**White Paper**

# The Future of
# First Article Inspection
# and
# Quality Planning

**January 2010**

## Industry Standards

The aerospace, automotive, and medical industries have numerous quality standards that require a great deal of production oversight. Thus, there is a tremendous emphasis on engineering details in the manufacturing and quality assurance.  All of these industries require suppliers to prove that they can manufacture a part in accordance with the design intent -- before they start making more than a few parts.

For manufacturing and quality, the aerospace industry is governed by AS9100 (and/or EN9100) under the auspices of the International Aerospace Quality Group (IAQG - www.iaqg.org). Meanwhile, the automotive industry is governed by ISO 16949 (and/or QS-9000) with coordination provided by the Automotive Industry Action Group (AIAG - www.aiag.org).  Medical device manufacturing is governed by ISO 13485 (and/or 21CFR Part 820) with oversight provided in the US by the Food and Drug Administration (FDA – www.fda.gov).  All of these industries require a great focus on establishing and complying with design requirements.

| Industry | Key Standards | Coordinating Organization |
|---|---|---|
| Aerospace | AS9100 (EN9100) | International Aerospace Quality Group (IAQG) |
| Automotive | ISO 16949 (QS-9000) | Automotive Industry Action Group (AIAG) |
| Medical | ISO 13485 (CFR Part 820) | Food and Drug Administration (FDA) |

Figure 1 – Industry Standards for Quality

## History of Quality Planning

Less than thirty years ago, it was not uncommon for a manufacturer to only think about quality at time of production.  Many companies would take an approach where they distributed the standard part drawings on the shop floor and provided multiple inspectors on the production line to check for defects and "inspect-in" quality.

The automotive industry took the lead at addressing quality during earlier stages of the product lifecycle. The automotive industry defined Advanced Product Quality Planning (APQP) as a means of instituting an up-front approach for building-in quality. With this requirement in mind, the industry created a very rigorous approach for validating the production of a part with the Production Part Approval Process (PPAP).

The aerospace industry followed later with AS9100, which also requires a great focus on establishing and complying with design requirements. The industry created AS9102 to describe the detailed expectations for First Article Inspection (FAI), and AS9103 to define the details for Statistical Process Control (SPC).

The medical industry also has a strong interest in quality, but they have been less prescriptive than either aerospace or automotive. That is, the medical industry regulators promote the notion of detailed record-keeping for Good Manufacturing Practices (GMP) and Quality System Regulations (QSR), but leave the details of the implementation to the discretion of the individual companies.

## Current Compliance & Capability Reporting

All three industries typically create products that contain many high-precision mechanical parts. The industries differ in some facets of quality planning based on the size of the production runs. For example, aerospace and medical will typically produce in job shops with quantifies in the hundreds, while automotive suppliers will produce in the tens of thousands on transfer lines. As one would expect, this has ramifications on the details of quality planning. Nevertheless, regardless of calling a comprehensive inspection a PAPP, FAI, or any similar acronym, the OEMs require suppliers to confirm compliance and process capability for each part.

As shown in Figure 2 below, this FAI and PPAP reporting encompasses many detailed forms for reporting results on dimensions, materials, processes, etc. For example, the major automotive OEMs often require 18 different forms to fulfill the PPAP requirements for a single part. In addition, aerospace suppliers have to extract all of the requirements from the drawings and specifications to complete the 100% "characteristic accountability".



Figure 2 – Automotive/Aerospace/Medical Compliance & Capability Reports

The problem that has evolved over the last few years is the labor effort required to provide an FAI or PPAP report, as well as the perceived utility to the supplier. For example, a complex part could easily consume 40 man-hours to complete an AS9102 FAI report. For an aerospace supplier with an order for 20 parts and time-consuming machine setups, a classic approach of checking the first part does not really work.

For many companies, the provision of these customer reports has grown into a time-consuming effort, and the creation of the customer documents has become the end unto itself. Rather than address the intent of the advanced quality planning, many suppliers focus administrative resources to create the necessary documentation. As a result, the process focuses primarily on filling out the forms in a manner sufficient for "customer buyoff".

## The Core of the Quality Planning Processes

The common starting point for quality planning in all of these demanding industries is the Technical Data Package -- commonly called the TDP. The TDP is the collection of product images and narrative documents that enable a production source to take an abstract design and convert it into a tangible product.

As shown in Figure 3, the TDP is typically called out by a part number on the purchase order (PO). The PO will identify the pertinent CAD model and/or drawing. The model or drawing will then reference numerous specifications that define expected material properties and manufacturing processes. In addition, the PO, model, or drawing will often reference supplemental documents that define additional detailed requirements for the specific part.
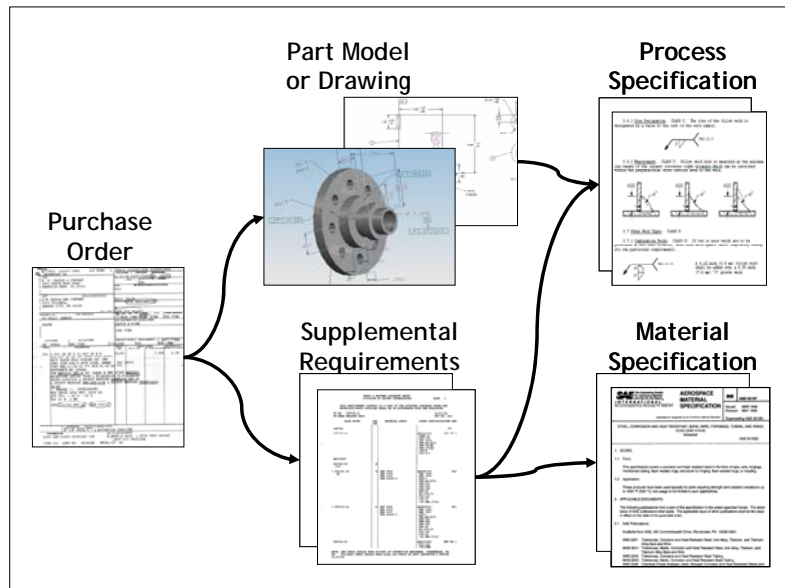
Figure 3 – Typical Technical Data Package

To create company-specific plans as well as the customer PPAP or FAI documentation, manufacturing engineers and quality engineers scrutinize all of the TDP documents (drawings, models, specifications, etc.). It is the specific part characteristics and requirements contained in the TDP that have to be identified and extracted to create many of the downstream plans and documentation.

In most companies, the review of part features, characteristics, and requirements contained in the TDP is repeated on multiple occasions. For example, a cost estimator may identify critical features and characteristics during the quoting stage while responding to an RFQ. Once the order is received, another engineer responsible for process planning analyzes the part again to identify features and characteristics for the creation of work instructions. The TDP is then passed to the CMM programmer who once again analyzes the annotations on the drawing to create the programs for the inspection software. The TDP is then shared with a quality engineer who analyzes the documents to create the documentation for the FAI.

When a company has a strong focus on being cost competitive, it does not really make sense to duplicate engineering efforts. An approach that repeats the tasks of organizing and analyzing a TDP is very inefficient and error prone.

## The Evolution of Manufacturing and Quality Engineering

As shown in Figure 4, the TDP is the common thread that feeds many of the manufacturing and quality engineering activities. The most resourceful companies recognize that there are great advantages in organizing the TDP in an "intelligent" structure that makes it usable in a digital manner for all of the downstream functions.
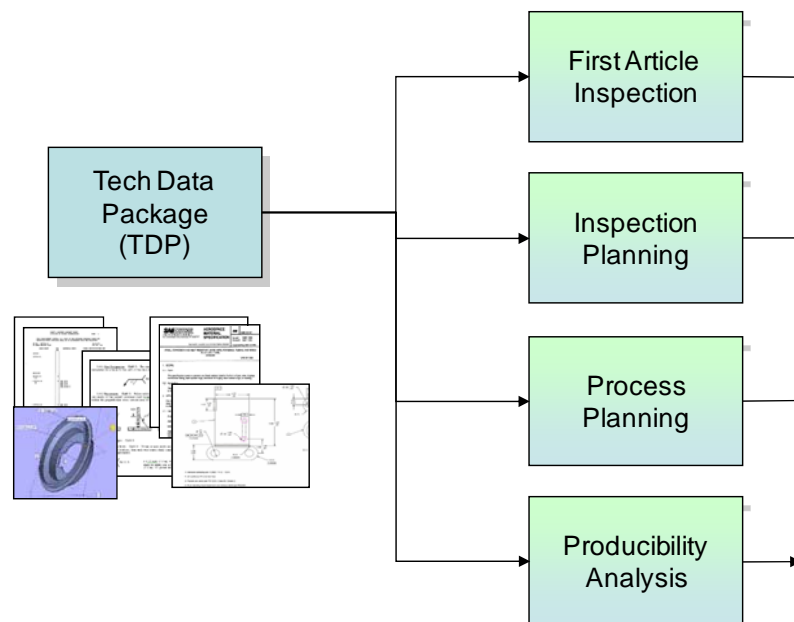


Figure 4 – The TDP and Manufacturing/Quality Engineering

One of the first capabilities associated with the intelligent TDP is pulling together electronic versions of the documents and identifying the specific part features and characteristics. With the evolution of the model-based enterprise (MBE), the ability to interrogate 3D CAD models used in the TDP has become an essential capability.

The complete itemization of expectations is captured in a digital Bill of Characteristics (BoC), which is a listing of all the detailed requirements for a part. For example, a hole can be considered a feature defined as a 'through hole' with characteristics such as 'hole diameter', 'hole depth', etc.; and requirements such as 1.50 +/- 0.01 inches. This level of semantic identification enables a TDP to be commonly useful for CMM programming, process planning, inspection planning, etc.

## DISCUS Approach

The DISCUS software suite was created with the recognition that the TDP is the core for manufacturing and quality planning. The PPAP and FAI are one of many reports that result from having a TDP structured in an intelligent format.

The DISCUS core competency is managing a part's TDP at the characteristic level of detail. DISCUS enables a user to view a 2D drawing or a 3D model and quickly identify the features and characteristics (see Figure 5). This identification can then be used to efficiently create downstream artifacts for manufacturing and quality assurance. This includes First Article Inspections, In-Process Inspection Plans, Manufacturing Process Plans, and Producibility Analyses.
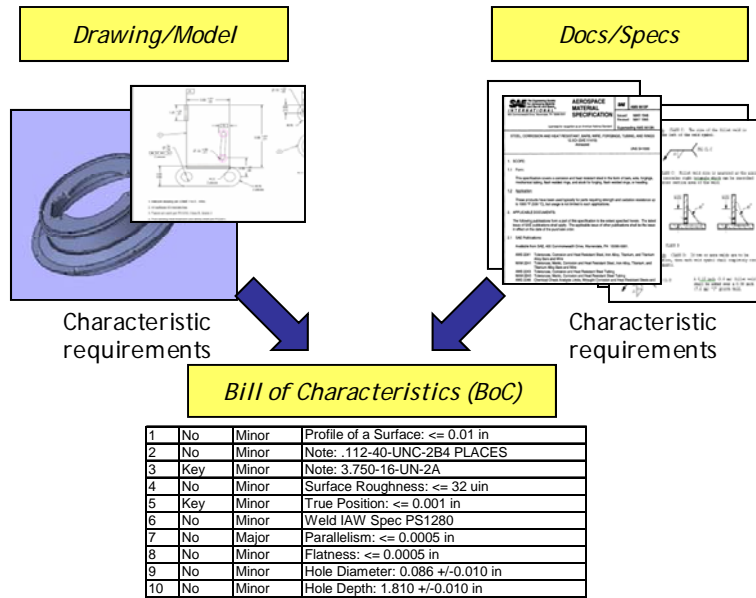
| | | | |
|---|---|---|---|
| 1 | No | Minor | Profile of a Surface: <= 0.01 in |
| 2 | No | Minor | Note: .112-40-UNC-2B4 PLACES |
| 3 | Key | Minor | Note: 3.750-16-UN-2A |
| 4 | No | Minor | Surface Roughness: <= 32 uin |
| 5 | Key | Minor | True Position: <= 0.001 in |
| 6 | No | Minor | Weld IAW Spec PS1280 |
| 7 | No | Major | Parallelism: <= 0.0005 in |
| 8 | No | Minor | Flatness: <= 0.0005 in |
| 9 | No | Minor | Hole Diameter: 0.086 +/-0.010 in |
| 10 | No | Minor | Hole Depth: 1.810 +/-0.010 in |

Figure 5 – Organizing the TDP and Extracting Features & Characteristics

DISCUS is specifically designed to enable engineers to organize the TDP and capture part characteristics (see Figure 6). DISCUS has a panel for analyzing and extracting characteristics from the 2D drawing or 3D model, as well as from the specifications. DISCUS generates the list of part-specific characteristics and creates associated illustrations. The resulting Bill of Characteristics is the linchpin that is used to reduce the time and labor for manufacturing and quality engineering.
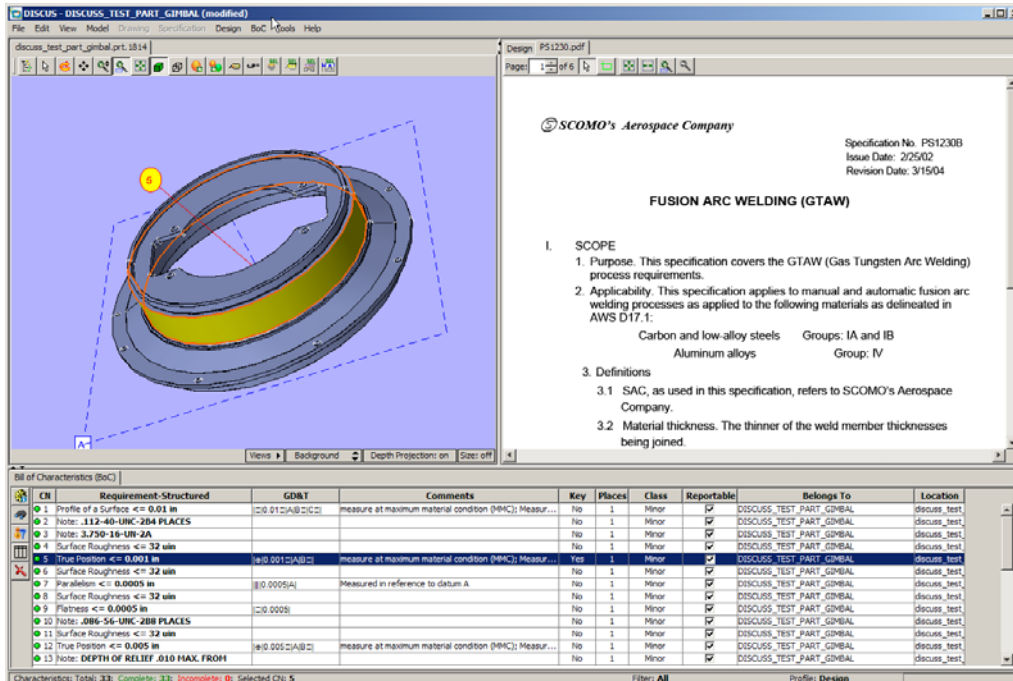


Figure 6 – DISCUS and the TDP

## Conclusion

As manufacturing continues to evolve in the 21st century, the creation of the intelligent TDP will become more common place. A Bill of Characteristics enables a shared understanding of the customer's expectation in relation to the supplier's interpretation. An intelligent TDP allows a user at any level of the supply chain to further reduce the likelihood for errors, as well as to optimize productivity in downstream operations.

## References

1. "AS9100 Quality Management Systems - Requirements for Aviation, Space and Defense Organizations", Americas Aerospace Quality Standards Committee, 2009.

2. "Code of Federal Regulations, Title 21 – Food & Drugs, Part 820 - Quality System Regulation", Food & Drug Administration, 1996.

3. "Enabling Six Sigma Design through Characteristic Lifecycle Management", Contract W9113-05-C-0210, Missile Defense Agency, 2007.

4. Feng, S.C., et al, "Conceptual Process Planning - A Definition and Functional", National Institute of Standards & Technology, 1998.

5. Fenves, S.J., et al., "Master Product Model for the Support of Tighter Integration of Spatial and Functional Design", Technical Paper, National Institute of Standards and Technology, 2003.

6. "Production Part Approval Process (PPAP) Overview", Automotive Industry Action Group, 2008.

7. Wujek, B.A., et al., "A Distributed, Component-Based Integration Environment for Multidisciplinary Optimal and Quality Design", American Institute of Aeronautics and Astronautics, 2003.

8. Bailey, I., et al., "PLM Collaboration in the Commercial Airline Industry", Eurostep Meeting, 2004.

## Glossary

BoC – Bill of Characteristics
CAD – Computer-Aided Design
CMM – Coordinate Measuring Machine
ERP – Enterprise Resource Planning
FAI – First Article Inspection
GMP - Good Manufacturing Practices
MBE - Model-Based Enterprise
PPAP - Production Part Approval Process
MES – Manufacturing Execution Systems
PLM – Product Lifecycle Management
QSR - Quality System Requirements
SME – Small/Medium Enterprise
SPC - Statistical Process Control