Executive Report

Federal Aviation Administration
Special Technical Audit of
Boeing Commercial Airplane Group
December 1, 1999 through February 11, 2000

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Executive Report of the FAA Special Technical Audit of
Boeing Commercial Airplane Group

Forward

This report contains the findings and recommendations of the Federal Aviation Administration's (FAA) Special Technical Audit (STA) team, chartered to conduct an in-depth product and process review of Boeing Commercial Airplane Group's (BCAG) design, production, and airworthiness processes. BCAG operates in accordance with the requirements of Title 14 Code of Federal Regulations (CFR), part 21, subpart G, Production Certificate (PC). The PC was issued by the FAA and entitles BCAG to produce airplanes in accordance with FAA issued Type Certificates (TC). The objectives of this special technical audit were to determine: 1) whether BCAG is producing airplanes in compliance with the requirements of their PC and; 2) whether BCAG is consistently designing airplanes that are in compliance with the requirements of Title 14 CFR, part 25. The STA was conducted December 1, 1999 through February 11, 2000.
Abbreviations

ACO - Aircraft Certification Office
ACSEP - Aircraft Certification Systems Evaluation Program
ASE - Aviation Safety Engineer
ASI - Aviation Safety Inspector
BCAG - Boeing Commercial Airplane Group
BMT - Boeing Materials and Technology
CFR - Code of Federal Regulations
CMO - Certificate Management Office
CMU - Certificate Management Unit
DER - Designated Engineering Representative
DMIR - Designated Manufacturing Inspection Representative
ECS - Environmental Control System
FAA - Federal Aviation Administration
IP - Inspection Pick-up
MOA - Memorandum of Agreement
MIDO - Manufacturing Inspection District Office
NCR - Nonconformance Report
ODA - Organization Designation Authorization
PAH - Production Approval Holder
PC - Production Certificate
PRR - Production Revision Records
PSD - Process Specification Departure
REDARS - Reference Engineering Data Automated Retrieval System
SB - Service Bulletin
STA - Special Technical Audit
TC - Type Certificate
Executive Summary

Beginning December 1, 1999, the FAA performed an extensive audit of Boeing Commercial Airplane Group's engineering, quality and manufacturing practices. The audit covered all Boeing Commercial Airplane Group's facilities in the greater Puget Sound area (Everett, Renton, Auburn, Seattle, Fredrickson, and Spokane, Washington and Portland, Oregon).

As a result of the audit, the FAA identified that Boeing type designs are mostly in compliance with Title 14 CFR, part 25; however, in some cases, processes were not sufficient to ensure compliance to applicable regulations, processes were not followed, or substantiation of compliance was unclear. As a result, some parts have been released that do not comply with the applicable regulations. The FAA also identified that Boeing does have a system in place to ensure that parts conform to the type design as required by Title 14 CFR, part 21, however, in some cases, manufacturing planning was not adequate, requirements were not followed, inspections were not sufficient, or personnel were not knowledgeable of the requirements. As a result, parts, assemblies and installations are released through the system that do not conform to the type design.
Background

BCAG has been striving to overcome production and quality problems over the past several years. During the fall of 1999, a number of nonconforming or noncompliant parts were delivered on Boeing Models 737, 747, 757, 767 and 777 aircraft. Vertical fin bolts, cockpit drip shields and environmental control system (ECS) duct insulation are some examples of parts that did not meet requirements or did not conform to the type design.

Boeing has taken immediate corrective action to address each of the above issues as they have come to light, both for its in-service fleet and for airplanes yet to be delivered. However, the FAA was concerned that these discrete events may be indications of systemic problems in BCAG's overall design, production, and quality control processes. Therefore, the Transport Airplane Directorate initiated a Special Technical Audit (STA) of BCAG.

Objectives

The objective of this audit was to conduct an in-depth and comprehensive evaluation of BCAG's current practices and procedures as they relate to design change, production and airworthiness approval methods in order to determine BCAG's compliance with the policies and procedures established to meet the requirements of Title 14 CFR, part 21, Certifications Procedures for Products and Parts, subpart G – Production Certificates and part 25, Airworthiness Standards: Transport Category Airplanes for Boeing Models 737, 747, 757, 767 and 777 airplane programs.

Audit Process

The STA involved an in-depth review of the quality, production and engineering functions across most BCAG divisions in the greater Puget Sound area. The STA team was made up of six engineers, eight manufacturing inspectors and four technical specialists. The team used an integrated team approach to perform the audit with a focus on engineering, manufacturing and inspection processes. The team performed product audits to verify conformance of parts to the type design and also conducted extensive interviews with personnel in various positions throughout BCAG to determine the level of knowledge among the workforce.
The audit was conducted over the course of 11 weeks at the major production facilities in the greater Puget Sound area. The audit also included visits to BCAG supplier facilities in the greater Puget Sound area. Approximately two weeks were spent at each major facility. The audit was both process and product-oriented and included personnel interviews; process reviews; product audits; and type design data compliance reviews.

The engineering team members audited selected BCAG engineering groups to determine if there were processes in place that would assure compliance to the regulations, and if those processes were being followed. They also performed thorough reviews of approved type design data to verify that it was properly approved and that it had proper substantiating data to support the approval.

The manufacturing inspection team members performed audits of the manufacturing and inspection processes used by BCAG to manufacture, assemble and inspect aircraft to determine if the manufacturing planning was adequate and reflected the type design, and if personnel complied with the requirements of the manufacturing planning, procedures and type design. The team performed 125 product audits to determine if the parts, assemblies and installations conformed to the type design and to evaluate the effectiveness of the quality system.

The STA differed from the FAA's Aircraft Certification Systems Evaluation Program (ACSEP) evaluation. The audit had a significant focus on compliance data and conformity of hardware. The audit incorporated the use of compliance data audits to verify compliance to Title 14 CFR, part 25, process reviews to determine if processes are sufficient to ensure compliance and product audits to verify conformance to the type design, whereas, ACSEP evaluations focus on the overall systems evaluations. Additionally, the members of the audit team were chosen for their expertise and for their years of experience in the aerospace industry.

As with most FAA audits, this STA was a snapshot in time of the current processes and procedures within BCAG as they relate to engineering, manufacturing and quality practices. The audit results were based on a sampling of areas throughout company and are not all-inclusive. Therefore, some statements made in this report are, of necessity, generalizations based on the data gathered during the course of this audit.
Audit Results

The following are the findings of the STA team. For the purposes of the STA, the term "finding" is used to classify the results of the audit, whether or not it was a violation of the CFRs.

FAA Engineering Audit Results

Several areas were reviewed within BCAG for which positive feedback can be provided. These areas include: 1) clear procedures are documented and followed for the Material Review Board; 2) individual engineers seem to take pride and ownership of their work; 3) many discrete procedures are documented within BCAG; and 4) the audit did not document any instances of safety being knowingly compromised. Further, major portions of the type design appear to be compliant with the applicable regulations.

However, there are several areas of deficiency which have resulted in the delivery of airplanes with non-compliant parts. In addition, nine Potential Safety Hand-off Items were documented and passed to the Seattle Aircraft Certification Office for further investigation.

Finding 1: BCAG lacks a comprehensive process to ensure that all changes to type design are consistently reviewed for, and found compliant with the applicable regulations.

No comprehensive procedure exists to ensure appropriate approval - There are many procedures developed for different purposes and used by the various groups within BCAG involved in developing and releasing changes to type design. Some of these procedures are documented and some are not documented at all. However, these procedures are not tied together into a system that necessarily leads to fully reviewed and compliant changes to type design.

Data approval process is passive - Inherent in many of the processes mentioned in the previous paragraph are passive approvals of data. While FAA Order 8110.37C, "Designated Engineering Representative Guidance Handbook" states that the Designated Engineering Representative (DER) may use as many experienced engineers as needed to completely evaluate engineering technical data, there often is no positive indication of acceptability provided to the DER prior to the DER approving the data. In interviews, DERs stated that where no input is received from their staff, the DERs often understand this to indicate that data is approvable.
Assumption that engineering system is working - Interviews of both DERs and their support engineers documented that they believe that the "system" is working, referring to a comprehensive process ensuring that any given change to type design is reviewed and found compliant to the applicable regulations. This belief is held even though they do not understand this "system" and they do not verify to ensure the "system" is working. In addition, there is no group responsible to perform an independent audit to verify the "system" is working. In fact, there is no comprehensive process in place. The current "system" is disjointed to the point that it does not positively ensure compliance with the applicable standards.

Support engineers are unaware of their role in certification - Engineers supporting DERs regularly make determinations that changes to type design do not need further review by a DER. Interviews documented that some support engineers do not know that they are involved in the certification process, and are essentially making findings of compliance on behalf of the DER. Further, some support engineers indicated in these interviews that they do not know certification is required for changes to type design.

Boeing Materials and Technology (BMT) material and process specification approval process does not ensure compliance - Although it has documented procedures, BMT is another example of the results previously described in this section. In addition to no response being taken as approval, and the BMT specialists not realizing they are essentially making findings of compliance on behalf of the DER, the BMT specialist makes a determination that a given change has, "no adverse impact to fit, form or function." Although this is the specialist’s criteria as to whether a DER needs to specifically review changes to material and process specifications, the specialist makes this determination without knowledge of all the various applications of a given specification.

Service bulletin approval process does not ensure compliance - In addition to having the problems described above, the audit team discovered there is no positive verification to ensure that all required approvals are made prior to release of the service bulletin. During the course of this audit, the team became aware of seven recent service bulletins that were released without approval for compliance to the required regulations.

Finding 2: Processes that are documented within BCAG are not always followed.

Where documented, processes are not always known or followed - As stated earlier, there are many individual processes documented by various groups as their respective needs dictate. These documented processes do reflect, to a large degree, how certain activities are carried out. However,
interviews of both DERs and their support engineers indicate that these discrete processes are not necessarily known by the people intended to follow them. Furthermore, engineers feel that they know how to do their jobs and do not always treat the written documentation as requirements that must be followed.

The attitude described above is particularly evident with respect to interviews of the support engineers who make determinations that changes to type design do not need further review by a DER. Specifically, many do not think about design changes in terms of compliance to rules and some indicated that they feel that compliance to FAA regulations is a paperwork exercise.

Memorandum of Agreement (MOA) is out of date and not followed - Multiple examples were documented of both Boeing and FAA personnel not adhering to the requirements of the MOA.

Finding 3: Data generated by BCAG to show compliance to Title 14 CFR, part 25 was unclear and didn’t consistently document compliance.

Through reviews of compliance data, the team found that the data intended to substantiate given design changes were often not sufficient to demonstrate compliance. This lack of clear records substantiating compliance may lead to further deliveries of airplanes with non-compliant parts.

FAA Manufacturing Inspection Audit Results

The manufacturing inspection team found that BCAG does have a system in place to ensure the parts conform to the type design as required by Title 14 CFR, part 21, subpart G. However, there are inadequacies in the system and personnel do not always comply with the established system. As a result, parts are released through the system that do not conform to the type design. The following are the findings of the manufacturing inspection team:

Finding 1: The manufacturing planning used by personnel to manufacture, assemble and inspect the aircraft is not adequate to ensure that the aircraft is built to the type design. The following conditions were identified:

Manufacturing planning errors - A substantial number of manufacturing planning reviewed during the audit contained some type of planning error. Drawings, specifications, tools, materials, and parts needed to perform an operation were not called out on the manufacturing planning, were called out but was not applicable to the operation being performed, or were otherwise in error.
Manufacturing planning is lacking detail - Many of the manufacturing planning reviewed during the audit did not provide sufficient detail to allow manufacturing personnel to perform the operation. In most cases, the manufacturing planning made reference to drawings and process specifications applicable to an operation, however, they did not provide additional details from those documents. The responsibility was placed on the shop personnel to research the requirements and make a determination of which requirements applied to the operation they performed. Based on interviews with the shop personnel, the team found that in many cases, personnel did not have access to the systems where the information was contained or they did not understand how to navigate through the systems and documents to determine what the requirements were.

Finding 2: BCAG personnel do not consistently follow the requirements of the planning, procedures and type design data. The following conditions were identified:

Planning does not accurately reflect the operation being performed - In several instances, the manufacturing inspection team members witnessed operations being performed differently than the way it was supposed to be done as stated in the manufacturing planning. Interviews with the personnel involved found they had performed the operation the way they had been told or shown versus performing the work in accordance with the written instructions. However, when the operation was complete, they stamped off the manufacturing planning indicating the work had been performed as specified in the manufacturing planning.

Personnel lack knowledge of the requirements - A substantial number of personnel interviewed throughout the audit did not know what the written requirements were for the work they performed. A majority of the personnel were doing the job as it had been told to them, not because they had knowledge of or understood the written requirements. There seemed to be a perception within BCAG that the personnel in the shop are fully knowledgeable of the written requirements; however, the team found that the majority of the personnel interviewed were not. This item is discussed in more detail in Finding 4.

Personnel lack discipline in following established requirements - There was a behavior among some of the personnel within BCAG that focused on building and delivering aircraft and not on compliance with procedures and conformance to type design. The manufacturing inspection team members found a number of instances where personnel were not following the planning, procedures or type design during manufacturing and inspection operations. When interviewed, these individuals did not think this was a problem because they had to complete their operation and move onto the next. Some individuals
thought the operation they were performing was not very important or significant and therefore, rationalized the fact that they had not followed the requirements.

Finding 3: The inspections performed by BCAG are not sufficient to assure completed parts conform to the type design. The following conditions were identified:

Incomplete inspections - In several instances, inspections were not performed as required by the manufacturing planning. Interviews with the inspectors involved found they had arbitrarily selected only a few dimensional characteristics or portions of assembly/installations to inspect instead of performing the inspection as required by the manufacturing planning. Additionally, several inspectors stated that when an operation was performed by a certified operator, they did not always inspect the entire operation as required, but accepted the operation because a certified operator performed it.

Knowledge level of inspectors - Personnel performing inspection operations were not knowledgeable of the requirements for the work they had inspected. Manufacturing inspection team members selected jobs that had been inspected and accepted by BCAG personnel and asked the individual who performed the job to explain what exactly they had inspected. Two inspectors could not interpret the drawing requirements for the jobs they had just completed. Several inspectors, including manufacturing personnel who had been delegated inspection responsibilities, did not understand the requirements called out in the drawing notes and the process specifications for jobs they had just completed.

Supplier oversight - During the STA, the team went to nine BCAG approved suppliers in the Puget Sound area to determine if BCAG was ensuring their suppliers were in compliance with the requirements imposed on them by BCAG. The audits revealed that several of the suppliers were not in compliance with the quality and/or purchase order requirements. Additionally, a significant number of parts found nonconforming at BCAG by the STA team were parts manufactured by BCAG suppliers that had previously been inspected and accepted by BCAG's system.

Finding 4: Personnel performing manufacturing operations are not knowledgeable of the written requirements for the work they perform. The manufacturing inspection team members documented 100 interviews with shop personnel. Of the 100 people interviewed, only 25 were able to access the systems and understand the requirements for the work they performed. The team felt there were contributing factors, which are discussed in detail below, which had a direct effect on BCAG personnel's ability to access the systems and their knowledge of the requirements. The following conditions were identified:
**Complexity of the systems** - BCAG's quality system and type design data has become so complex, it is difficult for the people to follow the requirements.

Over the years, BCAG's quality system has become very complex with voluminous numbers of procedures and multiple layers of requirements. Each division within BCAG has their own manual and methods of performing the same or similar tasks. As a result, the quality system is not always complied with due to its complexity and as a result of movement of personnel between divisions.

BCAG's drawing and process specification systems used by shop personnel to determine what the requirements are for the work they perform are very complex and difficult to understand and work through. The engineering drawings and process specifications have evolved into multiple layers of requirements with virtually no single source providing the necessary information. The process specifications are written as engineering documents and in such a way that they are not easily understood by the people using them to perform the work.

Process Specification Departures (PSD) are issued against process specifications and allow for deviation from the process specification requirements. There are often many PSDs issued against a process specification and in some cases, a PSD may have more pages than the basic process specification. A majority of the shop personnel interviewed did not understand what PSDs were or how they applied to the work they performed.

**Ability to access systems** - BCAG has instituted an on-line system for accessing procedures, process specifications and design data. This is the only method that people have to obtain the information they need for the work they perform.

One of the areas the team focused on during the audit was the ability of manufacturing and inspection personnel to access the systems and obtain the information necessary to perform their job. The team found there are two types of access to the system. The first is an on-line system open to all employees that does not require the use of individual passwords. The second is an on-line system which requires the user to have a password. Forty-three of the 100 people interviewed could not access the system either because they did not have a password or they had not been trained on how to use the system. This included some of the area leads, who were, in some cases, responsible for providing the information to their workers.

The quantity and locations of the computer terminals is seen as another obstacle which affects personnel's ability to access the system. In some areas there are only two or three computers for dozens of workers to share. The computers are located on the factory floor and not on the work platforms where a
significant amount of work is performed. The team did find people in some of the areas that are very proficient in accessing and working through the system. These workers provide assistance to other workers who have difficulty accessing the systems. However, a system which relies on a small number of personnel gaining access to a system and providing information to those who need it results in a people dependent system versus a process reliant system.

Training - BCAG has a very extensive certification program for those operations they deem “critical operations.” Outside of this program, there is no structured training program that outlines the minimum training requirements or the need for recurrent training for manufacturing and inspection processes. The training requirements vary by each division and are basically left up to an individual’s supervisor to determine whether or not training is needed. The team found several instances where, as a result of personnel being moved around, personnel were put into an area where they did not have the knowledge for the work they were performing and had received no approved training prior to performing the work.

The BCAG system for building airplanes is based on an assumption that people in the shop have a full knowledge and understanding of the requirements. The manufacturing engineers, who generate the manufacturing planning, assume the mechanics and inspectors in the shop have the necessary training, knowledge, and understanding of the requirements to build and inspect the aircraft. Because of this, the manufacturing planning generated by the manufacturing engineers does not contain sufficient detail to perform the operations. During the audit, the team found that in many cases, this perceived level of expertise is not in place. If the personnel doing the work do not have access to the systems to obtain the information needed to perform their work and do not understand the requirements, then BCAG cannot assure that they are working to the appropriate requirements and that the parts, assemblies and installations conform to the type design.

Finding 5: During the STA, the FAA performed 125 product audits on detailed parts, assemblies and installations. Product audits are a tool used by the FAA to evaluate the effectiveness of the quality control system. The results of the 125 product audits are as follows: 33 passed; 37 resulted in a noncompliance to a procedure, planning document or process requirement, but did not have an affect on the hardware; and 55 resulted in a nonconformance where the part did not meet the type design and a Nonconformance Report (NCR) or an Inspection Pickup (IP) had to be generated.
Conclusions

Engineering approvals are based on a system that relies on discrete and often undocumented processes and has no internal audit function. This system lacks positive indication of compliance prior to DER approval and results in poor substantiation for changes to the type design.

Production is based on a very complex system of drawings, procedures and processes which creates an environment where personnel are not likely to have a full knowledge of the requirements and where personnel do not always follow the established system.

Consequently, compliance and conformity have become an afterthought of the process, instead of the primary focus of the process, which leads to the delivery of non-compliant airplanes and results in nonconforming parts, assemblies and installations getting through the quality system.
Follow-on Actions

FAA:

Issue a Letter of Investigation (LOI) to BCAG addressing the findings of this audit, which can be categorized as noncompliances with Title 14 CFR, part 21.

Issue a letter to BCAG addressing additional areas that require further action.

BCAG:

Respond with the immediate and long-term corrective action plans for the specific nonconformances and noncompliances identified in this audit.

BCAG and FAA together:

Identify common threads leading to the major system issues and prioritize the corrective actions to be taken by BCAG.

Develop and execute a corrective action implementation plan including addressing root cause corrective actions for the major systemic issues.

Use metrics to assure that the commitments are producing the expected results with visibility at the executive levels.

Plan follow-up activity in 6-12 months.
## Appendix A

### FAA Special Technical Audit Team

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<th>Engineering</th>
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