Implementation of the FREOP™ System
The Quality Solution Provided for
Northrop Grumman Corporation

Donna O. Fulenwider, Meridian Software, Inc.
Bradley W. Klenz, Meridian Software, Inc.
Lorraine Schacht, Northrop Grumman Corporation

Abstract

The Georgia Production Site of the Northrop Grumman Corporation produces frames, doors, and subassemblies for the 747 fuselage as a supplier to the Boeing Commercial Airplane Group. In an effort to improve the quality of their manufacturing process, the Georgia Production Site chose SAS® Software and Telxon radio-frequency technology to implement a statistical process control (SPC) data collection and analysis system. The FREOP (Frame-End-of-Part) System provided the solution for automating the SPC data collection and analysis process, which includes the immediate validation of data according to engineering tolerances, and real-time SPC analysis and reporting.

This paper focuses on the implementation of the FREOP System at Northrop Grumman Corporation. The FREOP System Version 1.0 was developed by Meridian Software, Inc. using SAS Version 6.08 and Microsoft C Compiler™ Version 6.00A in the Operating System/2® environment.

Introduction

The Northrop Grumman Corporation has been producing parts and assemblies for the 747 aircraft under contract with the Boeing Company since 1967. To support this contract, in 1991 the Northrop Georgia Production Site began producing frame assemblies, doors, and subassemblies.

In 1992, the Boeing Company contacted Northrop Grumman about a quality problem with the frame assemblies. Defective frame assemblies were being delivered to the customer from the Perry facility. In response to customer complaints, Northrop Grumman initiated a manual statistical process control collection and analysis system. The primary objective of this system was to ensure that no defective parts were delivered to the customer. The secondary objective was to ensure that acceptable parts were built the first time.

After collecting data manually for a year, Northrop Grumman decided to automate the system to increase efficiency and lower costs. Northrop Grumman conducted a product search of available software and hardware vendors and decided to use radio-frequency technology. This solution provides real-time data collection and analysis on the manufacturing floor. The SAS system was selected to perform data analysis and to store the data. Telxon radio-frequency devices were selected to transmit data from the manufacturing floor to the SAS system. Meridian Software, Inc. was selected as a consultant to provide system development and integration services.

For a discussion of the problem and design benefits of the automated SPC data collection and analysis system see the companion paper entitled The Quality Solution Provided By an Automated Statistical Process Control System at Northrop Grumman Corporation, authored by Lorraine Schacht, et al.

The FREOP System was developed in two phases over a one-year period. The first phase (or start-up phase) successfully implemented all hardware and software components. At the completion of the first phase, mechanics on the manufacturing floor were receiving immediate feedback of tolerance checks for their part measurements.

With the first phase completed and acknowledged as providing valuable information in an extremely timely manner, the second phase of development began. The second phase of FREOP consisted primarily of software additions to the system. Real-time SPC analysis became the focus of this phase in development.

This paper focuses on the implementation of the FREOP System at Northrop Grumman Corporation using many of the SAS system tools, which included SAS/QC® software.
The Structure of the FREOP System

Figure 1 shows the system hardware configuration.

![System Hardware Diagram]

The FREOP System comprised of the following three major hardware components:

- Telxon Corporation's PTC-960, hand-held radio-frequency (RF) terminal. The Portable Tele-transaction Computers (PTCs) are used by mechanics at each Operation (OP) Center to enter and transmit frame measurements and related measurement information. A base component receives signals from each PTC via RF waves and relays the information via the RS-232 port on an OS/2 system server PC. Each PTC is able to scan bar codes for recording frame identification information and also to interface with attached depth probes for recording frame measurements. Each PTC has a keyboard for entering information or responses as necessary.

- A PC running OS/2 with RFxpress™ system software for routing information from the PTCs to the FREOP Menu System.

- A Local Area Network (LAN) that houses the SAS data sets for the FREOP System, allowing the sharing of data between multiple operating systems (OS/2, and Windows™).

The following FREOP System Software components are:

- The FREOP Menu System, a SAS Software application that starts or stops data collection. The FREOP Menu System also enables you to edit or browse SAS data sets used within the FREOP Application. These data sets either control the FREOP Application, are look-up tables for tolerance checks; or contain measurement data. The FREOP Menu System is written using SAS/AF® and SAS/FSP®. Frame entries are utilized as well as FSEDIT and FSVIEW screens for data browsing and edit.

- The FREOP Collector, a SAS Software application that performs all tolerance comparisons, SPC analysis, and data management. The FREOP Collector is a second SAS session started by pressing the START button on the FREOP Main Menu. This action executes an OS/2 command file that creates the second SAS session and executes a Frame entry in a catalog to begin the Collector. Once started, the Collector is designed to run continuously as long as PTCs are operating on the manufacturing floor. When necessary the Collector can be stopped by pressing the STOP button on the FREOP Main Menu. (Note: The FREOP menu system is not...
required to run while the FREOP Collector is running. After the Collector is started, you can close the FREOP Menu System and start it at a later time to stop the Collector or manage other menu options.

The Collector uses two named pipes to communicate to the PTCs.

- The FREOP Manager and RFxpress System Manager, which manage the flow of information from the OP Center's PTCs to the OS/2 System Server PC. RFxpress Software is Telxon's system integration tool for developing applications that communicate between RF devices and other software applications running under the OS/2 operating system environment. RFxpress supplies a library of functions (written in several programming languages) that provide the communication link between the OS/2 operating system and the PTCs. The FREOP Manager, written in the C programming language, uses these functions to interface with Telxon's RFX Interpretive Prompting System (TRIPS) software running on each PTC.

Data Accessed and Managed by the FREOP System

The FREOP system reads and writes to several data sets. Measurements taken at each OP center are recorded for two positions on the aircraft frame. These measurements are referred to as A and B measurements. Each measurement exists independently, however in most cases, an operator will record both the A and B measurement.

The TOLERANCE Data Set: For frame, stringer, type of aircraft, and measurement position, tolerances exist in a TOLERANCE data set. This data set contains the upper and lower tolerances for the nominal or should-be A and B measurements. The Collector checks these should-be measurements to determine if measurements are within tolerance.

The COLLECTION Data Set: The Collector stores recorded measurements and other identifying information in the COLLECTION data set.

The TYPE Data Set: The Collector determines the type of aircraft being measured based on a specific Unit ID that identifies the part being measured. The TYPE data set is a look-up table that provides the Type and Cumline values for a specific Unit ID. This table is maintained by the QC Analysts at the GPS.

The CLiMITS Data Set: The CLiMITS data set contains control limits information for use during SPC analysis. The information in the data set is either calculated and stored, or read by the SHEWHART Procedure for a particular frame, stringer, type and measurement position.

The PARTLOG Data Set: The PARTLOG data set stores measurement information for parts that do not meet tolerance standards.

The PROCLOG Data Set: The PROCLOG data set stores measurement information for parts that do not meet SPC standards.

Overview of the FREOP System

In brief, the FREOP system operates as follows (see Figure 2 on page 4).
OS/2 System Server PC

SAS applications

1, 15 Starts and stops the collector

FREOP menu system

Collector

4, 10 Sends data to Collector

RFXpress application

FREOP Manager

PTC

2, 8 Operator enters data or response

3, 9 Transmits data to Manager

7 Sends message to operator

LAK (Network Server)

COLLECTION data set

11 Writes data to COLLECTION data set

PARTLOG data set

12 If measurement out of tolerance, Collector writes information to PARTLOG data set

CLIMITS data set

13 If control limits do not exist (10+ measurements), they are analyzed in CLIMITS

PROCLOG data set

14 If part out-of-control, Collector writes information to the PROCLOG data set

TYPE data set

5 Checks TYPE and TOLERANCE (look-up table) data sets

TOLERANCE data set

6 Informs Manager of findings

Figure 2, Overview of the FREOP System
The FREOP menu system is used to start the SAS Collector application.

The operator enters frame measurement information into the PTC for a specific frame number, stringer number, and unit ID.

Information from the PTC is transmitted by radio frequency waves via an antenna on the manufacturing floor to the FREOP Manager on the OS/2 system server.

The FREOP Manager takes the transmitted data and sends it to the Collector.

The Collector checks the unit ID in the TYPE data set to determine the aircraft type and CUMLINE value. Then it compares the measurement values against the tolerance values found in the TOLERANCE data set on the LAN.

The Collector informs the FREOP Manager of its findings.

The FREOP Manager sends measurement messages to the operator via the PTC.

The operator re-enters values or remeasures as necessary. The operator then instructs the system that he or she does not want to remeasure.

The FREOP Manager receives the operator’s response from the PTC.

The FREOP Manager routes the operator’s response to the Collector.

The operator’s measurement data is written to the COLLECTION data set on the LAN.

If the operator’s reported measurement is out of tolerance, the Collector writes information about the measurement to the PARTLOG data set.

After the tolerance tests are completed, the Collector determines if there are ten or more initial frame measurement values for the FRAMENO, STRNO, and TYPE variables (only if this is the first time the frame, stringer, type, and unit ID have been measured). If there are ten or more, SPC analysis is performed. If there are less than ten initial frame measurement values for these variables, a message is displayed to the operator indicating that not enough data is available for SPC analysis.

The Collector sends messages to the operator via the PTC. The messages report whether a part is in-control or out-of-control. If the part is out-of-control, the Collector writes this information to the PROCLOG data set.

The FREOP menu system is used to stop the SAS Collector application.

SPC Analysis

As noted above in Step 13, the FREOP Collector determines when enough information has been collected to perform SPC analysis. The analysis is conducted if at least ten measurements exist for a particular frame, stringer, type of aircraft, and measurement position (A, or B). To perform SPC analysis, the Collector application executes (%INCLUDES) the report program COLSPC.SAS. This SAS code consists of DATA Step, Macro, and SAS/QC Procedure code which assesses the status of the manufacturing process.

The SHEWHART Procedure is used to calculate control limits for the individual measurements. The IRCHART statement is used with the NOCHART option since no graphical display is desired. Control limits are stored for each frame, stringer and type of aircraft when a total of twenty measurements exist. A provision is made for the Quality Analyst to tag points at any time that are out-of-control due to a Special Cause, and which are not to be used for the SPC analysis. In this case, the FREOP Collector eliminates those special cause measurements from the data sent to the SPC analysis program.

The TABLEALL(EXCEPTIONS) option and the OUTTABLE data set are used to record measurements that are flagged as out-of-control for the individual and/or the moving range chart. The data set is known in the FREOP application as the Process Log (PROCLOG) data set. If a mechanic receives information from the FREOP Collector that a measurement is out-of-control, the QC analyst can be
contacted and information concerning the part reviewed from accessing the PROLOG data set. The QC Analyst is running SAS Software for Windows and uses SAS/Share software to access the data sets on the LAN created by SAS/Software for OS/2.

If the process is determined to be in-control, the CAPABILITY Procedure is used to calculate Cp and Cpk values. The capability indices and the control status of the process are returned to the FREOP Collector to be sent to the operator in the OP center.

Summary

The FREOP System at Northrop Grumman Corporation is a successful implementation of an automated statistical process control system. Using the SAS System, and RF technology, Northrop Grumman has developed a decision support system for their manufacturing staff that ensures that only quality parts are shipped to the customer.

For More Information

Donna Fulkner
Meridian Software, Inc.
4308 Oak Park Road
Raleigh, NC 27612
919-787-4250

Trademarks

Frame End of Part System (FREOP) is a trademark of Northrop Grumman Corporation.

Microsoft C Compiler is a trademark of Microsoft Corporation.

Operating System/2 is a registered trademark of International Business Machines.

RFxpress System Manager is a trademark of Telxon Corporation.

SAS, SAS/AF, SAS/FSP, and SAS/QC are registered trademarks of SAS Institute Inc.

Windows is a trademark of Microsoft Corporation.