Handheld Precision Test Data Collector

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Abstract - Precision physical dimensional measurements are required for many aerospace structures to assure adherence to demanding tolerances. Data collection devices have typically interfaced to specific dimensional gauges to measure physical attributes of a manufactured part. This data is usually transferred to a computer via cable. This paper describes a new approach to data collection at Boeing Defense and Space Group manufacturing centers. This new approach uses a wireless, precision data collector that incorporates an integral laser bar-code reader and interfaces to industry standard gauges. Data is transferred by an internal 2.4 GHz radio to the statistical process control (SPC) data base used throughout The Boeing Company.

I. INTRODUCTION

Aerospace structural elements create the very backbone of some of our industry’s greatest achievements. The performance of our fighter and commercial aircraft are dependent on manufacturing to meet exacting and repeatable tolerances in machined parts and structures. Aerospace companies work very hard to assure design requirements are accurately translated into manufacturing instructions. Measurements of each feature of mechanical assemblies are needed to assure tolerances are met and maintained.

Process engineers use data collection to monitor manufacturing tolerances, and establish real time control limits for quality-critical products. Precise measurements made by various types of gages and micrometers examine each controlled feature of each part under evaluation. The derived measurements are collected and organized as part of a statistical process controlled (SPC) data base system. Immediate feedback data and trend analysis enable the process engineers to continually adjust the procedures required to create a product fulfilling the expectations of their customers.

Industry has used a variety of techniques to collect test data. Lately, there have been a number of special purpose, computer controlled data collectors used in Boeing manufacturing operations. These typically interface with one or two gage types, and can be configured to provide some feedback to an operator that the operation is getting close to tolerance limits.

These data collectors must serially download their test data at a local work station/computer. This test data is eventually sent to a custom data base on a host computer.

This paper describes the development of a new generation of data collector that takes advantage of state-of-the-art computing, bar-code and wireless technologies.

II. REQUIREMENTS DEFINITION

This project started with an analysis of currently used data collectors and formulated a set of desirable characteristics that would ease some of their shortcomings. It used earlier studies by Boeing Commercial Airplane Group (BCAG) Operations Technology organization to identify the desires of operators who use data collectors.

A. Operator Interface Requirements

The operator using a data collector doesn’t want to be bothered by large units or complex operating instructions. The data collector is just another tool to the equipment operator that is used to assure parts are made to requirements. As such, the user interface of the data collector needs to be as simple and direct to the task as possible.

To meet these operator desires, the data collector needs to be a hand-held unit, operating off battery power for extended periods of time. It also needs to be small enough to be operated with a single hand in most uses.

It needs to provide displays to the operator in both text and graphics. The usual manner for displaying limits to an operator is to show upper and lower tolerance bands graphically, with several previously taken data points showing, and a distinguishing symbol for the current measurement. This way the operator can quickly see that the measurement is in the tolerance band, and how close it is to the upper or lower limit.
The display needs to have provisions for backlighting, and be readable in many lighting conditions. The display size is driven by the hand-held dimensions of the data collector, but need to be as large as possible, so that information portrayed can be read with reasonable ease.

Studies by BCAG’s Operations Technology organization indicate the positive effects of a minimal set of keys on the data collector. Most operations do not need a full QWERTY keyboard, but rather just a set of number keys and a few function keys. A button is needed to initiate measurements. This needs to allow both left and right handed operation.

B. Computing Requirements
The data collector needs to have local memory and processing capabilities in order to take measurements and display this in a variety of ways to the operator. Data gathered must be stored for transmittal to the company SPC data base for long term retention and trend analysis.

The mission and requirements of the data collector do seem to change over time. We found that with simple variations, the same data collector could satisfy much more than just collect measurements via gages. If the data collector computing capabilities were more general purpose, and adaptable to re-programming easily, the data collector could meet more universal needs of operations.

C. Gage Interface Requirements
There are many types of gages used to take precision dimensional measurements of manufactured parts. These range from micrometers to hole depth gages, and tape measures to calipers. Many manufacturers of these gages exist, and there are several digital interfaces (used to get data from these gages) that have been developed over the years. However, in Boeing operations, the most prevalent gage interfaces are those defined by Mitutoyo and Federal Maxim. As a consequence, the data collector needs to have interface compatibility with both of these gage types.

D. Bar-Code Requirements
The reason the keypad requirements can be so minimal, is that most input is provided by bar coded data. The operator is identified by scanning the bar-code on his badge. The task to be performed is also input via a bar-coded sheet for the operation being done. The task bar-code can be rather long, since it will contain all the information needed to setup the data collector to take measurements on the part being manufactured, or other operation being performed.

Since some operations expect the data collector to be positioned some distance from a bar code, it is most desirable to have the data collector use a focused laser reader to scan the bar-codes, rather than have a wand-type reader. Furthermore, the wand type reader typically has a three foot cable attached to it, which can be dangerous in a machine tool environment.

E. Communications Requirements
Existing data collectors required the operators to take too much time uploading data taken, since they had to physically connect to another computer work station. As a consequence, the data collector needs to have a way to remotely send its data to the SPC data base without a physical connection. Some form of wireless communication is needed. Optical, or infrared is not desirable, since it requires line-of-sight. Wireless communication frequencies are available in several standard bands to better support conventional communication protocols. It is also desirable to have this a two-way communication, so that up-to-date information can be down-loaded into the data collector, based on the operation being performed.

III. PROTOTYPE DEVELOPMENT
ARGOSystems worked together with many of the manufacturing operations organizations within Boeing Defense and Space Group (D&SG) to complete the design requirements for the data collector. We initiated a co-operative project to develop a prototype of the data collector, and to have it tested by people on various shop floors to determine a final configuration.

A. Prototype Data Collector
The prototype data collector was developed using as many industry standard interfaces as possible to give it an open-ended architecture. It used commercial-off-the-shelf components to minimize risk and schedule.

A commercially-available, 2 inch square (16 line x 21 character/graphic) LCD screen was used to provide the operator display. The engine selected for the prototype data collector was an Intel 386 computing module about the size of a credit card. This provided a useful computing platform, with many interfaces built in, so we could focus development on the application, and not the computing engine.
A proven laser bar-code scanner from Symbol Corporation was selected that could be placed on the top of the data collector and rotated for left or right hand operators.

For communications, we selected a 2.4 GHz radio link from Proxim. This was packaged by Proxim into an ISA form factor, which helped meet the size constraints of the data collector.

Specific circuits were designed to integrate these COTS components into the data collector. Interfaces were designed to meet the needs of reading Mitutoyo gages, the display, the bar-code scanner, the radio and a simple thin film keypad. We packaged them into a COTS composite material case.

The resulting prototype data collector is pictured in Figure 1 with a typical gage, a cable to the gage and a receiving antenna which is part of a base station that communicates with several data collectors.

B. Testing of Prototype

One of the key objectives of the integrated product development team for the data collector was the eventual testing by various shops. The prototype was tested in three shops with varying requirements and experiences with other data collection approaches.

It was run through tests in the gear shop, tooling center and development operations at Boeing D&SG. The results of these tests and trials provided specific feedback to the design team that changed several aspects of the data collector design. As more was learned about the operators desires and needs, we were able to incorporate and re-test various features prior to committing to further production of the final data collector.

This period also allowed other groups to understand how the technology of the data collector could be used in their areas to satisfy remote data collecting needs. One of these was more of an inventory collection requirement, and another was the collection of FOD observations in a flight test area.

IV. DATA COLLECTOR PRODUCTIZATION

A. Upgraded Features

The production version of the data collector has been designated the AS-225 Precision Data Collector. Figure 2 shows the AS-225 with a typical gage and cable. It incorporates the results of all testing of the prototype and is designed to take advantage of more tightly integrated electronics in a more ergonomometric package.
B. Integrated Computing Electronics

The AS-225 had to part ways with the COTS Intel 386 computer on a card in order to minimize overall weight and power consumption. The AS-225 still provides a standard PC computing environment internally, but doesn't have un-needed general purpose interfaces. We expanded RAM and ROM to maximum allowed by size, weight and power.

Interface to both Mitutoyo and Federal Maxim gage types is provided through a unified connector at the bottom of the AS-225.

A smaller version of the Symbol laser bar-code scanner is used at the head of the AS-225.

An upgraded version of the Proxim 2.4 GHz radio is used that minimizes power consumption when idle.

Throughout the design, power optimization was essential to allow the AS-225 to operate for extended periods on two standard AA batteries.

C. Ergonomic Case Design

During the same time we were developing and testing the prototype, DataMyte Corporation was developing a case with an integrated keypad that seemed to meet most of our packaging needs. ARGOSystems worked with DataMyte to make slight adjustments to this case, so it would meet all our needs. This case and keypad provide the basic housing for the AS-225.

ARGOSystems designed the electronics of the AS-225 to fit this hand-held case, and interface with the keypad. Special provisions were made to allow mounting of the laser bar-code scanner.

V. NEXT STEP

The next step in the life of the AS-225 Precision Data Collector is formal incorporation into production operations. Its first assignments are on the F-22 shop floor, in the F-22 flight test areas and in the tool center.

VI. SUMMARY

The definition of the AS-225 Precision Data Collector is a fine example of an integrated product team. This Integrated Product Team (IPT) worked through uncharted sets of needs, desires, technology analysis, COTS hardware and software trade-offs, and extensive hands-on testing. The result is the integration of all these efforts, and creates a useful production tool for the operator in Boeing manufacturing operations.