BY **MELISSA R. BOWERS** AND **GARY ADAMS**

Turbo TOC

The thrust behind Delta's maintenance success

Delta Airlines is going against industry trends in maintenance, repair, and overhaul (MRO). In 2006, Delta Airlines Technical Operations (Delta Tech Ops) expanded its engine maintenance business with a resounding 33 percent increase in orders from external customers. This remarkable achievement was accomplished not only during a time when Delta was facing bankruptcy, but also amidst an industry push to continue outsourcing airline MRO operations. Such substantial growth was achieved through the infusion of a new execution management system rooted in the theory of constraints (TOC).

In 2005, Delta Airlines filed for Chapter 11 bankruptcy. As part of Delta's recovery plan, the Tech Ops Group was charged with increasing 2006 revenues to $270 million. Moreover, workers were required to achieve this goal without added capital investment or labor. Operationally, this goal translated to a 20 percent increase in production volume, as well as a 20 percent reduction in turnaround time.

An attitude of loyalty and determination in the workforce to "keep Delta my Delta" created an atmosphere ripe for change and improvement. Through the implementation and sustainment of a drum-buffer-rope (DBR) scheduling system in its repair and support shops and critical chain method (CCM) in the engine disassembly and reassembly areas, Delta's Engine Maintenance Group played a critical role in Delta's emergence from bankruptcy.

Key elements

The design and implementation of the new execution management system at Delta was built on 7 simple principles:

1. Use the system constraint to set the drumbeat: Restrict the rate of release of engines into the disassembly area to match the capacity of the Delta system constraint—the repair and support shops.
2. Manage backshop queues: Release work to the repair and support shops based on a DBR system, and process jobs according to a strict "first in, first out" discipline.
3. Avoid multitasking: Delay the reassembly of each engine until 100 percent of the parts are available.

Delta's rules and methods of management were turning the repair and support system as a whole into a constraint.

4. Synchronize execution priorities: Use CCM to provide integrated priorities across all engine disassembly and reassembly shops in parallel with both DBR management and a real-time information system to track and manage component parts through all stages of the repair process.
5. Anticipate and rectify the potential for delays: Enforce a well-defined set of rules in order to manage parts approaching their targeted turnaround time (less than 5 percent of total parts).
6. Use flexibility to respond to variation: Reallocate a flexible workforce and other resources among different areas to respond to variation in workload.
7. Adopt and adhere to a doctrine of accountability: Establish a dedicated workforce, consisting of people who are committed to sustaining the highest level of accountability, communication, and discipline.

Identifying the system constraint

Identifying the system constraint presented a significant challenge in the MRO environment due to the number and complexity of products. Depending on the type of repair required at any particular time, the repair and overhaul of each product may be viewed as a unique project comprised of a specific set of tasks with a number of constraints in the repair process.

Identifying the system constraint started with a basic question: Why is it so hard to get parts back on time for reassembly? Labor and equipment originally were thought to be the predominant constraint. However, after some analysis, it was established that there were no physical constraints in the existing system, only policy and managerial constraints. Delta's rules and methods of management were turning the repair and support system as a whole into a constraint.

With repair and support identified as the system constraint, a solution was needed to exploit, subordinate, and elevate the constraint. Because the repair and support shops are shared resources among 9 distinct product lines—as well as with line, hanger, and component maintenance—these resources adopted a simplified DBR system to control the release of work into the repair and support shops and provide uniform priorities to all the shops.

The simplified DBR scheduling system for the repair and support shops used the due date for each product as a simplified drumbeat. A single, uniform, predetermined length of time served as the rope to pull parts into the system regardless of individual work content. An explicit time buffer then was specified to guard against unexpected delays and variation.

Even though the repair and support shops' turnaround time ranged from 20 to 80 days, leaders discovered that the task times or mechanic touch times for most parts in the repair and support shop areas were less than 5 days. Given this disparity, the appropriate rope length or parts release point was based on the lead time of the repair and support shops' longest-lead-time part. The release point or rope length was determined to be 15 days—5 days for the longest work content plus 10 days of buffer time. Thus, regardless of specific work content, parts are released into the repair and support shop area 15 days ahead of the drumbeat or the scheduled assembly date. Of those 15 days, the last 5 are used in conjunction with an exception-management policy to provide a time buffer against unexpected delays and variations.

Once parts begin the 15-day journey through the repair and support shop area, all parts are processed in "first in, first out" order for the first 10 days after parts release. Any part remaining in the repair and support shop area 10 days after entry (release date) is labeled "red" and requires special handling via an exception-management process during the remaining 5-day buffer period. This serves to protect the project against unexpected delays.

All red parts are pushed to the front of all work queues in the repair and support shop areas and processed in order of due date. Once a part is deemed red, it follows the same red scheduling protocol at all consecutive downstream repair and support shops until serviceable.

To accommodate unusual cases involving unexpected delays, one additional job class—expedited parts—is added to the priority processing list. Recognizing that, occasionally, extreme circumstances can justify the need for the expedite action, managers permit no more than 20 total expedited parts anywhere in the repair and support shops at any one time.

This straightforward scheduling system provides the repair and support shops with a simple tool to prioritize work.

The 20 expedite tags represent only 0.2 percent of all parts (20 out of 10,000) typically in process at any given time. These parts are labeled clearly with large, green expedite tags.

The simple priority processing rules used to facilitate the DBR scheduling system are to process

1. all parts with green expedite tags,
2. red items in order of due date,
3. all other items in "first in, first out" order.

This straightforward scheduling system provides the repair and support shops with a simple tool to prioritize work so as to only schedule work precisely when it's needed. Queue lengths are minimized, as mechanics no longer perform tasks in big batches ahead of due dates.

CCM for engine shops

Delta used CCM to drive the product schedule so that work could be released to the repair and support shops through the DBR system at a prescribed rate to control work in process (WIP) in backshops. CCM does not pad each individual task or operation with a time buffer to guard against unexpected delays. Instead, CCM sets shorter, more aggressive individual task times and adds a small number of time buffers within the network of tasks as well as an aggregate time buffer at the project's end, termed the project buffer. The execution of CCM then enables employees to focus on managing these time buffers.

CCM was implemented using Realization Technologies Concerto software to prioritize each project task to meet customer due dates. The concept of staggering or "pipelining" the beginning of each project was used to subordinate the system to the constraint of the repair and support shops. Formal steps were required to coordinate the CCM in the repair and support shops with the CCM in the engine shops. The engine production was broken down into 9 simple milestones: induction (I0), completion of disassembly (D0), disassembly plus 2 days (D+2), disassembly plus 7 days (D+7), begin assembly minus 15 days (A-15), begin assembly minus 5 days (A-5), begin assembly minus 2 days (A-2), begin assembly (A0), and final due date to engine test cell (T0). The time from the end of product disassembly to the start of reassembly is at least 22 days.

Prior to induction, each engine must have a prescribed set of repairs or work scope documented along with an assigned work order number. Engine inductions are staggered to smooth the flow of work and control WIP levels. Induction dates are determined based on a combination of demand, desired WIP levels, and shop capacities to subordinate the engine shop schedule to the identified constraint—the repair and support shops.

By D0, engines are disassembled and an accompanying bill of material is completed. Shop orders are created with the accompanying due date for each part that requires repair. An internal software package plays a crucial role by tracking each part associated with a given work order or engine as it progresses through the repair process. By D0 completion, all exception parts are released as quickly as possible into the repair and support shops for further inspection and disposition. Identifying "exception" parts at D0 begins the process of elevating problems in the engine repair process.

The third milestone is D+2, which is largely exception management. D+2 marks the completion of the inspection and disposition of all exception parts. During D+2, non-exception parts in need of internal repair are routed to a central holding area inside engine maintenance to await release into the repair and support shop system.

At the D+7 milestone, the status of all parts that require either replacement or outside repair is updated. Specific inbound purchase order numbers are assigned to engine work orders for parts purchased for replacement or incoming from outside repair shops. This process provides parts visibility across the system and highlights any potential problems or delays. At D+7, enough time remains in the repair process to adjust to variability in parts repair or procurement.

The fifth milestone is A-15, during which non-exception parts are released from the central holding area to the repair and support shops. This occurs at the rate of 35 parts per hour, the rate of processing in the repair and support shops. Synchronizing the rate at which parts are released into the system with the processing rate of the system constraint provides subordination to the constraint and increases visibility to parts waiting to be released. For example, if the engine type mix changes significantly, parts WIP can be seen building up in the holding area, which, in turn, is a trigger to schedule overtime.

At A-5, each part remaining in the repair and support system turns red, which elevates the part status for scheduling and initiates an exception management process for each red part to decrease any delays and unexpected varia-

tion in the part's remaining processing time. In general, A-5 provides managers with a comprehensive picture of engine status with clear visibility of the location and condition of all parts required to begin engine assembly.

All parts not yet available for engine rebuild are scrutinized at A-2. Parts not returned for engine assembly at this point follow a set of exception rules established by managers to minimize any delay. At A-2, any obstacle that may prevent the completion of the engine assembly by its due date is visible to everyone in the value stream.

A0 marks the start of the engine assembly process. All parts required for any particular engine serial number should be kitted and ready for assembly. To avoid wasted time due to multitasking, rules of engagement stipulate that engine modules wait for 100 percent of the required parts before beginning the assembly process. Assembly may start without 100 percent of the required parts only with documentation that a missing part will reach the engine when needed to meet the test cell delivery date.

One key to the implementation and sustainment of this successful production management system at Delta is a doctrine of accountability, discipline, and communication among all stakeholders in the engine maintenance process. The doctrine is reinforced with a daily morning production meeting, which includes a representative from each engine line, each repair and support shop functional area, the materials and inventory area, procurement, and upper level management.

Each individual participating in the meeting has ownership in the new system, believes in the system, and is responsible for instilling the necessary discipline and accountability in individual areas to make DBR succeed on the shop floor. At the conclusion of the meeting, the key stakeholders are all "marching to the same beat."

True success

Implementing DBR and CCM enabled engine turnaround times to drop 15 percent and throughput to increase 22 percent. In one year, the repair and support shops decreased turnaround times on parts by 40 percent, increased throughput by 18 percent, and cut WIP levels in half. In addition, Delta was able to increase the total engine maintenance workload from customers outside of Delta Airlines by 33 percent. As for the bottom line, not only did Delta's Tech Ops Group meet its 2006 revenue goal of $270 million, but the company also exceeded that goal by $42 million and emerged as a leader in airline MRO.

Melissa R. Bowers is an associate professor in the department of statistics, operations, and management science at The University of Tennessee. She may be contacted at (865) 974-1736 or mrbowers@utk.edu. Gary Adams is manager, continuous improvement support group, technical operations at Delta Airlines.