NCAMP Standard Operating Procedures (SOP)

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1. Introduction

1.1 Purpose

The intent of this document is to describe the standard operating procedures (SOP) employed by the National Center for Advanced Materials Performance (NCAMP) for material property data acquisition, material qualification, material allowable generation, and material equivalency processes. The material property data acquisition process is designed to generate basic material property data with sufficient pedigree and control for submission to *Complete Documentation* sections of Composite Materials Handbook 17 (CMH-17). The material allowable generation process creates statistically-based basis values using CMH-17 procedures and guidelines. The material qualification process involves qualifying new materials into material procurement specifications while establishing process control documents and process specifications necessary to ensure consistent and reliable material properties. The equivalency process is designed to evaluate the effects of minor changes in material or process; it compares a new dataset with an existing dataset using statistical tests outlined in DOT/FAA/AR-03/19 and Section 8.4.1 of MIL-HDBK-17-1F.

NCAMP is a center within the National Institute for Aviation Research (NIAR) and operates independently of other NIAR laboratories and research initiatives.

1.2 Scope

The NCAMP shared material property database contains material property data and material and process specifications of common usefulness to a wide range of aerospace projects. The intent of NCAMP is to promote the publication of data for advanced composite materials which may be used in the design and certification of aircraft structure. However, it is not anticipated that the data provided will fulfill all the design needs of every project. Each user will need to assess the data available against the specific properties, environments, laminate architecture, and loading situations of their individual projects. In most structural applications, additional testing will be required.

1.3 Usage 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) is

designed to control material property. They 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 the certifying agencies involved.

The use of NCAMP material and process specifications do not guarantee material or structural performance. Material users must institute at a minimum, but not limited to, required quality control including, perform regular purchaser quality control tests, perform periodic equivalency/additional testing, participate in material change management activities, conduct statistical process control actions defined in their specification, and conduct regular supplier audits in order to properly implement NCAMP specifications.

Care must be taken when utilizing material allowables derived using NCAMP procedures. 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 and accuracy of NCAMP material property data, material allowables, and specifications must be evaluated on case-by-case basis by the applicant and certifying agencies. In most cases, the material allowables published by NCAMP are not directly usable as design values which satisfy all regulatory requirements. Material users may need to derive design values from the material allowables provided to ensure compatibility with the actual laminates being used, their internal analytical methods, certification approach, and other factors. In many cases, additional tests are required to supplement NCAMP data in order to derive a complete set of design values for a given program. The amount of additional testing is dependent on the complexity and criticality of the structure being designed. NCAMP assumes no liability whatsoever, expressed or implied, related to the use of the material property data, material allowables, and specifications.

1.4 Definitions of Key Terms

Material Allowable:	Statistically-based material strength basis values such as A- and B-basis values.
Material Design Values:	Values which are actually used to design structure and are compliant with governing regulations. Generally, design values are based on material allowables adjusted to account for actual use of the structure being designed (i.e. layup of materials, operational temperatures, and expected operational moisture environment.)
Material Equivalency:	The process of comparing two datasets, typically between a larger (3 or 5 batches) qualification dataset and a smaller (1 or 2 batches) equivalency dataset.

Material Qualification:	The process of qualifying a material into a material specification. In the NCAMP process, material qualification and material allowable generation are conducted concurrently; the same data is used to generate material allowables and establish material specification limits.

1.4.1 Acronyms

AIR	Authorized Inspection Representative
AER	Authorized Engineering Representative
ASAP	Agate Statistical Analysis Program
CMH-17	Composite Materials Handbook 17 (formerly MIL-HDBK-17)
RGB	Regulatory Governing Board (an NCAMP Board consisting of U.S. Air Force, Army, FAA, NASA, and Navy)
MAB	Manufacturers Advisory Board (an NCAMP Board consisting of original equipment manufacturers and their tier-1 suppliers)
MMPDS	Metallic Materials Properties Development and Standardization
NCAMP	National Center for Advanced Materials Performance
PCD	Process Control Document
STAT17	CMH-17 Statistical Analysis Program for Single Point Analysis
SAB	Suppliers Advisory Board (an NCAMP Board consisting of material suppliers, tier-2, and tier-3 suppliers)

1.5 Background

Traditionally, aircraft companies have had to perform their own material qualification and data acquisition programs because there was no available source of shared material property data that can be readily used in certified applications. The datasets that existed in MIL-HDBK-17 (now known as CMH-17) Revision F and earlier did not have the necessary pedigree for use in certified applications. The data generated by the aircraft companies remained proprietary, forcing individual aircraft companies to repeat qualification efforts. This process has resulted in redundant qualification efforts and multiple specifications for the same materials. Since the FAA often had to provide oversight on the qualification programs, the process also created an enormous and redundant workload for the FAA.

In 1995, NASA Advanced General Aviation Transport Experiment (AGATE) program began developing a composite material property shared database process in partnership with the FAA and MIL-HDBK-17. The AGATE shared database process covers the original material qualification, material property data acquisition, and equivalency processes. The AGATE process was recognized as an acceptable means of showing compliance with 14 CFR Part 23.613 through FAA Small Airplane Directorate's policy memorandum (Policy Statement Number ACE-00-23.613-01; Volume 65, Number 114).

The AGATE process was more efficient than the traditional process because it eliminated the redundant qualification programs, which also reduced the burden on the FAA. Several material systems were qualified by the AGATE program in which the FAA was directly involved in every material qualification program.

The AGATE process continued to be used by the general aviation industry even after the AGATE program ended in 2001. Its popularity prompted the realization that the AGATE process should be extended beyond the general aviation segment to the entire aerospace industry. In 2005, NASA established NCAMP with the purpose of refining and enhancing the AGATE process to a self-sustaining level to serve the entire aerospace industry in partnership with CMH-17, FAA, and SAE (Society of Automotive Engineers).

As with all previous AGATE programs, every NCAMP material qualification program has continued to require the appropriate level of documentation such as test plans, material and process specifications, conformity inspection on specimens and test setups, and test witnessing. Such work was conducted per an approved process with direct FAA involvement. From 1995 to 2008, over fifty material qualification and equivalency programs have used the AGATE process which required direct FAA oversight. Approximately 22 more material systems are going through qualification process at the time of this publication. The AGATE process has become the routine and standard process for generating shared composite material property database for the general aviation industry. All material property data are generated in accordance with CMH-17 requirements and are intended for publication in CMH-17 volume 2.

While being more efficient than the traditional process, the NCAMP process is not fully matured, especially when compared with the Metallic Materials Properties Development & Standardization (MMPDS) handbook for metallic materials. In early 2008, the FAA, CMH-17 leadership, SAE, and NCAMP began discussing a long-term goal to develop an even more streamlined and harmonized process, one that would allow the ease of use and access to composite material allowables similar to the MMPDS shared material allowables that exists for the metallic material industry. The procedures described in this working draft document are the first steps toward that long-term goal. They will be revised periodically to reflect the continual growth and maturity of the composite materials industry.

The procedures described in this document are similar to the AGATE process wherein every key procedure that existed in the AGATE process is retained in this document. NCAMP procedures are being vetted by the FAA to allow the data being generated to be acceptable for showing compliance to the regulations. This will allow potential users in the aerospace industry to use NCAMP supplied data with confidence in its acceptability to the FAA. It is the goal of NCAMP to publish design data in CMH-17 along with the procedures potential users will need to follow to properly utilize the data. For the data being generated by NCAMP to remain acceptable to the FAA it is vital that individual users of the data also follow procedures for validating the materials being purchased and processed in their facilities are compatible with the published data.

As the NCAMP process matures there is a fundamental difference with data provided in MMPDS for metallic materials potential users must keep in mind. MMPDS has evolved over the years taking full advantage of the fact that basic design and analytical methods for metallic construction have been standardized and needed design properties have long been clearly identified. Also, metallic materials are in general not as process dependent as their composite counterparts and what processes that do affect the final material properties (for example heat treatments) are well understood and controlled. At the time of this publication the same level of standardization cannot be assumed for composite materials. As such user of the composite data generated by the NCAMP method need to be aware that they will still be required to perform some tests to validate that the published data is applicable for their unique combination of materials and manufacturing methods. The users will also need to assess if the data published is compatible with their internal analytical tool and supplement NCAMP data with their own tests as required. These supplemental tests will need to be approved by the certifying agency to show compliance with the relevant regulations and/or requirements. It is expected that NCAMP data will significantly reduce the work load and associated costs of both the applicant and regulatory agencies. Over time as analytical tools and design value requirements are standardize by industry, NCAMP data will become increasingly valuable to both the industry and regulatory agencies.

1.6 Executive Summary

A description of NCAMP organizational structure is given in Section 2. Section 3 describes the core NCAMP documents. Section 4 describes the initial material qualification and property data acquisition process including material allowable generation process which creates statistically-based basis values using CMH-17 procedures and guidelines. Section 5 describes the equivalency process allowing part fabricators to utilize an existing material property database. Section 6 covers the process of analyzing pre-existing material property datasets. Section 7 describes the ongoing process of maintaining existing material property databases along with the corresponding specifications and process control documents.

2. NCAMP Organization

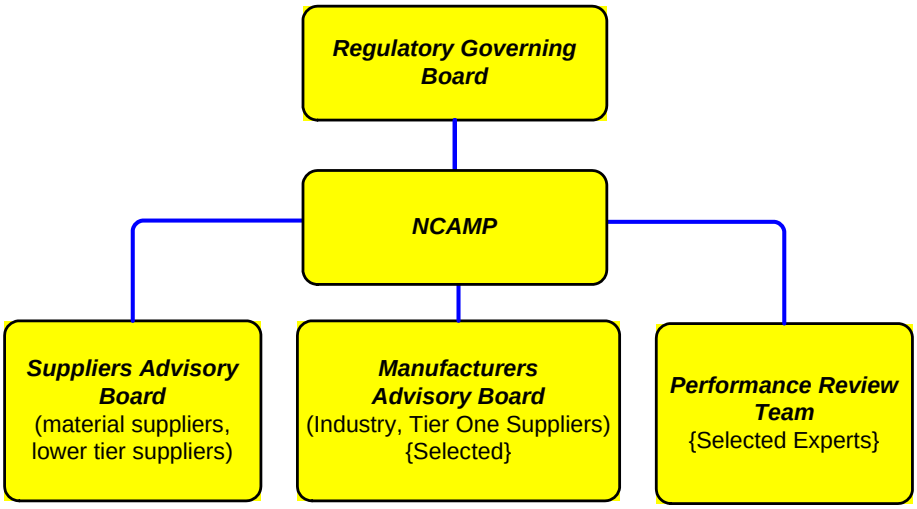

Figure 1. NCAMP Organizational Structure

2.1 Overview of Organization

The NCAMP Organizational Structure, as shown in Figure 1, was established to create effective and efficient relationship among all stakeholders. NCAMP staff members are required to maintain regular communication with all the members through meetings and news-bulletins. NCAMP has the responsibility to ensure that every member feedback and comment is given fair consideration. NCAMP maintains a close relationship and holds regular joint meetings with CMH-17 to ensure that NCAMP generated industry-shared material property datasets along with material and process specifications meet Complete Documentation section requirements of CMH-17 Volume 2 Revision G.

2.2 Regulatory Governing Board (RGB)

The Regulatory Governing Board consists of individuals from the U.S. Air Force, Army, FAA, NASA, and Navy. RGB's primary role is to oversee the NCAMP procedures such as this SOP to ensure design data generated meet regulatory requirements. RGB also oversees NCAMP activities to ensure competence and performance in meeting industry needs. When necessary, RGB may establish guidelines for specific NCAMP process; such material selection process. NSP 110 Operating Procedures and Bylaws for NCAMP Regulatory Governing Board (RGB) describes the approach and procedures to conducting business within RGB.

2.3 Manufacturers Advisory Board (MAB)

The Manufacturers Advisory Board (MAB) consists of aerospace companies that are Original Equipment Manufacturers (OEMs), primes, and tier-1 suppliers. There are currently more than forty five (45) MAB members. Every MAB member has to designate an individual to serve as a company representative on the NCAMP MAB. The representative serves as the official point-of-contact between NCAMP and the company for activities such as voting and document review. MAB plays an important role in ensuring that the NCAMP process, procedures, material properties, and specifications meet aerospace application requirements. Each MAB member has the responsibility to

provide feedback and comments to NCAMP staff to ensure that the NCAMP deliverables meet their individual needs. NSP 120 Operating Procedures and Bylaws for NCAMP Manufacturers Advisory Board (MAB) describes the approach and procedures to conducting business within MAB.

2.4 Suppliers Advisory Board (SAB)

The Suppliers Advisory Board (SAB) consists of material suppliers, tier-2, and tier-3 suppliers to the aerospace companies. The primary function of SAB is to provide NCAMP with the latest material and process technology for inclusion in the material property shared database. SAB participates in NCAMP document review process and plays an important role in establishing quality standards for NCAMP materials. Material suppliers have the responsibility to provide feedback to NCAMP, especially those related to material specification requirements, and ensure that their materials meet all applicable NCAMP requirements. NSP 130 Operating Procedures and Bylaws for NCAMP Suppliers Advisory Board (SAB) describes the approach and procedures to conducting business within SAB.

2.5 Performance Review Team (PRT)

The Performance Review Team (PRT) consists of subject matter experts, NCAMP Authorized Inspection Representatives (NCAMP AIR), and NCAMP Authorized Engineering Representatives (NCAMP AER). A majority of the individuals in PRT are consultants. PRT members have the responsibility to be impartial and maintain high degree of integrity, sound judgment, and objectivity when performing the assigned tasks. Regardless of the employment (direct employee or hired consultant) status, an individual performing the duties of an AIR or AER is expected to be able to perform those duties without undue pressure from the company seeking their services in that capacity.

2.5.1 Authorized Inspection Representative (NCAMP AIR)

An NCAMP AIR is an individual qualified to conduct independent/un-bias inspection verifications. This individual's regular job function includes inspection verification of test panels and specimens. Companies and testing laboratories that participate in NCAMP activities typically have internal quality procedures and conduct internal inspection on test articles. In such cases, the NCAMP AIR may elect to conduct inspection verification on representative samples of test articles to ensure that the internal quality procedures and inspections are adequate. The NCAMP AIR may conduct more rigorous inspection verification frequency, at the sole discretion of the NCAMP AIR, if the internal quality procedures and inspections are deemed inadequate. Individuals desiring to hold this position must meet the requirements of NCAMP Authorized Inspection Representative (AIR) Qualification Plan (NCAMP Document No. NQP 100) and be approved by the NCAMP Manufacturers Advisory Board members participating in a given program. An AIR may be an independent/self-employed inspector or may be employed directly by the company that is performing the tasks for NCAMP. In the latter case, the AIR must not work for the same inspection/quality department and must be able to provide impartial inspection verification.

For inspection verification task on panel fabrication, the AIR is usually paid by the panel fabricator or the entity that is funding the qualification program. For inspection verification task on test specimens, the AIR is usually paid by the testing lab or the entity that is funding the qualification program.

2.5.2 Authorized Engineering Representative (NCAMP AER)

The NCAMP AER is an individual qualified to conduct independent/un-bias engineering functions. The NCAMP AER is typically responsible for (1) reviewing and recommending acceptance of documents such as test plans and specifications, (2) witnessing specimen testing, and (3) accepting test data. Individuals desiring to hold this position must meet the requirements of NCAMP Authorized Engineering Representative (AER) Qualification Plan (NCAMP Document No. NQP 200) and be approved by the NCAMP Manufacturers Advisory Board members participating in a given program. An AER may be an independent/self-employed engineer or may be employed directly by the company that is performing the tasks for NCAMP. In the latter case, the AER must not work for the same engineering department and must be able to provide impartial engineering approval or recommendation for approval.

For document review tasks, the AER is usually paid by the entity that is funding the qualification program. For test witnessing task, the AER is usually paid by the testing lab or the entity that is funding the qualification program.

3. Core NCAMP Documents

3.1 Material Property Data Acquisition and Qualification Test Plan

The test plan is designed to acquire material property data for material allowable generation and material qualification purposes. A unique test plan is usually created for each material system (i.e. combination of resin and reinforcement form). The test plan shall contain sufficient details and requirements such as test temperature, test method standards, and specimen configurations. Generally, the material properties are intended to be shared within many aerospace companies for a wide range of applications. The test matrices are intended to generate base-level, building block lamina and laminate data that are of common usefulness; consequently, the material property data may not fulfill all the requirements of any specific application. Additional testing may be required for specific properties, environments, laminate architecture, and loading situations of individual applications. Material specifications are linked to the material allowables through material specification limits that are derived from the material property data using the methodology of reference [3].

3.2 Material Specifications

The material specification and its associated detail specifications typically establish the requirements for continuous unidirectional and fabric impregnated with a modified B-

staged resin ("unidirectional tape and fabric prepreg"), carbon fiber tow, or carbon fiber fabric.

The specifications include specification limits which are derived from the qualification data and consultation with participating NCAMP MAB members and suppliers. In general, the specification limits are derived from qualification data using probability of rejecting a good property (α) of 0.01 (1%), per DOT/FAA/AR-03/19 and CMH-17 recommendation.

The products are usually produced in accordance with an NCAMP approved Process Control Document (PCD), as described in section 3.4 below.

To facilitate the conversion of NCAMP Material Specifications (NMS) to SAE Aerospace Material Specifications (AMS), the NMS's generally follow the SAE AMS material specification format described in SAE's "EDITORIAL STYLE MANUAL FOR THE PREPARATIION OF AEROSPACE MATERIIAL SPECIIFIICATIIONS (AMS)." Each resin system is generally assigned a unique base NMS number. Each product form (i.e. fiber reinforcement form) associated with the resin system is usually assigned a unique detail specification number (a.k.a. slash sheet). In order to comply with AMS format, trade names will not be included in the title or content of the specification. Trade names may be included in parentheses or the Qualified Products Listing only.

Each detail specification shall include a Qualified Products Listing (QPL) to uniquely identify the material name, manufacturer, and manufacturer address. In some QPLs, such as in the carbon fiber QPL, the carbon fiber production line number may be identified also. Since NCAMP will not be qualifying *alternate* materials, most QPLs will contain one material only. QPLs that contain more than one product will utilize classifications such as grade, style, and type to uniquely identify each product.

3.3 Process Specifications

The process specification describes the methods of fabricating test panels for use in material qualification, equivalency, and acceptance testing. A unique process specification is usually created for each resin system. At minimum, the process specification shall contain sufficient information about the panel fabrication process such as tooling, bagging materials, bagging procedures, and cure cycle to ensure the production of consistent and repeatable quality test panels.

This specification does not contain all the necessary information typically required in a composite process specification for the fabrication of aircraft composite structures, such as ply/core splicing procedures, personnel qualification, and layup room requirements. Users should refer to their existing company process specification for such information. DOT/FAA/AR-02/110 provides guidance for the development of composite process specifications.

3.4 Process Control Documents (PCD)

A PCD is a "recipe" for the production of materials that conforms to NCAMP Material Specification (NMS) requirements. It is used in conjunction with material specifications to control the material properties and quality. There are many rules associated with the creation, maintenance, and usage of a PCD.

To aid material manufacturers in creating and maintaining process control documents for a given material, NCAMP has created (1) NRP 101 "Prepreg Process Control Document Preparation and Maintenance Guide," and (2) NRP 102 "Polyacrylonitrile-Based Carbon Fiber Process Control Document Preparation and Maintenance Guide,"

These documents serve as a guide for prepreg material suppliers to prepare and maintain a prepreg PCD. It also serves as a review, approval, and auditing guide for the NCAMP Manufacturers Advisory Board (MAB), NCAMP Regulatory Governing Board (RGB), and NCAMP staff members.

3.5 Material Property Data Report

The material property data report contains material property data only. Generally, a unique material property report is created for each test plan. The data report must be accepted by the NCAMP AER(s) responsible for witnessing the tests. Material data reports shall be generated in accordance with the procedures provided in CP8122 Procedures for Generating Material Property Data Reports.

3.6 Qualification Statistical Analysis Report

The qualification statistical analysis report contains statistically-based material allowable numbers such as B-basis values. Generally, a unique statistical analysis report is created for each material property data report. The material allowables are calculated using the latest CMH-17 approved spreadsheet macros such as ASAP and STAT17, procedures, and guidelines. Qualification statistical analysis reports shall be generated in accordance with the procedures provided in CP8128 Procedures for Generating Statistical Analysis Reports.

3.7 Equivalency Test Plan

Equivalency test plans are used to generate a small set of material properties for statistical comparison with a larger dataset, typically the qualification dataset. A unique test plan is usually created for each equivalency program. Generally, the test methods and requirements are identical to those used in the original qualification program. The test plan shall specify the purpose of the equivalency program. More information about equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of MIL-HDBK-17-1F.

3.8 Equivalency Statistical Analysis Report

The equivalency statistical analysis report contains statistical comparison of datasets, typically between equivalency dataset and original qualification datasets. The comparison is usually performed using HYpothesis Testing of EQuivalence (HYTEQ) spreadsheet which uses DOT/FAA/AR-03/19 and CMH-17 test statistics for equivalency comparisons. For determining material equivalency, the probability of rejecting a good property (α) is usually set at 0.05 (5%), per DOT/FAA/AR-03/19 and CMH-17 recommendation, for all test methods that utilize the test statistics. One retest is allowed for each property, reducing the actual probability to 0.0025 (0.25%). Equivalency statistical analysis reports shall be generated in accordance with the procedures provided in CP8128 Procedures for Generating Statistical Analysis Reports.

3.9 NCAMP Forms

Various NCAMP forms are used during the material qualification, property acquisition, and equivalency processes. The sub-sections below describe the uses and purposes of the NCAMP forms. The term "company" typically refers to the companies fabricating the test panels. The term "material supplier" typically refers to the material manufacturers or suppliers. AERs and AIRs are responsible for submitting the completed forms to NCAMP.

3.9.1 NCAMP FORM 289-3 ENGINEERING ACCEPTANCE

This form should be submitted by an AER to NCAMP under the following circumstances:

1. For the purposes of showing that the AER has reviewed documents such as material specification, process specification, and test plans and is recommending acceptance of the documents for a given test program. Note: AER cannot accept test plans; AER can only recommend acceptance of test plans.

2. For the purposes of showing that the AER has witnessed the material testing and is accepting the data for a given test program. AERs are typically requested to witness the testing of at least one specimen per test method per test condition per test program. An AER may elect to witness the testing of more or less specimens at the sole discretion of the AER.

3.9.2 NCAMP FORM 168-10 REQUEST FOR INSPECTION VERIFICATION

This form should be submitted to an NCAMP AIR under the following circumstances:

1. By an NCAMP AER or NCAMP for the purpose of obtaining inspection verification on test panels created for a material qualification and/or equivalency program utilizing a material which could be used on an aircraft.

2. By an NCAMP AER or NCAMP for the purpose of obtaining inspection verification on test specimens in a material qualification and/or equivalency program which could be utilized on an aircraft.

This form must contain instructions of sufficient detail to allow for effective inspection verification. The "Instruction Guide for NCAMP 168-10 Request for Inspection Verification" contains generic inspection verification instructions.

3.9.3 NCAMP FORM 168-1 INSPECTION VERIFICATION RECORD

This form should be completed and signed by the company or laboratory performing the tasks (e.g. panel fabrication or specimen fabrication) and an NCAMP AIR under the following circumstances:

1. Inspection and inspection verification on test panels created for a material qualification and/or equivalency program utilizing a material which could be used on an aircraft. The company (typically an aerospace company fabricating test panels) will state that the test panels have been fabricated in accordance with applicable requirements of test plan and material & process specifications. The NCAMP AIR will conduct inspection verification in accordance with the instructions that accompany NCAMP Form 168-10 Request for Inspection Verification. The company and/or NCAMP AIR will document the deviations, if any, in NCAMP Form 168-1. The NCAMP AIR will sign and return NCAMP Form 168-1 to NCAMP.

2. Inspection and inspection verification on test specimens (including fastener torque verification when necessary) for a material qualification and/or equivalency which could be utilized on an aircraft. The laboratory will state that the test specimens are in accordance with applicable requirements of test plans. The NCAMP AIR will conduct inspection verification in accordance with the instructions that accompany NCAMP Form 168-10 Request for Inspection Verification. The company and/or NCAMP AIR will document the deviations, if any, in NCAMP Form 168-1. The NCAMP AIR will sign and return NCAMP Form 168-1 to NCAMP.

If certain inspection tasks have been performed by qualified personnel and records of the inspection are available for verification, the AIR may elect to perform verification on the inspection record and need not repeat the entire inspection tasks again, at the sole discretion of the AIR.

4. Material Qualification and Property Data Acquisition Process

Considerable amount of research & development and shop trials must have taken place prior to the production of qualification material to ensure that the material and process are sufficiently robust to produce high quality test panels and complex aerospace parts. For newly developed materials or processes, discriminatory panels measuring about 3 feet by 4 feet, reminiscent of the intended aerospace parts with complex features such as thick/thin sections, ply drop-offs, curvatures, integral stiffeners, and cocure/cobond

sections, are typically used to demonstrate the robustness. Material property data acquisition and qualification program should begin only after both the material and process are mature. The discriminatory panels are usually instrumented with thermocouples at suspected cold and hot spots during cure to reveal potential heat transfer issues and exothermic reactions. The panels are usually inspected for quality using ultrasonic and then sectioned into subpanels and specimens for additional tests such as photomicrograph, void content, resin content, cured ply thickness, and glass transition temperature, with particular attention given to geometrically complex areas.

The initial material qualification and property data acquisition process is delineated in Figure 2, which begins with the creation of *draft* versions of the following NCAMP documents:

1. Material Property Data Acquisition and Qualification Test Plan
2. Material Specification
3. Process Specification

Additional information about the documents is provided in section 3. The documents of previous programs that have been reviewed by NCAMP members are usually used as "templates" to create the draft documents for new programs; changes are made to reflect the unique nature of the new material or process requirements of the new material system. If the program is qualifying a new material form or new manufacturing process that has never been previously qualified by NCAMP, NCAMP may hire subject matter expert(s) to assist in the creation of the draft documents. The cost of qualifying a new material form or manufacturing process can be substantial due to the need to conduct research to develop awareness and understanding of the new material and process. The participants of the program, which includes MAB members and the material supplier, will review the draft documents. After their comments are incorporated, the documents are *released* under revision control and sent to NCAMP AER for review. The documents may be revised based on the comments from the NCAMP AER. The NCAMP AER will recommend approval of the documents to the program participants using NCAMP Form 289-3. All the program participants, which include at least an MAB member and at least a SAB member, must agree with and authorize approval of the documents. NCAMP staff will sign the approval of the documents on behalf of the members after obtaining their approval authorization, which could be in the form of an email or letter. At this stage, most material specification limits are labeled as "TBD" (or To Be Determined) because the limits will be derived from the actual material property data that will be obtained from the project. NCAMP will stamp the material specification with "FOR TEST USE ONLY."

The material supplier must prepare a Process Control Document (PCD) to produce the qualification and production prepreg material in accordance with section 3.4. The PCD must be released under revision control prior to the production of the qualification material. However, at this stage, the PCD is approved for the production of the qualification material and material that will be used for other experimental purposes only.

The mechanical test panels are typically fabricated by aircraft companies, composite part fabricators, or material suppliers. Panel fabrication will not begin until after the material

and process specifications and test plan are approved, and the NCAMP AIR has received the NCAMP Form 168-10 Request for Inspection Verification. The request will contain specific inspection instructions for panel fabrication. The AIR will complete NCAMP Form 168-1 Inspection Verification Record. If deviation(s) is reported by the panel fabricator or found by the AIR, the deviation(s) must be dispositioned by the AER (with consultation with participating MAB, if needed). The AER and participating MAB may decide to use the test panels "as-is" or have the test panels re-fabricated/reworked and then re-inspected.

The test panels along with the completed Form 168-1 and 168-10 for test panel fabrication must be sent to the appropriate locations as specified by NCAMP. The test panels are typically inspected for thickness, warpage, and outer ply orientations prior to through-transmission ultrasonic inspection. NCAMP is usually involved in reviewing the results before sending the test panels to the laboratory for machining into test specimens. The AIR will receive Form 168-10 for test specimen inspection verification which contains a specific inspection checklist. The AIR will complete NCAMP Form 168-1 Inspection Verification Record for test specimens. If deviation(s) is reported by the laboratory or found by the AIR, the deviation(s) must be dispositioned by the AER (with consultation with participating MAB, if needed). The AER and participating MAB may decide to use the test specimens "as-is" or have the test specimens re-fabricated/reworked and then re-inspected. The AER will witness the test and accept/reject the data using Form 289-3. If the data is contained in a material property data report, the Form 289-3 may reference the data report number. Once the data is accepted by the AER, NCAMP may begin the statistical analysis, typically in accordance with CMH-17 approved procedures and guidelines. The statistically analysis involves generating material allowables such as b-basis values and material specification limits. The material supplier will revise their PCD to include the specification limits. The participating MABs will be asked to review the PCD and audit the supplier again, and review all NCAMP-generated draft documents. After NCAMP has resolved or incorporated all the comments, NCAMP staff will sign the PCD on behalf of the MAB members and release all NCAMP documents.

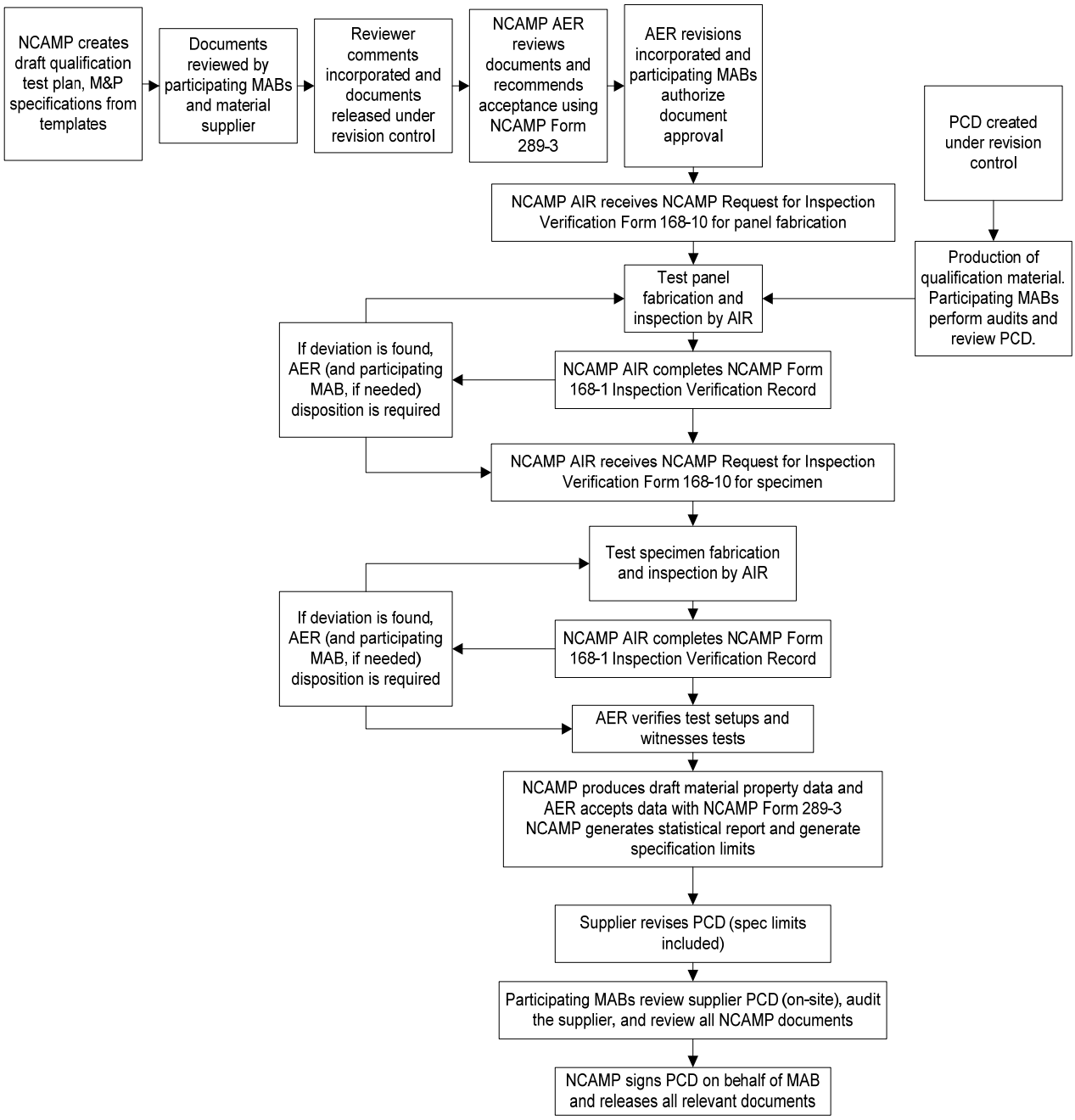

Figure 2. Flowchart of Material Qualification and Property Data Acquisition Process

4.1 Benefits and Cost-Sharing

The NCAMP industry-shared material property database approach aims to create a standardized approach for material qualification, material property data acquisition, and material allowables generation. The approach pools expertise from the aerospace industry while eliminating redundant material qualification and material property data

generation efforts. It also promotes "One Material One Specification" system which is more efficient than the system it tries to replace where multiple material specifications are created by individual aerospace companies for essentially the same material.

These benefits translate directly to MAB members and other part fabricators in the form of reduced testing efforts and more efficient use of resources. Material screening test program is often reduced or eliminated. The MAB members can begin preliminary design phase earlier based on published data so there is a reduced-time benefit as well. The cost of utilizing the "pre-qualified" material property data, allowables, and specifications through a process known as equivalency, as described in section 5 below, is often about 10% to 15% of the cost of a new material qualification and allowables program.

Since the materials that have properties in NCAMP industry-shared material property database require less effort to employ in aerospace applications, they are often the materials that aerospace companies consider first. In addition to improved marketability, material suppliers also benefit by being able to produce a standard product with standard properties such as fiber areal weight and resin content that appeal to multiple customers, rather than custom manufacturing the materials based on slightly unique requirements of individual customers. The aerospace companies, in turn, also benefit by improved material availability by being able to purchase the material "off-the-shelf" rather than having to wait for custom manufacturing schedule.

The RGB members benefit from NCAMP industry-shared database by being able supervise the material qualification and property data generation programs at the procedural levels to ensure compliance with applicable regulations and/or requirements, as opposed to at the individual programs level where more resources will be needed. The Department of Defense and NASA members, as users of aerospace vehicles, will also benefit from the cost and time savings offered by the shared property database process.

5. Equivalency Process for Part Fabricators

Part fabricators that wish to utilize an existing "pre-qualified" material property data, allowables, and specifications may be able to do so by demonstrating the capability to reproduce the original material properties; a process known as equivalency. More information about this equivalency process including the test statistics and its limitations can be found in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of MIL-HDBK-17-1F. The applicability of equivalency process must be evaluated on program-by-program basis by the applicant and certifying agency. The applicant and certifying agency must agree that the equivalency test plan along with the equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of MIL-HDBK-17-1F are adequate for the given program.

In general, panels using one batch of material procured to the same material specification will be fabricated by the follow-on fabricator in accordance with the appropriate NCAMP process specification. The one-batch material properties will be statistically compared

with those obtained from the original material qualification. The purpose is to demonstrate that the follow-on part fabricator is capable of processing the material and producing test panels with properties equivalent to those of the original qualification. The equivalency process described in Section 6 of DOT/FAA/AR-03/19 and Section 8.4.1 of MIL-HDBK-17-1F are designed to evaluate "minor" changes only. Major changes may render the equivalency process inadequate. In addition, the applicant and certifying agency must examine the differences, if any, between the original test panel fabricator and the follow-on fabricator to make sure that the equivalency test plan is sufficient and adequate to investigate and substantiate their differences. A common type of difference is elevation levels of the fabrication sites; the original test panels may have been fabricated at sea level and the equivalency test panels might be fabricated at a higher elevation, such as at Denver, Colorado. Since out-of-autoclave cure systems might be sensitive to elevation level, the equivalency test plan must be tailored to examine the potential negative impact of changes in elevation level.

The equivalency program is delineated in Figure 3, which generally begins with the creation of a *draft* version of an Equivalency Test Plan. The material specification and process specification are usually the same as those in the qualification program; any deviation should be clearly noted in the applicable documents. The participating applicant and certifying agency must accept the deviation. The documents of a previous program that have been reviewed by NCAMP members are usually used as the "template" to create the draft documents for new programs. The participants of the program will review the draft documents. After their comments are incorporated, the documents are *released* under revision control and sent to an NCAMP AER for review. The documents may be revised based on the comments from the NCAMP AER. The NCAMP AER will recommend approval of the documents to the program participants using NCAMP Form 289-3. All the program participants must agree with the documents and provide authorization to NCAMP to *approve* the documents.

The mechanical test panels are typically fabricated by an applicant or composite part fabricator that is seeking to demonstrate equivalency. Panel fabrication typically should not begin until after the test plan is approved, and the NCAMP AIR has received the NCAMP FORM 168-10 Request for Inspection Verification. The request will contain specific inspection instructions for panel fabrication. The AIR will complete NCAMP Form 168-1 Inspection Verification Record. If deviation(s) is reported by the panel fabricator or found by the AIR, the deviation(s) must be dispositioned by the AER (with consultation with participating MAB, if needed). The AER and participating MAB may decide to use the test panels "as-is" or have the test panels re-fabricated/reworked and then re-inspected.

The test panels along with the completed Form 168-1 and 168-10 for test panel fabrication must be sent to the appropriate locations as specified by NCAMP. The test panels are typically inspected for thickness, warpage, and outer ply orientations prior to through-transmission ultrasonic inspection. NCAMP is usually involved in reviewing the results before sending the test panels to the laboratory for machining into test specimens. The AIR will receive Form 168-10 for test specimen inspection verification which

contains a specific inspection checklist. The AIR will complete NCAMP Form 168-1 Inspection Verification Record for test specimens. If deviation(s) is reported by the laboratory or found by the AIR, the deviation(s) must be dispositioned by the AER (with consultation with participating MAB, if needed). The AER and participating MAB may decide to use the test specimens "as-is" or have the test specimens re-fabricated/reworked and then re-inspected. The AER will witness the test and accept/reject the data using Form 289-3. If the data is contained in a material property data report, the Form 289-3 may reference the data report number. Once the data is accepted by the AER, NCAMP may begin the statistical analysis, typically in accordance with CMH-17 approved procedures and guidelines. The statistically analysis involves comparing the baseline/qualification dataset with the equivalency dataset. The participating MABs will be asked to review the both reports. After NCAMP has resolved or incorporated all the comments, NCAMP staff will release the NCAMP material property report and statistical analysis report. Equivalency reports are usually treated as customer-proprietary documents by NCAMP.

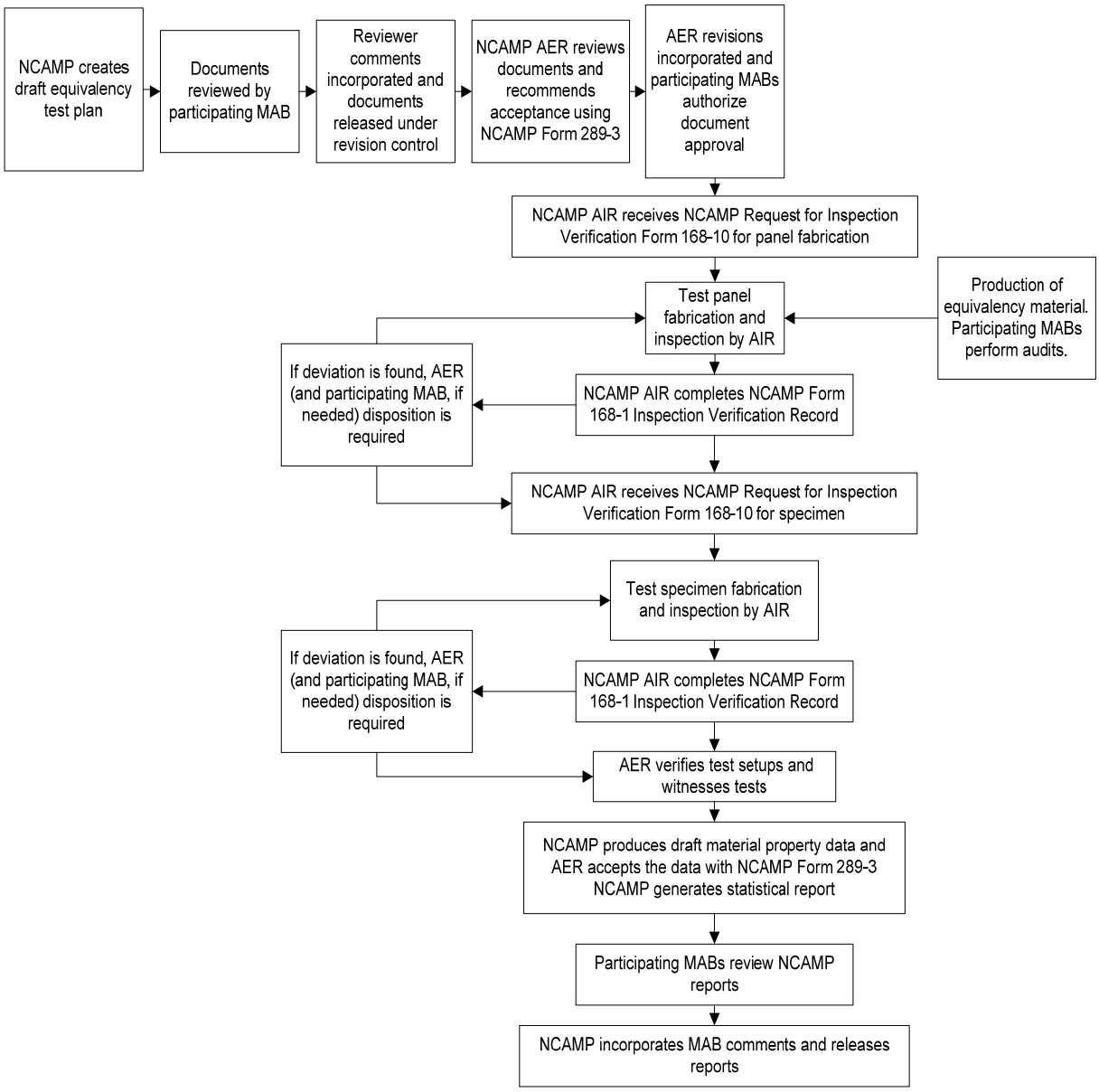

Figure 3. Flowchart of Equivalency Process for Part Fabricators

6. Pre-existing Material Property Datasets

Materials that have been previously qualified for certified applications, commercial or military, may be incorporated into NCAMP shared material property database if pedigree information and material control requirements *equivalent* to those described in this document exist. The procedures for managing such programs, including document review and approval, generally follow those described in section 4 also. The frequency of such activity is expected to be very low because NCAMP will generally refer the data

submitter to CMH-17 secretariat. NCAMP will analyze pre-existing datasets only when CMH-17 secretariat is unable to do so, for reasons such as resource or budget constraints. Every NCAMP document generated based on the pre-existing material property dataset will contain pedigree information about the data source. Users must evaluate the pedigree information to determine the suitability of the data for their applications.

7. Maintenance of Existing Shared Material Properties Database

A material supplier is expected to comply with the quality control and statistical process control requirements per applicable NCAMP material specifications. Routine facility audit is the responsibility of material users, although NCAMP is working with Nadcap to create a more streamlined supplier audit process.

The supplier PCDs must be maintained in accordance the NCAMP PCD preparation and maintenance guides, document number NRP 101 or 102.

Revisions to NCAMP material specifications, process specifications, material property data reports, and material allowables reports must be in accordance with Figure 4. NCAMP begins the process by creating draft document(s) with "Track Changes" turned on, along with a detailed description of and reason for the change. The documents will be uploaded to NCAMP Portal where members will receive email notification of the revision process and instructions on how to download the document(s).

The members will be given approximately 2-3 weeks to review and provide comments. NCAMP will incorporate the comments and, if necessary, schedule teleconference or meeting to discuss the revision. Members may request a teleconference or meeting to discuss the revision. After the comments have been resolved, the members will be asked to vote (e.g. affirmative, negative, or abstain) on the revision. The ratio of affirmative to negative votes must be at least 75% for the revision to stand. This voting process is optional for editorial, typographical error, and computational corrections. Changes requested by RGB members designed to meet regulatory requirements are also exempted from this voting process.

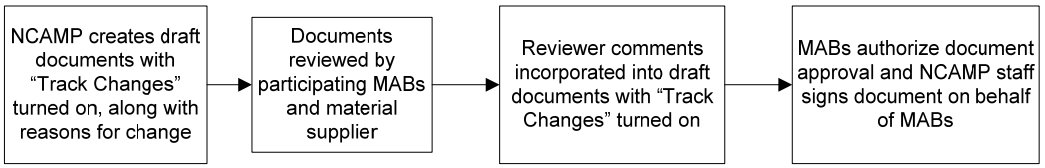

Figure 4. Flowchart of NCAMP Document Revision Process

8. References

[1] DOT/FAA/AR-07/3 – Guidelines and Recommended Criteria for the Development of a Material Specification for Carbon Fiber/Epoxy Unidirectional Prepregs Update

[2] DOT/FAA/AR-06/10 - Guidelines and Recommended Criteria for the Development of a Material Specification for Carbon Fiber/Epoxy Fabric Prepregs

[3] DOT/FAA/AR-03/19 – Material Qualification and Equivalency for Polymer Matrix Composite Material Systems: Updated Procedure

[4] DOT/FAA/AR-02/109 - Guidelines and Recommended Criteria for the Development of a Material Specification for Carbon Fiber/Epoxy Unidirectional Prepregs