Planning of Non-routine Work for Aircraft Scheduled Maintenance

Josanne Aungst, Mary E. Johnson, Sung Soo Lee, Denver Lopp, Marc Williams
Purdue University
jaungst@purdue.edu, mejohnson@purdue.edu, lee564@purdue.edu, denver@purdue.edu, mewillia@purdue.edu

Abstract

Aircraft maintenance repair and overhaul (MRO) outsourcing has grown rapidly over the past few years with many airlines approaching more than 50 to 60 percent of their maintenance contracted to third-party operators. With MRO providers performing maintenance on several different airlines and aircraft types within the same hangar facilities, the standardization of maintenance practices and tasks within the MRO has become more difficult. One area of maintenance, the non-routine process, has become a central point for reducing redundancy of work tasks and maintenance cycle time. Non-routine tasks are additional maintenance needs found during aircraft maintenance checks but not included in the scheduled task requirements. A graduate class in the Aviation Technology Department at Purdue University has designed a futuristic process of the non-routine system that shows promise for reducing cycle time and improving the standardization of work. By comparing the existing non-routine processes to an innovative digital application, the total non-routine required tasks were reduced by more than 50 percent. The new system also moved critical information flow of expected non-routines forward in the process so that they begin prior to aircraft arrival, while maintaining the prevailing technician mindset in their current system and without forcing a new computer process ideology.

Introduction

Since the 9/11 events, large adjustments have been made to our aviation transportation system. To regain financial stability, the airlines have diverted their maintenance operations to third-party providers (maintenance repair and overhaul operators), which has been driven by the economical factors of lower labor costs, reduced fixed overhead cost, and the benefits of increased competitiveness in maintenance services through an open bidding system. Aircraft maintenance repair and overhaul (MRO) outsourcing has grown rapidly to the point where many airlines are approaching more than 50 to 60 percent of their maintenance contracted to third-party operators [1]. The present MRO industry in the United States now represents approximately 50 percent of the airline maintenance costs, consisting of an annual $45 billion service, with projections of growing to more than $68 billion in 10 years [2].

Because of the past independent nature of building specific individual maintenance programs and procedures tailored to each airline, the maintenance, repair and overhaul (MRO) operators now face inherent issues of complexity. For example, in a typical large MRO facility, there may be 10 aircrafts under repair, with five different models of different

ISBN 978-1-60643-379-9

manufacturers, represented by five different air carriers with individual service packages and work procedures. Contributing to this complexity, a large portion of the aircraft maintenance can be classified as non-routine. Non-routine tasks may be as high as 50 percent of the total maintenance completed during an aircraft scheduled service [3], adding several variability issues to be considered when adjusting labor loads, task preparation, and needed parts.

Through discussions with several large aircraft and general aviation MRO operator managers and airline maintenance representatives, this research effort found that the non-routine process was primarily manual and involved multiple steps and hand-offs. This research also found that approximately 40 percent of the non-routines created by inspectors during a typical maintenance check have been written up before as part of past maintenance services. Moreover, no overall standardization system has been created for these reoccurring non-routines, generating a large amount of paper work to be reproduced during each maintenance service. The non-routine process starts with the inspector writing up the non-routine, and then the supervisor reviews the non-routine at the aircraft. Next, the supervisor analyzes the inspection write-up, determines the work to complete the non-routine task, researches the latest service manuals for service work to be followed, and orders the parts and tooling needed for the technician to complete the task. The supervisor determines the estimated time and forwards the paperwork to planning personnel for scheduling sequence of the maintenance service and ordering of parts and required tooling. In most situations, this non-routine process has been found to occur when a non-routine has been written-up, regardless if it was repetitive from a past maintenance service or not. The Purdue graduate students observed that non-routines are a large portion of the MRO effort, that the process is mostly manual, and that non-routines are repetitive. The students took on these challenges and, acting with the big picture in mind, formulated a new non-routine process approach that could provide insight into reducing cycle time and increasing labor efficiency levels.

Method

Purdue’s Aviation Technology Department has many years of experience working with maintenance operations of airlines, large aircraft MROs, and general aviation maintenance repair operations. From this broad-spectrum knowledge of aviation maintenance processes and faculty guidance, a graduate class at Purdue formalized a generic non-routine process that represents what is used today in MRO operations. The information used for the generic process was based on past and current information gathered through discussions and visits of MRO operations, which included large aircraft and turbine general aviation providers. This process was reviewed by Purdue experienced faculty and outside consulting firms, who have extensive expertise in aviation maintenance operations. The process was modified to maintain commonality and represent a typical non-routine process being performed in today’s aviation industry.

The graduate class analyzed the generic non-routine process. Through root cause analysis methods [4], the class distinguished the value-added steps from the non-value-added steps that contribute to labor inefficiencies and task rework. From these analysis techniques, the class identified areas of inefficiencies and formalized a new process that would provide opportunities for efficient labor assignments and reduce the preparation time of repetitive non-routines. Important elements of the new non-routine process focused on using past history to help guide current actions, increasing the maintenance-related information communicated concerning aircraft scheduled for service, and utilizing optimization models for non-routine forecasting and scheduling.

In addition, two major strategic constraints governed the design of the new process: (1) system design features that build upon the existing process flow that technicians presently use in planning non-routine work; and (2) the utilization of existing and commonly used computer technology. For example, aircraft maintenance planners work in planning booths where tasks are planned, monitored, and controlled. In MRO planning booths, the faculty noticed that tasks cards and the sequencing of the task cards to be worked are laid out in designated racks separated into aircraft zone areas or technical skill requirements. Interactions of faculty with these planners and technicians have indicated the sequencing of work flow to be commonly analyzed in bucket-type approaches, allowing work progress to be quickly accessed by observing the grouping of task cards. The faculty also noticed when computerized systems have been incorporated into MROs for planning of work flow, they often do not follow this common process of presenting work flow data to planners or technicians in a bucket-type format. To plan the work flow, these computerized systems often require detailed precedence or sequence of each item to be worked. This detailed sequencing creates a mismatch between the required information and the logic flow used by technicians in the planning booths. This mismatch has forced the technician to adapt to the uncompromising computerized set of rules and procedures, resulting in resistance to change and failure to gain the overall benefits of the computerized system. The faculty guided the class to concentrate on designing the new non-routine system so that it would provide an overall visual approach for work task sequencing and mimic the logic flow of the maintenance technician at the worker level, while powered by recommended computer hardware and software used in today's existing market.

The current and redesigned non-routine processes were analyzed and compared against each other for efficiency differences in the number of tasks to be completed; non-routine information flow features that would contribute to improved optimization work planning and possible reduction of repetitive non-routine preparation; and adaptability to current logic planning concepts used by technicians. The next step will be to test the redesigned process in a practical setting, which is beyond the exploratory nature of this paper.

Discussion

When the Purdue graduate class developed a process model of the generic non-routine process commonly used today in MRO operations, it consisted of 103 tasks to be completed by supervisors, daily floor planners, and technicians. It became apparent from reviewing the process that our aviation industry has basically been left behind by technology in gaining the smart movement for decreasing cycle time and enhancing labor efficiency levels. This was indicated by the fact that only three of the 103 tasks involved computations or data sorting by computers. The class analyzed the tasks and determined that approximately 50 percent of the tasks were paper-handling tasks. Through discussions with planners and managers about the information used in sorting the non-routine tasks for entry into the scheduled maintenance service, it was found to be reliant on informal, local knowledge of the technicians, with limited or no databases provided for historical reference. This reliance has created a situation where non-routine assignments are treated as new information, individual work behaviors vary widely, and inconsistencies exist across the maintenance system.

Continuing to repeat the same non-routine produced a large level of duplication of effort from one aircraft to the next, due to the lack of accumulating a computer database of non-routines and forecasting the probability of reoccurrence in a scheduled maintenance check. Figure 1 illustrates the information flow of the non-routine. In the process, information on the non-routines did not occur until five steps after the aircraft arrived. Non-routines did not get scheduled into the aircraft maintenance plan until 26 tasks later, as shown by the last step where work began on task cards. With inspectors knowing that certain non-routines have a high prospect of being repeated from experience in past maintenance services, it would be beneficial to explore methods that calculate the probability of repeatability and estimate the cost of not preparing for such an event, such as the delay cost of receiving parts or the length of proposed work.

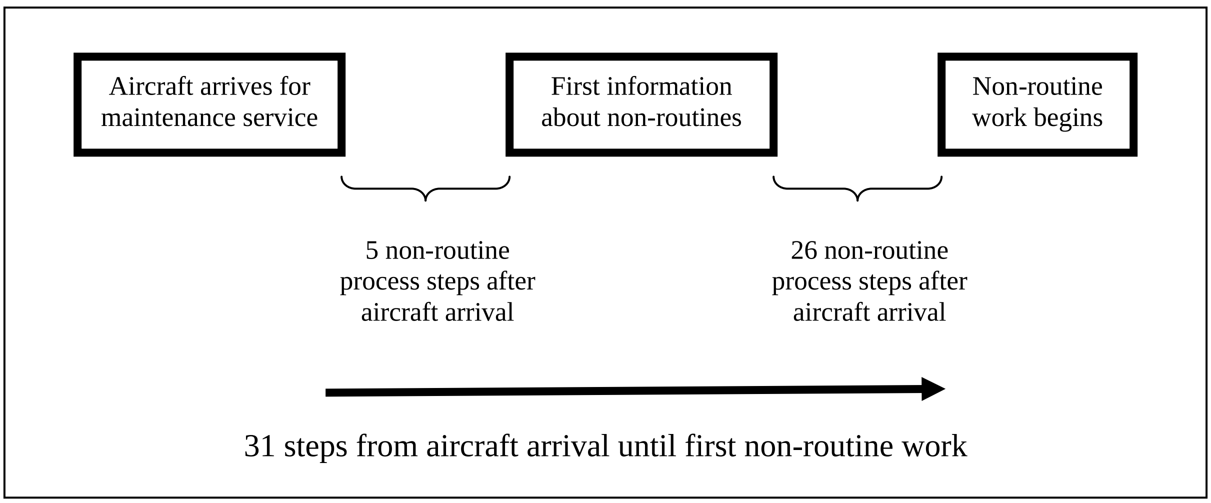

Figure 1. Non-routine Information Flow

A major and important element in developing the new process was moving the information flow on non-routine tasks to an earlier part of the process prior to aircraft arrival, as illustrated in Figure 2. It was anticipated that this change will help alleviate the firefighting mode typically seen in MROs and change the focus to fire prevention.

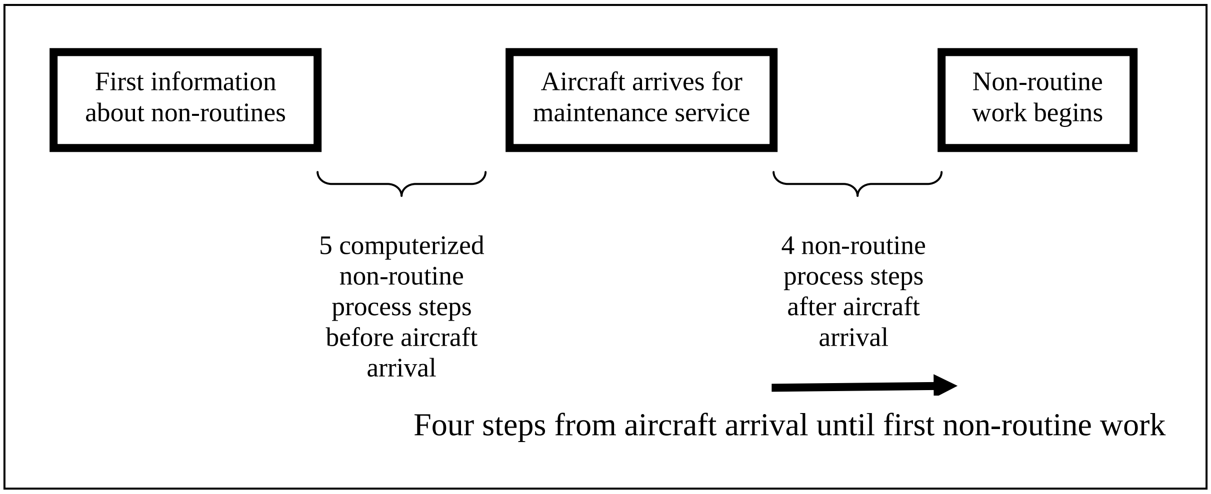

Figure 2. Re-designed Non-routine Process Flow

Integrating technology of the new process was focused on developing a standardized data base of non-routines and forecasting the probability of reoccurrence in a schedule maintenance check. Using computer technology, algorithms would be developed for sorting the database of non-routines and generating a digital non-routine task card that would be built upon updated electronic revisions of manuals and directives. The daily operational data would be entered by inspectors, technicians, supervisors, and others through electronic tablets, allowing a standardized template to be followed and the instant update of information to be generated in a computerized database. Calculation formulas would produce information for the probability of non-routines to be generated in a service and predict the return versus cost of not preparing for a non-routine before an aircraft maintenance service arrival. The process would allow the information to be forwarded on a real time basis, automatically providing visual displays to maintenance floor operational areas, as shown in Figure 3 [5]. It would be envisioned that the information would be provided in real time and displayed for the majority of the working groups on the floor, which would facilitate empowering of the technical teams. Interactive information would create the opportunity for the adaptation of decisions to be made at the floor level that matched the role and skill level of the working groups, assisting in reducing the common delay effect of passing the decision process up the chain of command and back down for final action at the floor level.

Using past history to guide current actions, two databases would need to be generated for the redesigned process. One would be needed for storing all past services completed by the MRO, which could include extensive coverage based upon contingent agreements between the MRO and aircraft owners/users. The second database would depend on data collected by an aircraft on-board computer and either stored or transmitted by on-board storage systems. It was proposed as a futuristic approach, where all maintenance data completed on an aircraft will be stored and recorded in a standardized base system as part of the aircraft itself. This would allow a historical record of the aircraft to be generated without the risk of losing information through ownership or operational changes. Determining a standardized system

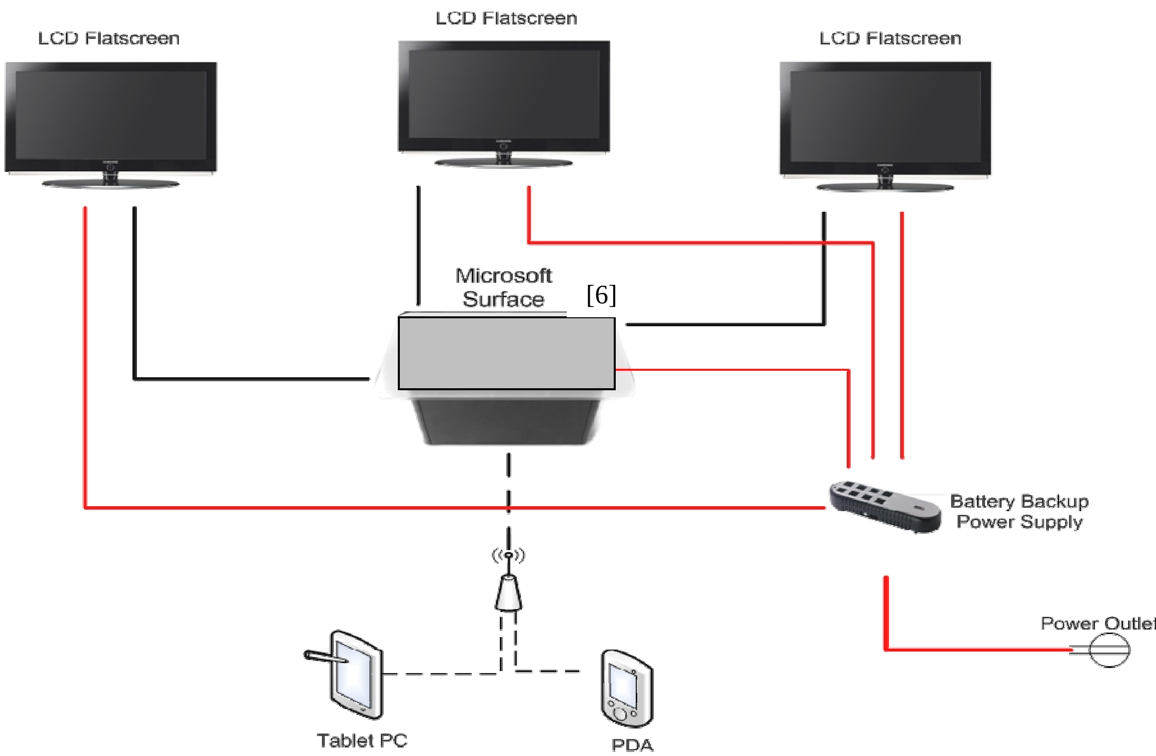

Figure 3. Non-routine Visual Display as a Component of Hangar of the Future Software [5]

would allow the accessing of instant and historical maintenance data, providing the ability for large accumulation of non-routines on aircraft types and models. This information could be centralized by maintenance associations, examples being established in ATA code format [7], providing overall system attainability and increasing information knowledge. In building the new process, the graduate class determined three functional computer needs: data sorting, manipulating of the data for calculations in the optimizing the model, and use in communicating and transferring the information from digital to useful visual display formats.

A guiding principle and challenge for the new system was to include functions that could rely on today's current technology. Included were requirements for e-authorization and electronic log recording, database sorting functions, and computer calculations that could prioritize and develop projected models. Although new input and standardized templates would have to be generated and put into service in the workplace, the process steps included could depend on the existing technology. For example, centralized library of digital manuals and documentation, standardized information from FAA or other regulators, information from manufactures, and predetermined customer policies and procedures for each aircraft service requirements are all technically attainable, but rely on building data collection systems and standardization. It is currently possible to build on-board computers that could store all of the aircraft maintenance records, as shown by the progress occurring today in the maintenance system dialogistic system of the Boeing 787 [8]. A major component would be the ability to run simulations with constant and instant upload data from the work floor, allowing an improved pattern of real time job assignments and support requirements to be generated.

ISBN 978-1-60643-379-9

These could be demonstrated with interactive visual tools, such as Microsoft Surface (Figure 3), which absorbs data directly from several sources and allows multi-dimensional movement of hangar operations to be generated.

An another key direction in building electronic information sharing and real time status of task completion was to stress design features that build upon the existing process flow logic. As mentioned earlier, the task cards and sequencing of task cards are typically put in scheduled racks by aircraft zone areas or technical skill requirements by technician planners. This allows planners to visualize a large amount of package data at once, getting a feel of how the task cards are being completed and signed off in the rack decks. The new system stressed a visual electronic update that provided a similar pattern, allowing planners to view large amounts of completed data at once. This could be represented on a display, such as Microsoft Surface, having the representative aircraft displayed into areas as shown in Figure 3. This would allow each section of the aircraft to be shaded in different code colors as the work was completed. It was underscored in the new process that the digitalization should not force computerization thinking on the maintenance practices but should supply a provisional role in how maintenance technicians mentally approach processing tasks.

A large part of expected gains from the new process would be the ability to shift information about the service into a proactive mode instead of reactive. This may be seen by comparing Figure 1 and Figure 2. The database functions described earlier would sort past historical records for non-routines related to the specific type of service and aircraft, across all interactive carrier databases. Through a statistical analysis that would create a designated significance indicator, a certain level of expected non-routines would be identified and forecasted to be critical for planning in the maintenance service. The significance level would be a function in the costs of forecasting the non-routine and the non-routine not to be written up by inspectors, as well as not forecasting the non-routine and the non-routine becoming part of the service requirement. From the results of this significance analysis process, a list of forecasted non-routines would be compared against past services for that specific aircraft scheduled for service. These expected and known non-routines would be tagged as "expected" and added into the maintenance service planning. A simulation of the outlined optimizing model was not accomplished in this study and was beyond the scope of the development of the new exploratory process. It would be expected that the theory and concept would create further interest in developing practical working programs, which would determine if a non-routine should be scheduled for task preparation before arrival of the aircraft.

Results

The formulation of the new smart system minimized, simplified, and automated tasks, which resulted in approximately a 50 percent decrease in process steps, as illustrated in Figure 4.

	Current Process	Redesigned Process
Number of Computerized Steps	3	30
Total Number of Process Steps	103	49

Figure 4. Process Step Comparison Current and Redesign Process

The current process had only three computerized steps, and the redesigned process required 30 computerized steps. Several of these process tasks were redesigned to include computerized database sorts and calculation functions that would replace manual duties assigned of either technicians or support groups, reducing the requirement of labor and repetitive auditing processes. When reviewing the redesigned tasks, it was found that the total computerized activity consisted of 50 functions: 27 for data sorting, 19 for transmitting and transferring data for use by technicians and support groups, and only 4 required for computing data for optimization. This indicated when fulfilling the requirements of computer functions for the new process, the majority would entail database functions, allowing the selection and possible use of any one of several different database programs presently used in the industry. The implied results suggested a large reduction of labor to be achieved, reducing overall task requirements by more than 54 individual processes, and replacing 27 of those tasks with computer data sorting, illustration tasks, or computer decision functions.

Redesigning the process offered the opportunity to build databases that could be useful when predicting non-routines prior to the aircraft arriving for service. Given that non-routines could be up to 50 percent of an aircraft total service task requirement and more than 40 percent of those non-routines previously performed before, generating a new decision process for preplanning certain critical non-routines has the potential to provide large cycle time benefits. The ability to predict critical non-routines would reduce lead time in ordering parts and decrease the time needed to plan labor allocations.

As the graduate class worked through the matching of computerized functions with the current non-routine processes being performed in today's work environment, it became clear new technology could be incorporated that allowed enhanced visual displays for front line workers. It also became apparent that computer functions of data sorting, computer calculations, and visual displays could be designed in patterns the technicians have been currently using in today's work environment. As illustrated in Figure 3, displays can be quickly arranged with today's technology that provides up-to-date information that technicians can easily relate to the aircraft in service.

Summary

The new process was developed to demonstrate the gains that may be attainable with increasing smart systems in aircraft maintenance services, especially in the important role of non-routine work. Although several modules of new and progressive computerized programs have been developed and brought into aircraft services, the overall scope and comprehensive approach of these programs appears to be lacking. The purpose of this study was to identify the concept of a more complete digital approach to the non-routine process in aircraft maintenance service, and provide insight into some of the benefits that could be achieved. A large gain identified in this study was the reduction of task steps by approximately 50 percent, required in a typical non-routine process through the replacement of manual tasks with a computerized smart system. Importantly, this was accomplished by building upon the existing process flow technicians presently use in planning non-routine work, and not forcing canned computerized systems onto technicians. Another reason for exploring the changes was realizing through the standardization of work across carrier, aircraft models, and service types that there would be a potential increase in quality and safety and an integration of more flexibility into the system. A large component of the new system to reduce cycle time was moving the information flow of the non-routines up earlier in the process, allowing for increased recovery time of the non-routine impact in labor hours and in parts lead times. It would be expected that a shift from the localized knowledge of planners to a mathematical optimizing of the non-routine process would decrease the cycle time without increasing the manpower staffing levels.

The next step is to test the redesigned process in a practical setting, collect performance and adoption data, and incorporate the findings in the next generation of the non-routine process. This tested process could become the basis for the development of automated computer systems that predict non-routine work and develop more accurate maintenance plans, which are useful in reducing cycle times, labor costs, and part lead times. The overall concept and prospects of progress may be expressed best by Dr. Deming’s comment, “most possibilities for improvement add up to proportions something like 94 percent that belong to the system (process) and 6 percent to special causes” [9].

References

[1] Marcontell, D., “Future of MRO for the Americas,” Presentation at Renaissance Hotel, Las Vegas, NV. November, 2005, referenced in *Apogee and Perigee: Analysis of the U.S. Aerospace Industry*, Office of Aerospace and Automotive Industries International Trade Administration, U.S. Department of Commerce, June 2006, accessed June 10, 2008, http://www.trade.gov/td/aerospace/Apogee_and_Perigee_1_2006_final.pdf.

[2] Doane, C., “The Global Forecast, A Look Forward 2008–2018,” North American MRO Convention, Ft. Lauderdale, FL, April 2008.

[3] Andrick, R., "The Application of Handheld Devices in MRO," Aircraft Commerce, Oct/Nov, Issue 43, 2005, p. 54.

[4] Eckes, G., *Six Sigma Revolution*, John Wiley and Sons, Inc.: New York, NY, 2001, p. 131–138.

[5] Purdue University, "Hangar of Future," Presentation to USC, Purdue Student Research Team, Purdue University, West Lafayette, Indiana, May 5, 2008.

[6] Microsoft Surface, accessed Aug 28, 2008, http://www.microsoft.com/surface.

[7] Aviation InfoSearch, Aviation ATA 100 Codes/JASC Format, accessed June 10, 2008, http://www.aircraftshoptalk.com/ata100codes.php.

[8] Ramsey, J., "Boeing 787: Integration's Next Step," *Avionics Magazine*, June 1, 2005, accessed June 10, 2008, http://www.aviationtoday.com/av/categories/commercial/932.html.

[9] Harrington, H., *Business Process Improvement*, McGraw-Hill, Inc.: New York, NY, 1991.

Biography

JOSANNE AUNGST was a graduate student in the Krannert School of Management at Purdue University. She completed her undergraduate studies in Industrial Engineering at Purdue as well. She has begun working at United Airlines in a position focused on continuous improvement.

SUNG SOO LEE is currently a graduate student in the Aviation Technology Department at Purdue University.

MARY E. JOHNSON is currently an Associate Professor in the Aviation Technology Department and in the Industrial Technology Department at Purdue University. She is interested in performance measurement and improvement, and the incorporation of creativity in the learning process. Her PhD is in Industrial Engineering from UT Arlington.

DENVER LOPP is currently a Full Professor in the Aviation Technology Department at Purdue University, where he has conducted extensive work in the airline process improvement and optimization. He has held several airline maintenance and corporate finance management positions.

MARC WILLIAMS is currently a graduate student in the Aviation Technology department at Purdue University.