual Test Type	Test Type and Layup	Property	Number of Batches x Number of Panels x Number of Test Specimens Test Temperature/Moisture Condition		
			CTD	RTD	ETW
(25/50/25 - QI) UNT1	ASTM D3039 Un-notched Tension [45/0/-45/90]2S	Strength & modulus	3x2x3	3x2x3	3x2x3
(10/80/10) UNT2	ASTM D3039 Un-notched Tension [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength & modulus	3x2x3	3x2x3	3x2x3
(50/40/10) UNT3	ASTM D3039 Un-notched Tension [0/45/0/90/0/-45/0/45/0/-45]S	Strength & modulus	3x2x3	3x2x3	3x2x3
(25/50/25 - QI) UNC1	ASTM D6641 Un-notched Compression [45/0/-45/90]3S	Strength & modulus		3x2x3	3x2x3
(10/80/10) UNC2	ASTM D6641 Un-notched Compression [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength & modulus		3x2x3	3x2x3
(50/40/10) UNC3	ASTM D6641 Un-notched Compression [45/0/90/0/-45/0/45/0/-45/0]S	Strength & modulus		3x2x3	3x2x3
(25/50/25 - QI) SBS1	ASTM D2344 Short Beam	Strength		3x2x3	3x2x3

NCAMP Laminate Test Matrix for unidirectional (continue next page)

(%0º/%±45º/%90º) Actual Test Type	Test Type and Layup	Property	Number of Batches x Number of Panels x Number of Test Specimens Test Temperature/Moisture Condition		
			CTD	RTD	ETW
(25/50/25 - QI) OHT1	ASTM D5766 Open Hole Tension [45/0/-45/90]2S	Strength	3x2x3	3x2x3	3x2x3
(10/80/10) OHT2	ASTM D5766 Open Hole Tension [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength	3x2x3	3x2x3	3x2x3
(50/40/10) OHT3	ASTM D5766 Open Hole Tension [0/45/0/90/0/-45/0/45/0/-45]S	Strength	3x2x3	3x2x3	3x2x3
(25/50/25 - QI) FHT1	ASTM D6742 Filled Hole Tension [45/0/-45/90]2S	Strength	3x2x3	3x2x3	3x2x3
(10/80/10) FHT2	ASTM D6742 Filled Hole Tension [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength	3x2x3	3x2x3	3x2x3
(50/40/10) FHT3	ASTM D6742 Filled Hole Tension [0/45/0/90/0/-45/0/45/0/-45]S	Strength	3x2x3	3x2x3	3x2x3
(25/50/25 - QI) OHC1	ASTM D6484 Open Hole Compression [45/0/-45/90]4S	Strength		3x2x3	3x2x3
(10/80/10) OHC2	ASTM D6484 Open Hole Compression [45/-45/0/45/-45/90/45/-45/45/-45]2S	Strength		3x2x3	3x2x3
(50/40/10) OHC3	ASTM D6484 Open Hole Compression [0/45/0/90/0/-45/0/45/0/-45]2S	Strength		3x2x3	3x2x3

NCAMP Laminate Test Matrix for unidirectional

(%0º/%±45º/%90º) Actual Test Type	Test Type and Layup	Property	Number of Batches x Number of Panels x Number of Test Specimens Test Temperature/Moisture Condition		
			CTD	RTD	ETW
(25/50/25 - QI) FHC1	ASTM D6484 Filled Hole Compression [45/0/-45/90]4S	Strength		3x2x3	3x2x3
(10/80/10) FHC2	ASTM D6484 Filled Hole Compression [45/-45/0/45/-45/90/45/-45/45/-45]2S	Strength		3x2x3	3x2x3
(50/40/10) FHC3	ASTM D6484 Filled Hole Compression [0/45/0/90/0/-45/0/45/0/-45]2S	Strength		3x2x3	3x2x3
(25/50/25 - QI) SSB1	ASTM D5961 Single Shear Bearing [45/0/-45/90]2S	Strength & Deformation		3x2x3	3x2x3
(10/80/10) SSB2	ASTM D5961 Single Shear Bearing [45/-45/0/45/-45/90/45/-45/45/-45]S	Strength & Deformation		3x2x3	3x2x3
(50/40/10) SSB3	ASTM D5961 Single Shear Bearing [0/45/0/90/0/-45/0/45/0/-45]S	Strength & Deformation		3x2x3	3x2x3
(100/0/0) ILT	ASTM D6415 Interlaminar Tension [0]30	Strength	1x1x6	1x1x6	1x1x6
(25/50/25 - QI) CAI1	ASTM D7136 & D7137 Compression After Impact (1500 in.lb/in) [45/0/-45/90]4S	Strength		1x1x6	

Fluid Sensitivity Screening

Short Duration Contact:			
MEK washing fluid. ASTM D740	15 days min. @ 70° F ± 10° F	70° F	FS21RT
		350° F	FS21ET
Polypropylene Glycol Deicer (Type I) Mil-A-824 3	15 days min. @ 70° F ± 10° F	70° F	FS22RT
		350° F	FS22ET
Isopropyl Alcohol Deicing Agent (TT-I-735)	15 days min. @70° F ± 10° F	70° F	FS23RT
		350° F	FS23ET
Control Tests:			
Dry	Dry per section 6.1	70° F	FS32RT
		350° F	FS32ET
85% Relative Humidity	Per section 6.1	70° F	FS33RT
		350° F	FS33ET

Extended Contact:	Exposure	Test Condition	Code
100 Low Lead Aviation Fuel (ASTM D910)	70° F±10° F (Note 1)	70° F	FS11RT
		350° F	FS11ET
SAE AMS 2629 Jet Reference Fluid	70° F±10° F (Note 1)	70° F	FS12RT
		350° F	FS12ET
MIL-PRF-5606 Hydraulic Oil	160° F±10° F (Note 1)	70° F	FS13RT
		350° F	FS13ET
MIL-PRF-83282 Hydraulic Oil	160° F±10° F (Note 1)	70° F	FS14RT
		350° F	FS14ET
MIL-PRF-7808 Engine Oil	160° F±10° F (Note 1)	70° F	FS15RT
		350° F	FS15ET
MIL-PRF-23699, Class STD Engine Oil	160° F±10° F (Note 1)	70° F	FS16RT
		350° F	FS16ET
Sea Water (ASTM D1141 or equiv)	160° F±10° F (Note 1)	70° F	FS17RT
		350° F	FS17ET
Skydrol LD-4 (SAE AS1241, Type IV, Class 1)	160° F±10° F (Note 1)	70° F	FS18RT
		350° F	FS18ET
50% Water with 50% Skydrol LD-4 (SAE AS1241, Type IV, Class 1)	160° F±10° F (Note 1)	70° F	FS19RT
		350° F	FS19ET
PAO (Poly Alphaolefin) Cooling Fluid, MIL-C-87252	160° F±10° F (Note 1)	70° F	FS20RT
		350° F	FS20ET

Freezer Storage Life and Out-Time Verification

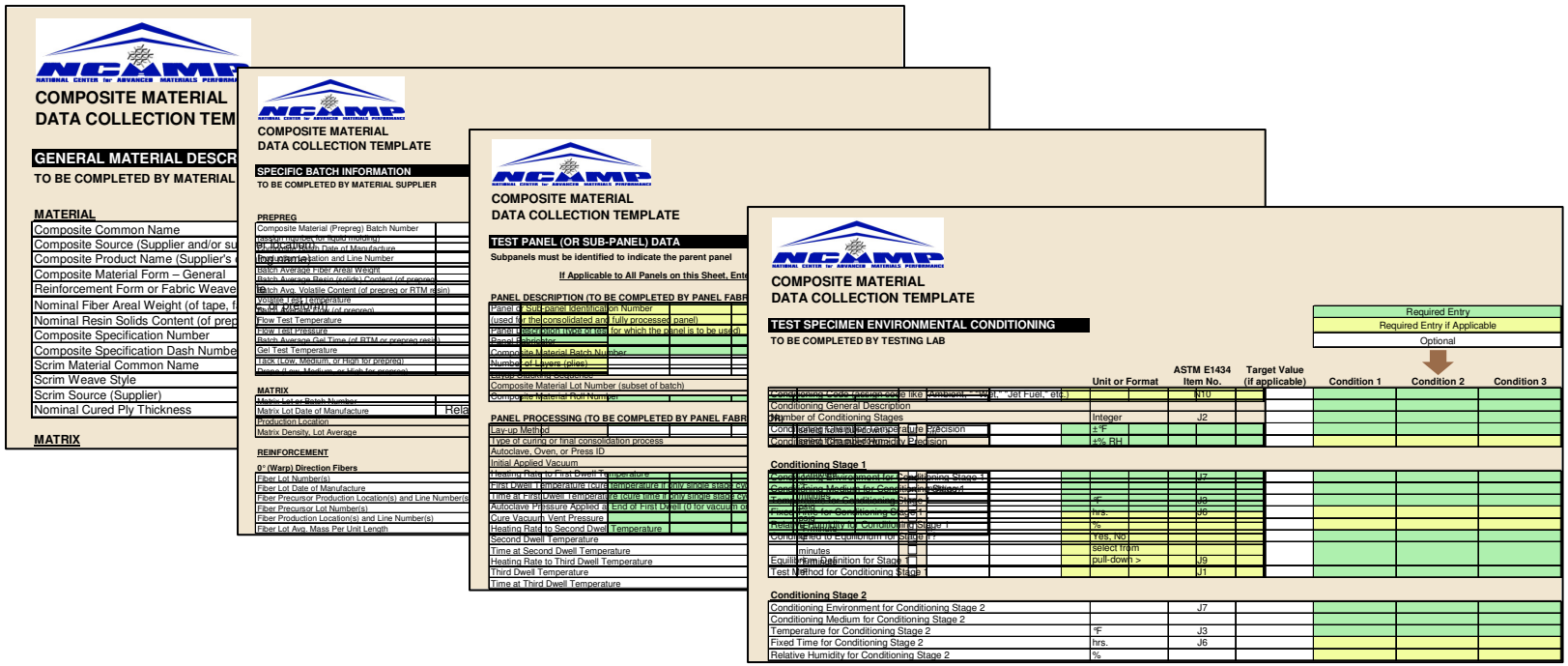
Property	Method/Condition	# Replicates per condition
Short Beam Strength (Note 3)	ASTM D 2344-00, RTD	5
Tack	See section 7.1 or use material supplier recommended method	3
Drape	See section 7.2 or use material supplier recommended method	3
HPLC (Note 2)	SACMA SRM 20R-94	2
Photomicrography and void content determination	Reference MIL-HDBK-17-1F section 6.6.7.3	As needed

Freezer Storage Life and Out-Time Verification (con't)

Freezer Storage Time <10° F	Out Time at 70° ± 10° F and 0-60% RH						
	< 1 day	3 days	5 days	7 days	9 days	11 days	13 days*
As manufactured Code	✓ 0/1	✓ 0/3	✓ 0/5	✓ 0/7	✓ 0/9	✓ 0/11	✓ 0/13
3 months freezer Code	✓ 3/1		✓ 3/5		✓ 3/9		
6 months freezer Code	✓ 6/1		✓ 6/5		✓ 6/9		✓ 6/13
9 months freezer Code	✓ 9/1		✓ 9/5		✓ 9/9		
12 months freezer Code	✓ 12/1	✓ 12/3	✓ 12/5	✓ 12/7	✓ 12/9	✓ 12/11	✓ 12/13

Detailed Documentation of Material, Panel Fabrication Procedures, and Test Methods Used

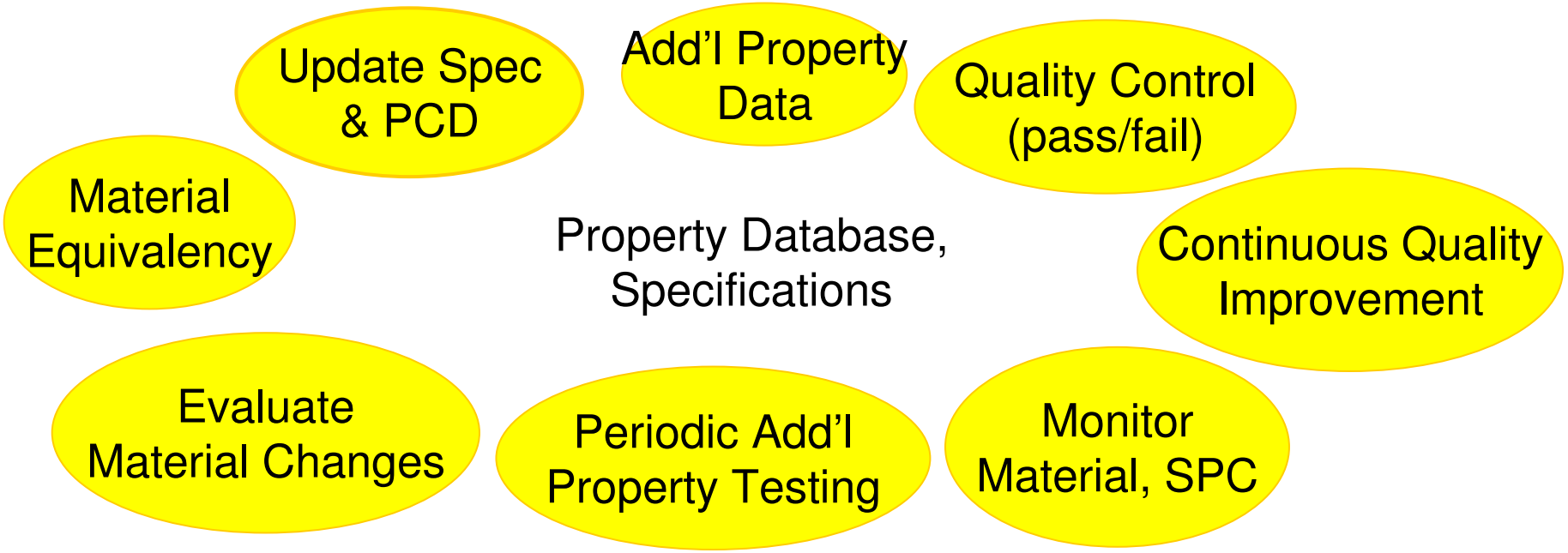
- Detailed documentation of pedigree information is a very important part of material qualification programs
- Standard forms have been created for use by NCAMP material qualification programs



Material Control

- Process Control Documents (PCD)
  - Prepreg
  - Carbon Fiber Tow
- Material Specifications with QPL
  - Prepreg
  - Carbon Fiber Tow (includes "fingerprint")
  - Carbon Fiber Fabric (no NCAMP-approved PCD but internal supplier PCD with change notification required)

Compliance with AC23-20 is a Continuous Process

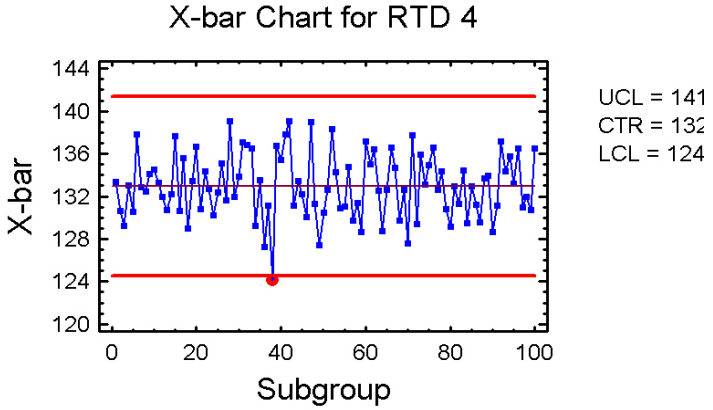


Active Supplier and User Participation Required with *minimal* FAA & DoD oversight

Material Property Monitoring

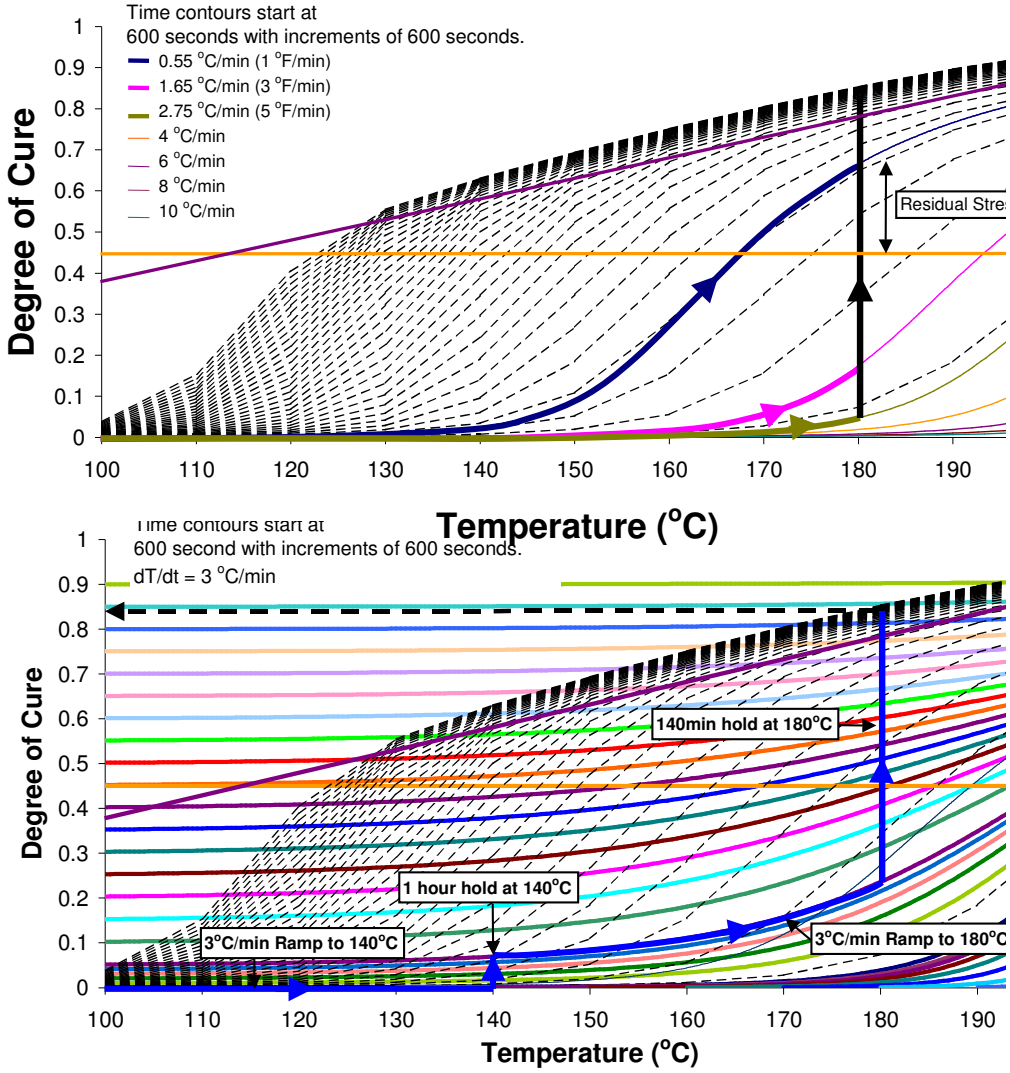
- Partnering with material suppliers and aircraft companies to monitor material property variations over time

Control Charts



- Everything varies at least a little bit. So how do you tell when you are just experiencing normal variation versus when something out of the ordinary is occurring? Control charts were designed to make that distinction
- As long as all points lie inside the upper and lower control limits, the variation is presumed to be normal or a common cause variation. When a data point falls outside those limits, it's time to look for a reason for the variation
- Two-sided monitoring for all properties including strength

Process Map Development



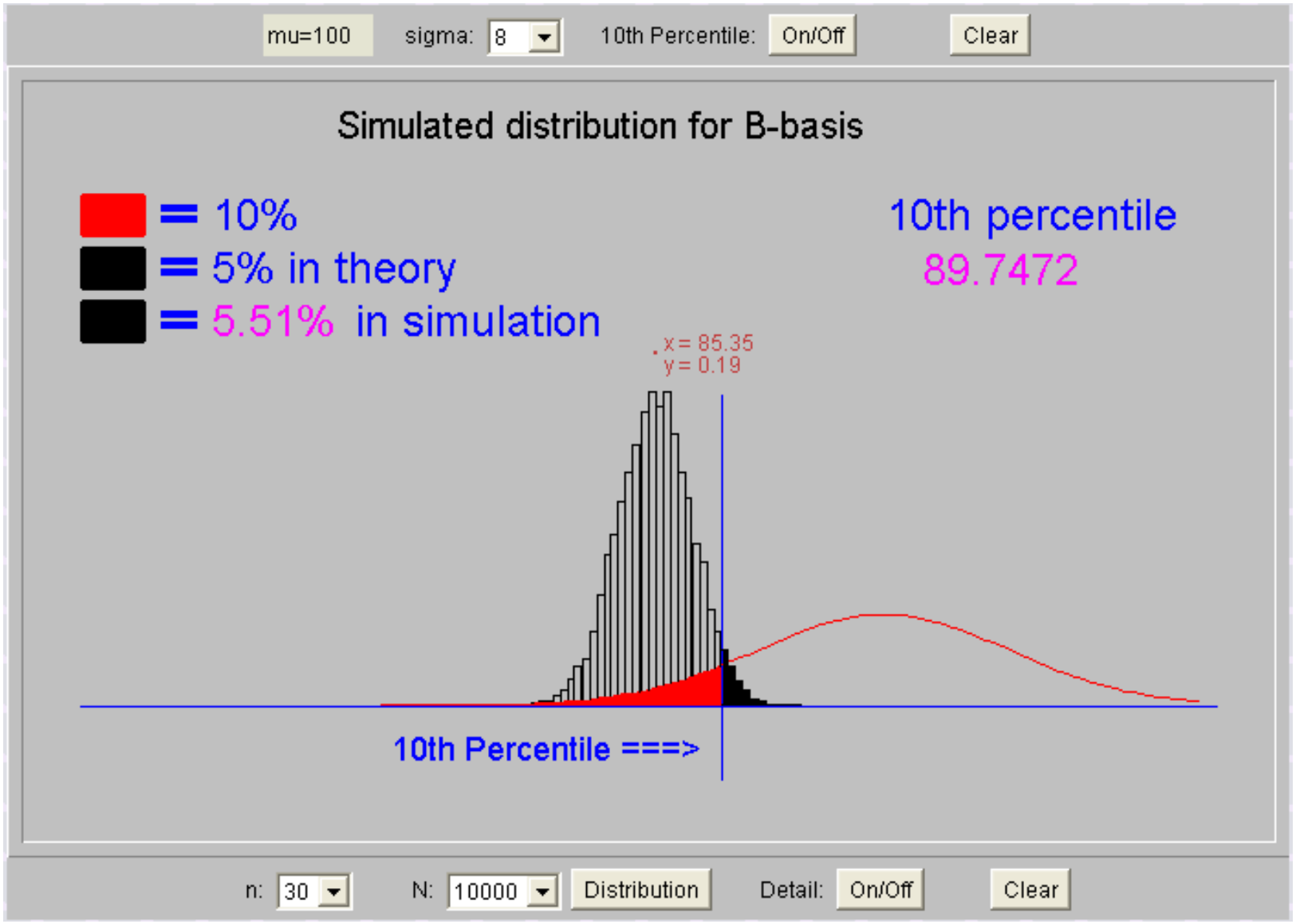
- Material is characterized using DSC for degree of cure; optionally other properties can also be characterized using DMA, TMA, etc.
- Process maps are generated with contours of time for isothermal holds, overlaid with dynamic ramps
- A map can either consider multiple ramps at the same ramp rate, or a single ramp at a different ramp rate
  - This is not a fundamental drawback, but a limit to how busy a map can be
- Any cycle can then be followed by following the ramp and hold contours
- The resulting cycle can then be overlaid on property maps with identical axes but with contours of the property of interest
- Other than limitations of graphical representation, same accuracy as running computer model, and much more informative
- A UBC spin-off company, CMT, is developing simple graphical applications using process maps for even further automation and convenience

Some NCAMP Research Projects

(Past, Current, and Future)

Basis Value Simulation Program

- Definition (that few people understand)
  - B-Basis (or B-Value) -- A statistically-based material property; a 95% lower confidence bound on the tenth percentile of a specified population of measurements. Also a 95% lower tolerance bound for the upper 90% of a specified population.



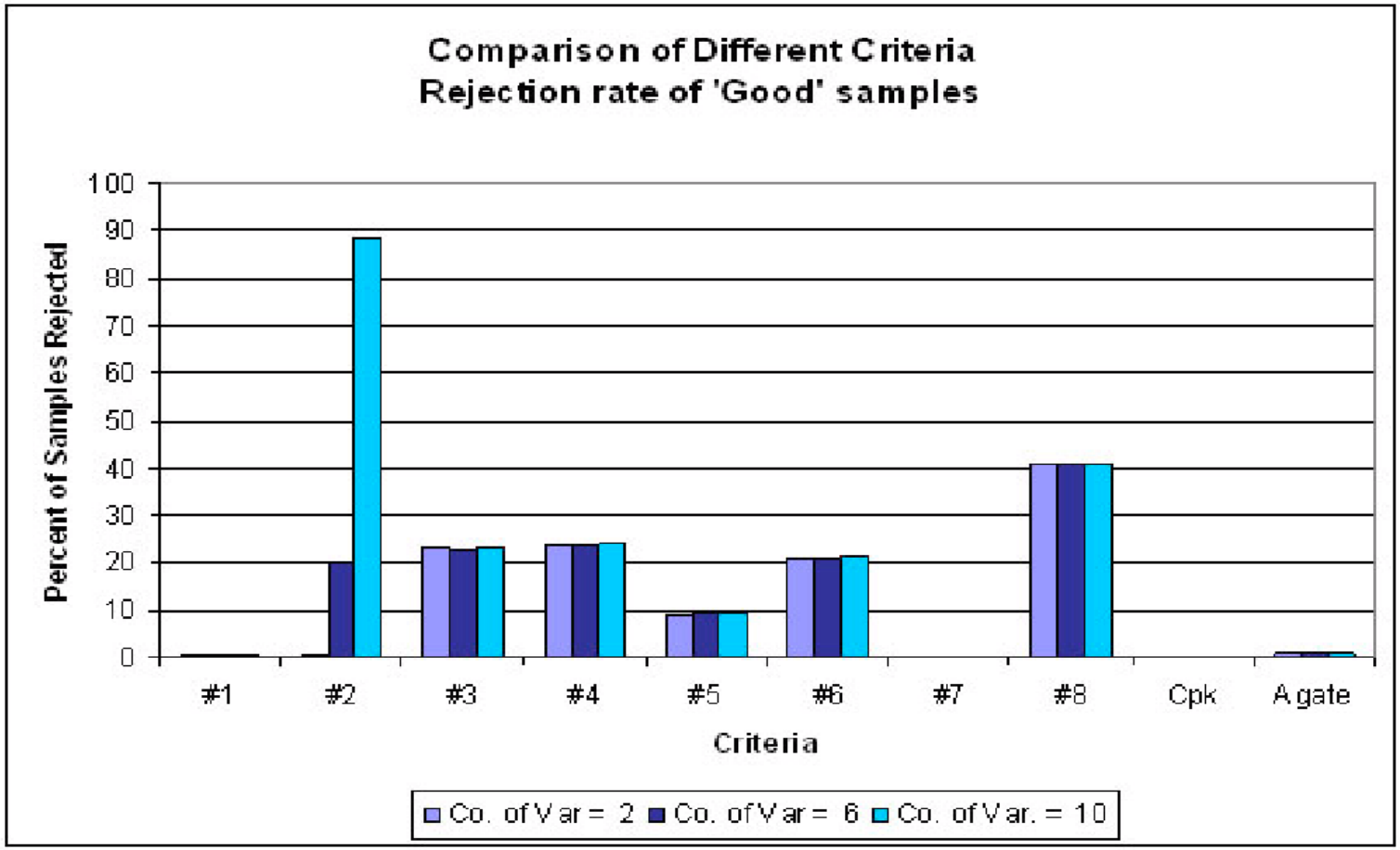
This internet browser-based simulation program is available at NCAMP website http://www.niar.wichita.edu/coe/ncamp_media.asp

Acceptance Criteria Comparison

(slide 1 of 2)

- Comparison of various acceptance criteria
  - Earlier methods investigated by Mark Vangel & Scott Reeve
    - Many used A and B-basis values as acceptance thresholds. The numbers used in the comparison were obtained from the basis value simulation program (previous slide)
  - Newer methods include AGATE acceptance criteria and CPK-based criteria
- Includes effects due to retests
- Presentation file available for download at http://www.niar.wichita.edu/coe/ncamp_media.asp

Figure 1: Percentage of good samples rejected



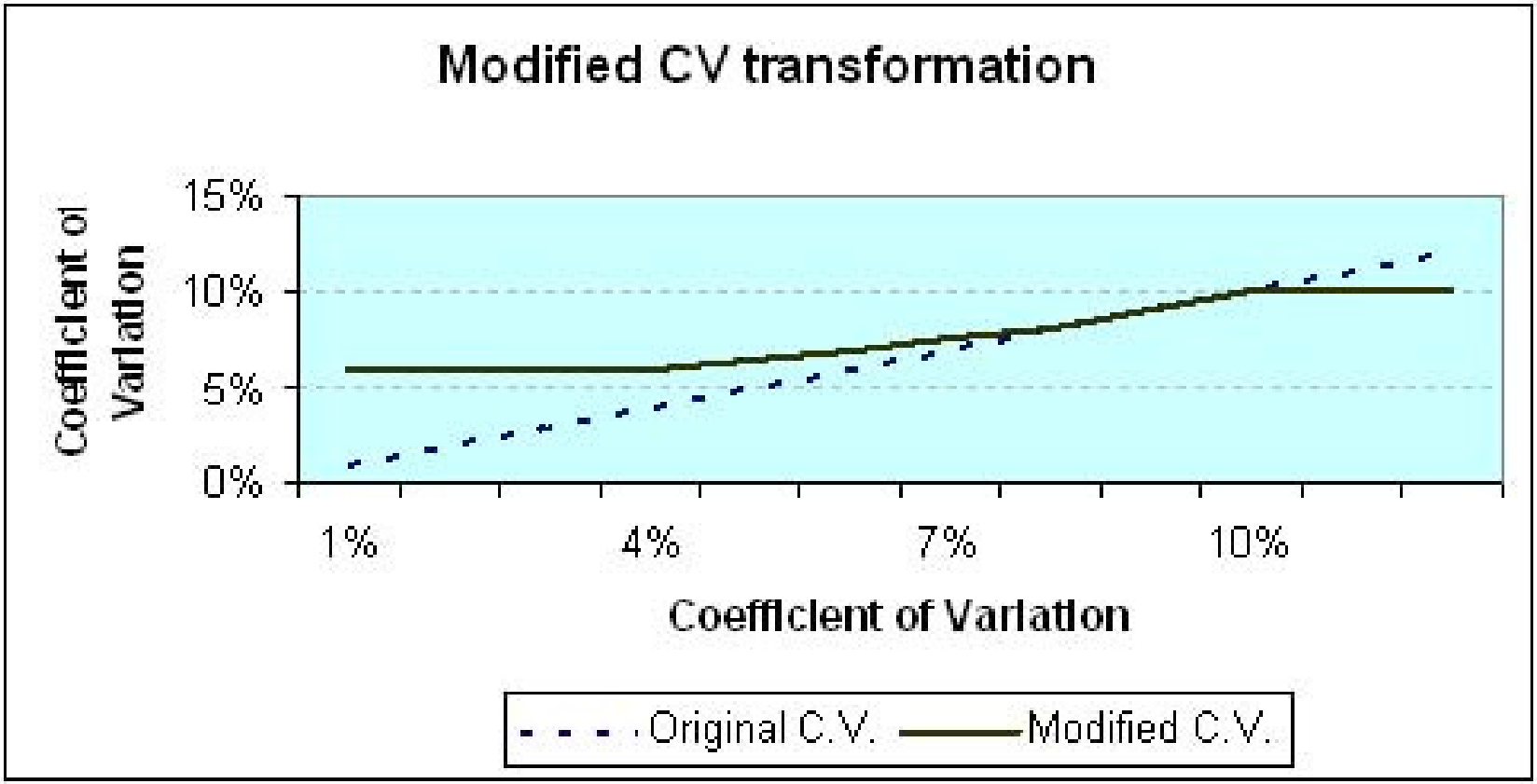
Beth Clarkson and Yeow Ng, "Comparison of Various Composite Material Acceptance Criteria," accepted for publication in Journal of Advanced Materials.

Temporary Use of Higher than Measured Coefficient of Variation (CV)

- Qualification programs often obtain very low coefficient of variations (CV) because
  - Materials are made within a short period of time (not representative of actual material property variation)
  - Materials are tested by the same operators using the same equipment setup/calibration/fixture/etc.
- Low CV leads to unrealistically high basis values and material specification limits
- NCAMP will assume higher than measured CV (therefore, lower basis values and material specification limits) for a temporary period of time as follows:
  - If the measured CV at a given test condition is 0% to 4%, use an assumed CV of 6% or the pooled CV, whichever is greater.
  - If the measured CV at a given test condition is between 4% and 8%, use an assumed CV = 0.5*(measured individual CV) + 4% or the pooled CV, whichever is greater.
  - If the measured CV at a given test condition is 8% to 10%, use the measured CV or the pooled CV, whichever is greater.
  - If the measured CV at a given test condition is 10% or greater, question the data. And for setting specification requirement use a maximum CV of 10%.
- When a sufficient number of production batches have been produced and tested (approximately 8 to 15 batches), the basis values and specification limits may be adjusted higher.

NCAMP recommends the use of allowables calculated from modified CV, but publishes those calculated from as-measured CV also.

Temporary Use of Higher than Measured Coefficient of Variation (CV)



CMH-17 Rev G, Vol. 1, Section 8.4.4

Additional tests previously suggested by NCAMP members, but never incorporated due to various reasons

Additional tests previously suggested by NCAMP members

- Fatigue: LEF and load truncation
  - BVID, open-hole, filled-hole
  - compression & shear, 3 laminates, RTD, RTW
  - Reason why this was not included:
    - members/consultants could not agree on an approach/test matrix/defects
- Co-cure sandwich structures properties
  - core and sandwich testing
  - Compression, tension, shear, flexure, peel, thermal conductivity, etc.
  - CTD, RTD, ETW
  - Includes honeycomb/foam core qualification
  - Reason why this was not included:
    - members/consultants could not agree on a specific adhesive and honeycomb density/cell size/thickness/etc.
- Expanded laminate test matrix
  - CTE, Cp, moisture diffusivity, ILT, ILC, ILS, fastener pull-through, countersink fastener, bearing by-pass, laminate flexure (unnotched/open-hole/filled-hole), thermal cycling, CAI (vary thickness, soft/hard, energy, impactor diameter), W/d ratio curves, add ETD & ETW2
- Countersink effects

Continued: Additional tests previously suggested by NCAMP members

- Properties of higher level building blocks: element (e.g. Pi, hat, etc.), detail, etc.
  - Compression, tension, shear, flexure, peel, thermal conductivity, etc.
  - Reason why this was not included:
    - Technology is still maturing; VARTM emerging
- Analytical Model Verification
  - To verify and fine-tune analytical models through a mini building block experiment
  - Test articles representative of larger structures