THE COMPOSITE MATERIALS HANDBOOK (CMH-17) (VOLUME 3, CHAPTER 3)

"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

- **BACKGROUND**

  - GENERAL ENVIRONMENT
  - THOUGHTS PROCESSES
  - WORKING GROUP
  - DEVELOPMENT EXECUTION

- **CMH-17 V3C3 (DRAFT)**

  - SECTIONS 1 THRU 5 (LESTER_C)
  - SECTION 6 (SIMON_W)

- **Q&A (DISCUSSION)**

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

- **GENERAL ENVIRONMENT**

  - IN RECENT YEARS, COMPOSITE UTILISATION HAS EXTENDED RAPIDLY AND EXTENSIVELY INTO AVIATION PRIMARY AND CRITICAL STRUCTURES – INCLUDING LARGER PASSENGER STRUCTURES.

  - INDUSTRY KNOWLEDGE HAS BEEN FRAGMENTED UNTIL RECENT YEARS.

  - CACRC HAS BEEN DOING A GOOD JOB FOR MANY YEARS TO CORRECT SOME ASPECTS OF THIS - BY LINKING OEM/OPERATORS/ SUPPLIERS/REGULATORS.

  - FAA HAS ACCELERATED THE PROCESS THROUGH ITS CS&CI PROCESS AND BY USING CMH-17 TO LINK OTHER KEY ORGANIZATIONS (E.G., CACRC, ASTM, SAMPE, ETC.).

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- **GENERAL ENVIRONMENT (CONT.)**

  - ALSO, DATA IS BEING GENERATED IN MANY OTHER ACTIVITIES, E.G.

  ^ MAINTENANCE AND DAMAGE TOLERANCE WORKING GROUP (FAA/EASA/BOEING/AIRBUS)

  ^ CACRC MAINTENANCE AND TRAINING GUIDANCE

  - AS USE OF COMPOSITE MATERIALS IN CIVIL AVIATION IS NOW STARTING TO MATURE – WE NEED TO COLLATE AND DEVELOP A COMMON COHERENT REFERENCE TO HELP STANDARDIZE APPROACHES.

  - ONE OF THE MOST USEFUL MEANS TO DEVELOP, AND MAKE READILY AVAILABLE, MUCH OF THIS INFORMATION IS CMH-17.
  NOTE: CMH-17 REVISION G IS DUE FOR 2008.

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- **GENERAL ENVIRONMENT (CONT.)**

  - FURTHERMORE, OTHER COMPOSITE REGULATORY AND GUIDANCE DOCUMENTS ARE DUE FOR REVISION (E.G., AC20-107A/ CS 25.603 AMC NOTE 1)

  - THEREFORE, WE CAN ALSO USE THE NEED TO REVISE CMH-17 AS A TOOL TO COLLATE DATA AND PROVIDE AN INDUSTRY SUPPORT BASE FOR THE DEVELOPMENT OF AMENDMENTS TO REGULATORY AND GUIDANCE MATERIAL.

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

- **THOUGHTS PROCESSES**

  - **GLOBAL EFFORTS:**

    ^ **Regulatory Authorities – FAA, EASA & TCCA**
    ^ **Industry Participation – OEMs & Operators**
    ^ **Organizations Support – (e.g., CMH-17, CACRC, ASTM, NCAMP, SAMPE, etc.)**

  - **CERTIFICATION FOCUS:**

    ^ **Integrated Approach – Design, Production & Maintenance**
    ^ **Potential Standardization – Guidance & Training**

  - **CONTENTS BALANCE (W.R.T):**

    ^ **Regulations (FAA, EASA, TCCA)**
    ^ **Aircraft Categories (Parts 23, 25, 27, 29)**
    ^ **Sibling V3 Chapters (e.g., C-1, C-2, C-12, C-14)**

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- **WORKING GROUP**

  - **REGULAR MEMBERS:**

    ^ **FAA: LARRY_I (CS&TA), ANGIE_K, LESTER_C**
    ^ **EASA: SIMON_W**
    ^ **TCCA: ALAIN_D**
    ^ **LBA: MARTIN_B**

  - **INDUSTRY PARTICIPANTS INCLUDING:**

    ^ **AIRBUS : CHANTAL FUALDES, PAOLA CARACCIOLO**
    ^ **CACRC/OPERATORS: CARLOS BLOHM**
    ^ **CANADA INDUSTRY**
    ^ **USA INDUSTRY**

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- **WORKING GROUP - CHAPTER**

  - **TO ESTABLISH A GUIDANCE (CHAPTER) AIMING TO:**

    ^ **Provide Top Level Guidance to the Regulations**
    ^ **Provide Guidance Regarding Basic Certification Process**
    ^ **Provide Guidance of Showing "Means of Compliance"**
    ^ **Provide a Base of Updating AC20-107A/AMC Note 1 CS25.603**

  - **TARGET AUDIENCE INCLUDES OEMS, OPERATORS, REGULATORS, AND MORE SPECIFICALLY WITHIN THEM:**

    ^ **Those new/recent to certification**
    ^ **Those new/recent to composites**
    ^ **Those new/recent to particular aspects of either composites and/or certification**
    ^ **Those would like to refresh their knowledge**

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- **DEVELOPMENT EXECUTION**
  - **WORKING MEETINGS**
    - ^ **COLOGNE/GERMANY MEETING - JAN/2007 [HOSTED BY EASA]**
    - ^ **OTTAWA/CANADA MEETING - JUN/2007 [HOSTED BY TCCA]**
    - ^ **CHICAGO/USA MEETING – AUG/2007 [HOSTED BY FAA]**
  - **DELIVERABLE (CMH-17: V3C3)**
    - ^ **V3C3 DRAFT WAS SUBMITTED TO CMH FOR REVIEW (YELLOW PAGE PROCESS) IN OCT/2007.**
    - ^ **FURTHER REVIEW/DISCUSSION WILL BE HELD IN CMH-17 MEETING [JAN/2008].**
    - ^ **V3C3 TO BE CONTAINED IN CMH-17 [REV G, 2008].**

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

TABLE OF CONTENTS - SECTIONS

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

THOUGHTS CONTAINED IN SECTION 3.1

3.1 INTRODUCTION

3.1.1 General (Background)

3.1.2 Purpose and Scope

- Certification requirements are used to guard the safety of civil aviation by regulators (e.g., FAA, EASA & TCCA).

- Certification processes apply to design, manufacturing and maintenance (repair).

- Integral consideration of these certification functions would further enhance the overall aviation safety in particular for composites.

- Expanded use of composites has prompted the collaborated effort of international community (industry and regulators) to establish engineering standards and guidance.

- This chapter is intended to be a general guidance to promote safe and effective use of composites in aircraft.

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

THOUGHTS CONTAINED IN SECTION 3.2

3.2 CERTIFICATION CONSIDERATIONS

3.2.1 PRODUCT DEVELOPMENT (INITIAL AIRWORTHINESS)

3.2.2 CONTINUED AIRWORTHINESS (MAINTENANCE/REPAIR)

3.2.3 PRODUCT MODIFICATION (CHANGED PRODUCT)

3.2.4 QUALIFIED WORKFORCE AND TEAMWORK

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- Safe operation of aircraft starts with aircraft airworthiness. The development and substantiation of composite aircraft structure requires close coordination between design, manufacturing, and maintenance.

- Product substantiation involves a combination of tests and analyses at different scales of study. A building block approach is often used for this substantiation.

- The successful completion of type certification implies that the aircraft design meets the airworthiness requirements. Manufacturing aircraft in a facility holding a valid production certificate implies the aircraft can be fabricated as designed.

THOUGHTS CONTAINED IN SECTION 3.2 (CONT.)

3.2 CERTIFICATION CONSIDERATIONS

3.2.1 PRODUCT DEVELOPMENT (INITIAL AIRWORTHINESS)
3.2.2 CONTINUED AIRWORTHINESS (MAINTENANCE/REPAIR)
3.2.3 PRODUCT MODIFICATION (CHANGED PRODUCT)
3.2.4 QUALIFIED WORKFORCE AND TEAMWORK

- "Continued airworthiness" is referred to when an aircraft enters service. Repairs and continued airworthiness procedures must be provided in service documents.

- Accidental damage (e.g., foreign object impact) is a critical threat for composites. Manufacturing flaws need to be considered. Degradation & damage caused by environmental effects and fluid compatibility for the particular composite material needs to be evaluated.

- Repairs are classified as "major" and "minor". Further discussions are presented in text.

- Documentation identifying all critical inspection items should be put together to support maintenance.

- Maintenance instructions need to include material and process controls, fabrication steps, cured-part tolerances, non-destructive inspection (NDI) and other quality control checks for bonded repair.

THOUGHTS CONTAINED IN SECTION 3.2 (CONT.)

3.2 CERTIFICATION CONSIDERATIONS

3.2.1 PRODUCT DEVELOPMENT (INITIAL AIRWORTHINESS)
3.2.2 CONTINUED AIRWORTHINESS (MAINTENANCE/REPAIR)
3.2.3 PRODUCT MODIFICATION (CHANGED PRODUCT)
3.2.4 QUALIFIED WORKFORCE AND TEAMWORK

- There exists the need to alter the product to accommodate changes in aircraft utilization after entering service.

- There are procedural requirements for certifying the changes of product to continue to ensure the airworthiness and safe operation of the aircraft

- Changes in type design are normally classified as “minor” and “major”. Further discussions are presented in text.

- International community agreed to a rule on the designation of applicable regulations for product design changes. This rule is known as the “Changed Product Rule” [i.e., 14 CFR 21.101 for FAA, IR Part 21.101 for EASA, and Part V (Section 511.14 and 513.14) of the CARs for TCCA.

- To correct unsafe condition, a mandated design change may be required via Airworthiness Directives (ADs) [i.e., 14 CFR Part 39 for FAA, IR 21A.3B for EASA, and CAR 593 for TCCA].

THOUGHTS CONTAINED IN SECTION 3.2 (CONT.)

3.2 CERTIFICATION CONSIDERATIONS

3.2.1 PRODUCT DEVELOPMENT (INITIAL AIRWORTHINESS)
3.2.2 CONTINUED AIRWORTHINESS (MAINTENANCE/REPAIR)
3.2.3 PRODUCT MODIFICATION (CHANGED PRODUCT)
3.2.4 QUALIFIED WORKFORCE AND TEAMWORK

- Successful design, production, and continued airworthiness certification relies upon a qualified workforce that is not only skilled in its own technical activities, but is also well aware of the associated activities.

- There is a heavy reliance on inspection processes and qualified inspectors to ensure that the production of composite parts conform to the design.

- A good balance of team members with engineering experience in composite design, analysis, manufacturing and maintenance practice is needed to coordinate a product development and certification program

- Teamwork is essential to composite maintenance, particularly as associated with the steps involved in aircraft structural inspection, disposition and repair.

- Good communication must exist between the engineering disciplines involved in the continued airworthiness management of composite products in service. Maintenance and operations personnel should have knowledge of factors affecting the performance of composite structure.

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

THOUGHTS CONTAINED IN SECTION 3.3

3.3 REGULATIONS

3.3.1 STRUCTURE, DESIGN AND CONSTRUCTION

3.3.2 PRODUCTION APPROVAL

3.3.3 CONTINUED AIRWORTHINESS (MAINTENANCE)

- For FAA, design requirements for aircraft are called out in the 14 CFR (Title 14 Code of Federal Regulations).

- In general, these requirements are grouped in four categories [i.e., Part 23, Part 25, Part 27, and Part 29].

- EASA rules are called CS (Certification Specifications); TCCA rules are called AWM (Airworthiness Manual) requirements.

- Table 3.3 groups the requirements that are deemed applicable to the various categories of aircraft using composite materials. With the exception of Section 23.573(a), these regulations are generic in nature and applicable to both metal and composite structure.

THOUGHTS CONTAINED IN SECTION 3.3 (CONT.)

3.3 REGULATIONS

3.3.1 STRUCTURE, DESIGN AND CONSTRUCTION

3.3.2 PRODUCTION APPROVAL

3.3.3 CONTINUED AIRWORTHINESS (MAINTENANCE)

- Production certification ensures that the manufacturing facility has a proper quality control system for the fabrication of article that meets the design requirements.

- For FAA, the procedural requirements are contained mainly in 14 CFR Part 21, Subpart G [Production Certificate].

- For EASA, IR Part 21 Subpart G covers production approval. For TCCA, the procedural requirements are contained mainly in AWM Chapter 561- Manufacture of Aeronautical Products.

- Details for production approval requirements are further described.

- Discussions relating to the specifics of composite manufacturing are presented in Section 3.5.

THOUGHTS CONTAINED IN SECTION 3.3 (CONT.)

3.3 REGULATIONS

3.3.1 STRUCTURE, DESIGN AND CONSTRUCTION

3.3.2 PRODUCTION APPROVAL

3.3.3 CONTINUED AIRWORTHINESS (MAINTENANCE)

- Compliance with maintenance requirements is necessary to ensure the continued airworthiness of the aircraft and thus its safe operation.

- FAA has developed a set of regulations pertinent to maintenance. These rules include the general requirements that may apply to various aircraft types and operations [e.g., Parts 43, 145], and any additional requirements that may be deemed specific to operating provisions [e.g., 91, 121, 125].

- Other authorities may use a different set of regulations to achieve the continued airworthiness oversight. Rules for EASA and TCCA are illustrated.

- To support continued airworthiness, ADs are issued to address the mandated requirements that relate to safe operation of aircraft.

- In general, no distinction is made between composite and metallic structures at the regulation level. Considerations specific to composites are presented in Section 3.6.

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

THOUGHTS CONTAINED IN SECTION 3.4

3.4 DESIGN SUBSTANTIATION

3.4.1 DESIGN AND PROCESS DOCUMENTATION
3.4.2 MATERIAL/ADHESIVE QUALIFICATION
3.4.3 ENVIRONMENTAL EXPOSURE AND FLUID COMPATIBILITY
3.4.4 STRUCTURAL BONDING
3.4.5 TOOLS AND PART CURE
3.4.6 FLAWS EXPERIENCED IN PRODUCTION
3.4.7 STRUCTURAL CONFORMITY PROCESS
3.4.8 STRUCTURAL SUBSTANTIATION (STATIC STRENGTH & DAMAGE TOLERANCE)
3.4.9 FLUTTER SUBSTANTIATION (AERO-ELASTIC STABILITY)
3.4.10 FIRE PROTECTION, FLAMMABILITY AND THERMAL ISSUES
3.4.11 LIGHTNING STRIKE PROTECTION
3.4.12 CRASHWORTHINESS

- The regulatory requirements apply equally to any material system used on an aircraft. Nevertheless, the use of composites as opposed to metals, introduces a level of complexity that requires special consideration.

THOUGHTS CONTAINED IN SECTION 3.4 (CONT.)

3.4 DESIGN SUBSTANTIATION

3.4.1 DESIGN AND PROCESS DOCUMENTATION
3.4.2 MATERIAL/ADHESIVE QUALIFICATION
3.4.3 ENVIRONMENTAL EXPOSURE AND FLUID COMPATIBILITY

- Critical materials and processes that affect the integrity of the structure must be traceable to approved material and process specifications.

- Need to have a well established configuration control system to track design changes, link between engineering and production, and quality program.

- All material systems and constituents used in the manufacturing of aircraft parts must be qualified to ensure the control of composite materials and repeatable processes.

- The effects of environmental exposure, which results in changes in structural performance need to be addressed. Environmental effects need to be considered in material qualification and allowables testing.

- Exposure to different types of fluids, and any likely combinations of fluids, that may come into contact with composite parts in service and their effect on strength degradation should be evaluated.

THOUGHTS CONTAINED IN SECTION 3.4 (CONT.)

3.4 DESIGN SUBSTANTIATION

3.4.4 STRUCTURAL BONDING

3.4.5 TOOLS AND PART CURE

3.4.6 FLAWS EXPERIENCED IN PRODUCTION

- Successful application of secondary bonding in aircraft structure depends on a number of material, process and design considerations. Adherend surface preparation plays a critical role in bonded structure.

- The tooling must yield repeatable results throughout a useful life. The tool configuration must be verified on a regular basis to make sure that the tool configuration is maintained per type design.

- Manufacturing procedures need to be in place for monitoring the temperature, vacuum and pressure throughout the cure cycle.

- Design should incorporate sufficient redundancy to account for manufacturing defects, which may not be detected by quality control procedures

- Engineering, manufacturing and quality personnel should jointly study the effects of defects and establish specific allowable defect limits for a particular material system, component, laminate design, detailed part, or assembly.

THOUGHTS CONTAINED IN SECTION 3.4 (CONT.)

3.4 DESIGN SUBSTANTIATION

3.4.7 STRUCTURAL CONFORMITY PROCESS

3.4.8 STRUCTURAL SUBSTANTIATION (STATIC STRENGTH & DAMAGE TOLERANCE)

3.4.9 FLUTTER SUBSTANTIATION (AERO-ELASTIC STABILITY)

- Composite part construction is process dependent and requires in-process conformity. Conformity begins at the incoming inspection for the materials and continues with test specimens for the coupon level up to the full-scale components.

- Structural static strength of a composite design considers critical load cases and associated failure modes, effects of the environment, repeated loading, manufacturing tolerance, and material and process variability.

- The damage tolerance and fatigue evaluation help establish procedures that allow the composite structure to retain the intended ultimate load capability when subjected to possible damage scenarios and expected fatigue loads during its operational life. Further discussions are presented.

- Aircraft structure needs to be free from flutter. The substantiation of composite structure needs to account for the effects of repeated loading, environment exposure, and service damage scenarios (e.g., large disbonds, water ingression) on critical properties (e.g., stiffness, mass, damping).

THOUGHTS CONTAINED IN SECTION 3.4 (CONT.)

3.4 DESIGN SUBSTANTIATION

3.4.10 FIRE PROTECTION, FLAMMABILITY AND THERMAL ISSUES

3.4.11 LIGHTNING STRIKE PROTECTION

3.4.12 CRASHWORTHINESS

- Flammability tests need to be conducted for interior parts. Interior parts made from composites must not add to the fire or release toxic fumes that pose safety threats to the passengers.

- Exterior fire protection issues associated with fuselage structure must include the effects of an exterior pool fire following a survivable crash landing.

- Attention should be paid to the protection of composite fuel tanks both during a fire in flight and during a post crash fire.

- Carbon composite structure has a much higher electrical resistance compared to aluminum structure. Caution is required when designing critical structures (e.g., wing, fuselage, fuel systems), and associated repairs, both external and internal (e.g., in fuel tanks).

- The design of the airframe should assure that occupants have every reasonable chance of escaping serious injury under realistic and survivable impact conditions.

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THOUGHTS CONTAINED IN SECTION 3.5

3.5 PRODUCTION - ESSENTIALS

3.5.1 PRODUCTION IMPLEMENTATION

3.5.2 MANUFACTURING QUALITY CONTROL

3.5.3 DEFECT DISPOSITION AND MANUFACTURING RECORDS

3.5.4 MODIFICATION OF PRODUCTION PROCESS

- It is crucial to identify and control the key manufacturing steps that ensure a consistent and repeatable product over time.

- Composite material and component manufacturing occur simultaneously. Conformity must be confirmed throughout the fabrication and assembly process. This is particularly important for large integrated composite structures with reduced part count.

- Production of similar parts at many facilities requires the proper consideration of any possible differences in materials, tooling and equipment.

THOUGHTS CONTAINED IN SECTION 3.5 (CONT.)

3.5 PRODUCTION - ESSENTIALS

3.5.1 PRODUCTION IMPLEMENTATION
3.5.2 MANUFACTURING QUALITY CONTROL
3.5.3 DEFECT DISPOSITION AND MANUFACTURING RECORDS
3.5.4 MODIFICATION OF PRODUCTION PROCESS

- The necessary manufacturing control steps are a function of the production methods used and will be defined via engineering and production planning processes and monitored through a quality program.

- An appropriately trained and qualified workforce is essential for manufacturing control, both with respect to engineering and production planning, when defining the key manufacturing steps, and with respect to workshop practice.

- Further discussions are presented relating to:
  - ^ Tooling
  - ^ Material storage and handling
  - ^ Lay-up environment
  - ^ Fabrication facility
  - ^ Cure cycle
  - ^ Parts removal & debagging
  - ^ Bonding & bolted assembly
  - ^ Inspection

THOUGHTS CONTAINED IN SECTION 3.5 (CONT.)

3.5 PRODUCTION - ESSENTIALS

3.5.1 PRODUCTION IMPLEMENTATION
3.5.2 MANUFACTURING QUALITY CONTROL
3.5.3 DEFECT DISPOSITION AND MANUFACTURING RECORDS
3.5.4 MODIFICATION OF PRODUCTION PROCESS

- Production substantiation requires the definition and understanding of likely manufacturing defects (structural, geometric, and cosmetic) and their causes.

- Not all defect types (e.g., weak bonds and incorrect ply orientation) can be detected through post process inspection. Other in-process controls, inspection techniques and manufacturing steps are needed to ensure quality.

- The development of reliable quality control procedures and a disposition process requires considerable interaction between the OEM and suppliers. Some interaction with the maintenance facilities and operators should also be expected once the product is in service.

- All acceptable defects and approved repairs that are considered significant should form part of the manufacturing record and be stored by the OEM and/or suppliers. Defect records should also be communicated to the operator.

THOUGHTS CONTAINED IN SECTION 3.5 (CONT.)

3.5 PRODUCTION - ESSENTIALS

3.5.1 PRODUCTION IMPLEMENTATION
3.5.2 MANUFACTURING QUALITY CONTROL
3.5.3 DEFECT DISPOSITION AND MANUFACTURING RECORDS
3.5.4 MODIFICATION OF PRODUCTION PROCESS

- The revision approval process must be robust, including documentation and recording processes. The process must also ensure that that all necessary parties have been involved (i.e., both in the organizational and technical sense). These activities are crucial to maintain proper configuration control of the type design.

- Suppliers should have agreed procedures with the OEM for change classification, ranging from different levels of minor to major. Any major changes will require additional structural design substantiation.

- Agreements on significant production modifications should clearly identify all changed steps and a joint assessment of the potential impact upon the product from production through to service.

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

THOUGHTS CONTAINED IN SECTION 3.6

3.6 MAINTENANCE - TECHNICAL ISSUES

3.6.1 REPAIR DESIGN AND PROCESS SUBSTANTIATION

3.6.2 TEAMWORK AND DISPOSITION

3.6.3 DAMAGE DETECTION AND CHARACTERIZATION

3.6.4 REPAIR PROCESSES (BONDED VS. BOLTED)

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DATA CONTAINED IN SECTION 3.7

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"AIRCRAFT STRUCTURE CERTIFICATION AND COMPLIANCE"

WE THANK FOR YOUR PARTICIPATION

YOUR WISDOM HAS MADE IT HAPPEN

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WE SHALL COUNT ON YOUR CONTINUED SUPPORT FOR UPDATING

AC 20-107A