Visual Basic as a Tool for the Automation of Engine Health Monitoring Systems in the Aerospace Industry

Jesús Adrián Velázquez Morales
Master of Engineering in Manufacturing Engineering
Edgar Torres, Ph.D.
Industrial Engineering Department
Polytechnic University of Puerto Rico

Abstract — *The aerospace industry presents many challenges when it comes to provide quality and reliability to its users. Many lives depend on the appropriate maintenance and on-time delivery of products and services on a daily basis. Through computerized automation of processes we are able to provide quick results in a reliable way to assure data is managed appropriately and enable good decision-making. Visual Basic for Applications is a programming language that provides a user-friendly foundation for the development of software tools. The scope of this project is to achieve the automation of the usage tracking of an engine health monitoring system and reduce the processing time by integrating multiple steps into one single automated process. The probability of human error and data mishandling was greatly reduced while enhancing productivity by shortening the data processing time. Another benefit is the user's ability to keep proper statistics of the system client demography.*

Key Terms — *aerospace, automation, engine health monitoring systems, Visual Basic.*

INTRODUCTION

Founded in 1925 with headquarters in East Hartford, Connecticut, aerospace company X has been a leader in the aerospace industry and for decades has been innovating with its products. As a subsidiary of United Technologies Corporation (UTC) this company has been competing mainly in the development of aircraft engines, for both military and commercial applications. Their engines have been powering important aircrafts and in its beginning formed part in the development of the space shuttle engines. In the last decades it has won contracts to provide engines for important military aircrafts such as the F-22 and F-35 fighter jets. Its engines have been powering the aerospace industry since the early 1900's when the development of the Wasp radial engine powered Amelia Earhart's plane and succeeding versions had important roles in the Second World War.

In the commercial aerospace industry aerospace company X form part of the big three commercial engine manufacturers, being the other two competitors Rolls Royce and General Electric Aviation. Aerospace company X commercial aircraft engines have powered from the Boeing 747 to Airbus A320 family and the most recent Airbus A380, currently the biggest commercial passenger airplane, through a joint project with Rolls Royce.

Aerospace company Y has been operating since 2003 in a small building in Mayagüez before moving its operations to Isabela, PR. The company resulted from a joint venture with aerospace company X, owning 51% of the company while aerospace company Z owns the remaining part. Aerospace company Y currently does outsourcing work for aerospace company X in almost all of their operations except for the actual manufacturing of engine parts, although support is given to this group through engineering design and manufacturing strategies.

With more than 13,000 large commercial engines being currently operational it is a large task to provide maintenance support to maintain trouble free engines and reduce downtime.

Aerospace company X gives operational support to multiple certified maintenance shops around the world. In fact, there are over 170 sites serving over 180 customers. Such a high number of engines being serviced generate a lot of data.

MAPNET (Module Analysis Program NETwork) is a FTP server based software that each and every maintenance site around the world uses to process engine data. There must be quantifiable data that should prove that an engine is suitable to be put back into service. After a scheduled or non-scheduled repair or maintenance the engine passes through an acceptance test to be validated. A set of multiple parameter data is recorded and compared to the limits and guidelines defined by the manufacturer. It is then when the maintenance engineers upload their data to MAPNET for an analysis. After making the calculations and generating a condition report MAPNET allows engineers to quickly assess the entire condition of the engine. But not only that, it allows aerospace company X to assess the effectiveness and quality of service being offered by each site.

The purpose of this project is to create a tool that would allow the users to keep a track of the usage of MAPNET. Through this the used will be able to pull out all the instances where MAPNET has been used and will give the opportunity to have in a clearer way numbers that will enable the understanding of the engines being serviced. One of the main utilities is to be able to quickly gather information about what engines has been serviced where, when and by whom.

In terms of quality this project has the objective to create a tool that shortens a process and makes it error-proof. By eliminating human error this tool will offer consistent results in a consistent way. By shortening processing time it will reduce waste and reduce costs.

BACKGROUND INFORMATION

Pratt &Whitney: An Aerospace Pioneer

Founded by Frederick Brant Rentschler in 1925, adaptability, innovation, and reliability were core values of the just started company. The adaptability was put to test when the Second World War started, to comply with the rising demand it started teaching the North American automotive companies to build parts of its own products. Innovation was required and demonstrated when they pioneered both liquid and air-cooled engines and leaped into the turbojets era. And decisively seeks reliability from its products, as evidence of this is that in 1942 aerospace company X wins the US Navy E (for excellence in production), this was a first for a company in the aircraft industry. To maintain its product reliability aerospace company X is committed with its clients through product support services.

As part of the continuing services to its clients aerospace company X offers maintenance services for its products. X’s Line Maintenance Services (LMS) is the division responsible of offering technical services on a long-term support strategy. Field Service Representatives (FSR) offers their services on-site at maintenance shops around the world. This personnel possesses extensive technical knowledge of aerospace company X products, maintenance requirements and techniques. They are an on-site resource for troubleshooting, training and act as the interface between customers’ personnel and aerospace company X. Their main responsibility is to maintain proper communication with the customer while technical support is provided from aerospace company X engineers and all personnel involved. Behind the continuous success are thousands of employees and tools that have been developed to provide a higher standard service and quality through consistency and expedited solutions.

Engine Health Monitoring Systems in the Aerospace Industry

Across the aerospace industry the aircraft engine manufacturers have designed systems and applications that make possible the monitoring of the engines health [2]. A system that aerospace company X uses to monitor in-flight information of its engines is the Advanced Diagnostics & Engine Management (ADEM), similar to Rolls Royce’s Aircraft Communications Addressing and Reporting System (ACARS) [1][4] and Aircraft Condition Monitoring System (ACMS), ADEM helps in the preventive maintenance if the engines, achieving lower shop visits rates and costs, reduced delays, in-flight shutdowns and unscheduled engine removals. Key engine parameters data is periodically transmitted whilst flying to technical support centers to keep track of operational conditions. As soon as a trend suggest an engine parameter is falling out of the established operational limits the engine is ordered to undergo inspection and in many cases taken off-wing to get maintenance. MAPNET, an aerospace company X proprietary software, is also one of multiple tools available to provide support and assure engine reliability. For those occasions where an engine has to undergo repair or maintenance, scheduled or unscheduled, MAPNET is a critical tool in engine health monitoring. The importance of MAPNET resides in the capability to automatically take inputs from an engine acceptance test and provides a technical report in a quick and prompt way so engine downtime is reduced and all proper maintenance and technical service is conducted. Maintenance specialists from around the world are capable of accessing MAPNET and do accurate decisions based on a state of the art tool. It enables them to drive quality service through reliable engine evaluations.

VBA: A Programming Language

Visual Basic, a computer language developed my Microsoft in 1991 and preceded by BASIC, expanded on the functions and ease of use of it. Today is one of the most widespread computer languages and has passed through multiple versions. Visual Basic for Applications (VBA), a dialect of Visual Basic, is used as a macro or scripting language within multiple Microsoft applications [5] including Microsoft Office. It is currently a language that is commonly used in the industries and provides the ability of interaction with industrial controllers [3]. VBA works by running macros, step-by-step procedures written in Visual Basic. By far the most common reason to use VBA in Excel is to automate repetitive tasks. For example, suppose that you have multiple workbooks, each of which has multiple worksheets, and each of those needs to have some changes made to it. With VBA you are able to automate the repetitive process by writing a macro code. You can also use VBA to build new capabilities into Excel like developing new algorithms to analyze data.

METHODOLOGY

For the development of this project one main tool was used, Visual Basic for Applications (VBA). As a computer language, Visual Basic enabled the opportunity to create a custom tool that would fulfill the necessity that we had.

A first step was to identify the problem. But to identify the problem we needed to characterize the actual process from the beginning. First, a user, for instance a maintenance engineer, runs an acceptance test to an engine recently repaired. With the data resulting from the test the engineer would create an input file. This type of file is an input to MAPNET. During the internal process of MAPNET it will search for electronic files for equations, tables, and values including engine limits. After MAPNET processes the input file data it generates a report. This report file is one of the outputs of MAPNET, along with other files. One function that MAPNET does after generating a report is sending the report to the user, in our example the engineer, and that MAPNET run will be registered in an electronic file, storing the date when the report was generated and the report filename. This is the file that keeps a basic history record of each time a report was sent to a user. It was taking a great effort and much time to keep track of the use of MAPNET. Along with those issues were the possibilities of human error and inconsistency of format. Since no standard procedure was defined for this the user did not had a set of instructions that would enable him or any other user to produce consistent results. (Benjamin, Schwartz, & Cole, 1999)

After defining the problem then the process of brainstorming a solution started. From the first approach the idea of automating the process though a code surged forward. Given the ease and convenience that a spreadsheet gives the users to generate tables, keep information well organized and do statistics it was decided that a VBA macro enabled software would populate a spreadsheet as its output.

The new software accesses the MAPNET history file and initially populate the spreadsheet with three columns, the report generation date, the maintenance shop that used MAPNET and the report filename. With that information the software has sufficient information to be able to access the archives for each individual maintenance shop and grab the generated report. After the software finishes populating the spreadsheet with those three parameters it goes through each report reading the information contained. It has the capability to identify several parameters in the content of each file. The software reads the report filename that it just wrote and searches in the corresponding directory, using the maintenance shop three-letter identifier and picks up the desired report. It opens it and starts reading it line by line to find parameters such as the acceptance test date, engine model, engine serial number, the operator of the engine, which is typically an airline, also information such as an error code and a description for that error in the case of a failed report. Other information that the software pulls from the report file is a correlation filename. A correlation filename is a text file that contains correction coefficients. These coefficients are used by MAPNET to do some corrections to parameters. Going into the technical aspect of this, for each engine that X manufactures there is literally one engine that has been run at a specific place, which is standard, to establish a baseline engine performance. This baseline is recorded along with the information about the technical characteristics of the installation and facilities of the maintenance shop. Since engines are serviced at more than 100 sites around the world, one engine put to the same test at different sites will yield different results. This correlation file contains the coefficients that will help bring the data from one shop into comparable terms with the baseline engine. This file is of extreme importance, and every time a test site undergoes an equipment change such as a new sensor or a physical change to the structure around the engine test stand, new coefficients are generated. That is why our software also looks for the correlation file used by MAPNET to generate the report.

Multiple iterations were conducted to validate the effectiveness and reliability of the software. Also, additional features were added since its first version. The error identification capability allows us to identify the failed reports and consider this when establishing maintenance statistics.

Through this software we are able to look at statistics of which shops are having a higher workload, which types of engines are being serviced, see the service history for specific engines and see which correlation files are the most used. Also, we can set how the data is shown to see the MAPNET usage through time.

DISCUSSION OF RESULTS

Since 2012 there has been an average flow of 1,962 MAPNET reports, and projections for 2014 shows that by end of year there will be 2,020 reports sent to engine maintenance shops around the world.

Figure 1 shows the current MAPNET process starting when data obtained from an engine acceptance test is conducted all the way through the delivery to the end user of the created report. That data is uploaded by the aircraft mechanics or engineers through a web-based interface to the MAPNET server for processing. There exist pre-requisites in order for MAPNET to accept the data it should be submitted as a text file (*.txt*) in a certain following a specific structure. Once the data is received and according to the input setting provided by the mechanics information about that specific engine is loaded from libraries such as baseline data, operational limits, coefficients and specific equations to be used in the creation of the final report. Once that information is loaded the different engine modules are assessed, deviations and errors are calculated, providing the final part of the report. At the final phase of the process a new entry is made in an outgoing logger to document each time a report is generated before being sent to the end user.

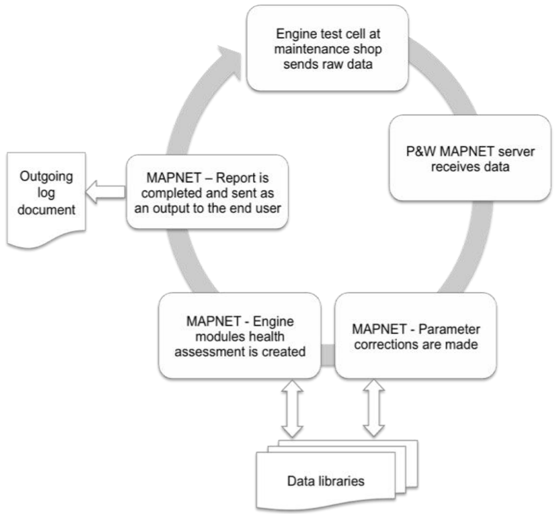

Figure 1
MAPNET data cycle

In figure 2 is a graphical representation of the basic elements that the developed software uses to create a usage record. From figure 1 we saw that every time a report is generated a new entry is made in an outgoing reports log. That log is one essential piece in the automation process. Once the user starts the automatic process the software accesses this file and checks the last report listed in the usage record spreadsheet and looks for it in the outgoing log file, in this way the software determines which new reports have been created since the last time the log file was accessed. After obtaining the report filenames from the log file and entering them into the usage record spreadsheet the software surfs through multiple folders in order to find specific MAPNET reports. Once the desired report is found the file is loaded into the computer memory and read by the software line by line determining specific parameters that are required to properly document each report into the usage record spreadsheet. This is basically the process the software do, along with other minor functions.

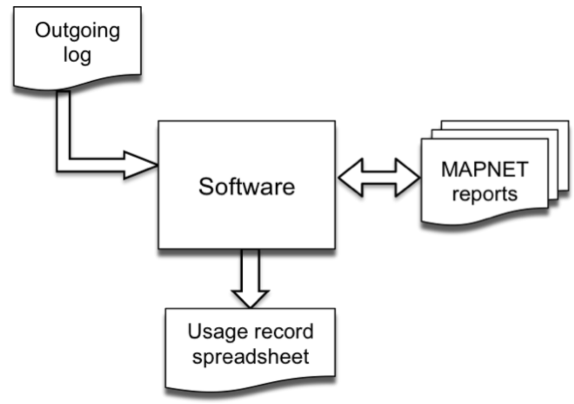

Figure 2
Process for MAPNET usage tracking with new software

Table 1 list the steps involved in the old process of maintaining a usage record tracking of every MAPNET report generated. Figure 4 shows the distribution of time consumed by each individual step. Table 2 summarizes the time taken by the developed tool to complete the same task as in Table 1. Figure 3 illustrates the reduction in processing time, with the new process the same task is done in 17% of the time it took before. Calculated using the current hourly rate for this service represents savings of $34,720 per year by automating this process. The development and implementation of this tool not only yield economic benefits but also improves the quality of the final product by eliminating the possibilities of human error in data management.

Table 1
Duration of old process for maintaining MAPNET usage record.

Step	Duration (min)
Access outgoing log record file	1.0*
Cross-check last report in usage record with last generated report in outgoing log	1.33*
Enter parameter data for new report into usage record.	40
Total	42.33
*One time only step Times are calculated for 10 cycles.	

Table 2
Duration of new process for maintaining MAPNET usage record.

Step	Duration (min)
Access outgoing log record file	
Cross-check last report in usage record with last generated report in outgoing log	
Enter parameter data for new report into usage record.	7.5
Total	7.5
All steps are integrated into one automated application. Times are calculated for 10 cycles.	

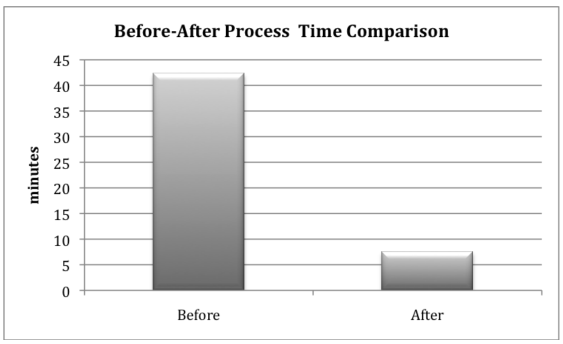

Figure 3
Before and after time consumption for entire process

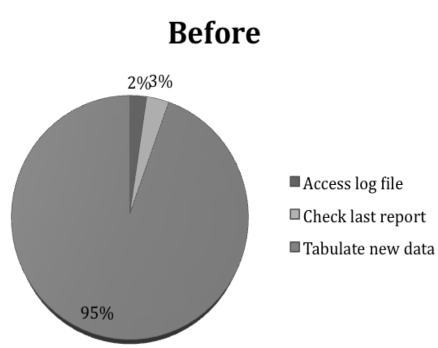

Figure 4
Old process step time consumption distribution

CONCLUSION

Through the automation of the MAPNET usage tracking process a great time reduction was achieved. When comparing the new process versus the old process a percent of reduction time of 564.40% was the final result of the project, a great improvement in productivity.

It has been shown that automation processes not only are seen in actual manufacturing lines where a new machine can be configured to do a manual job more effectively. With software tools engineers and professionals are able to automate process that at one time the computer helped us obtain faster results. With the accessibility of computer languages and the adequate technical knowledge we are able to even automate computer processes obtaining not only reductions in labor time but reductions in errors. With less or no errors we produce higher quality products, ensure reliability and open up resources to invest in new tasks and projects. With such a high volume use the development of this software has enabled its users to have a visible way of identifying MAPNET clients, understand their behavior, define the demography of its users and help in the process of customizing and fine tuning the system to better serve its purpose. For a future release, the software will include a logic that will enable it to create semi-automatic usage reports. Such reports will include statistic tables and graphs that will form part of a quarterly general report on MAPNET.

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