Warner Robins uses Theory of Constraints (TOC) for improvement efforts

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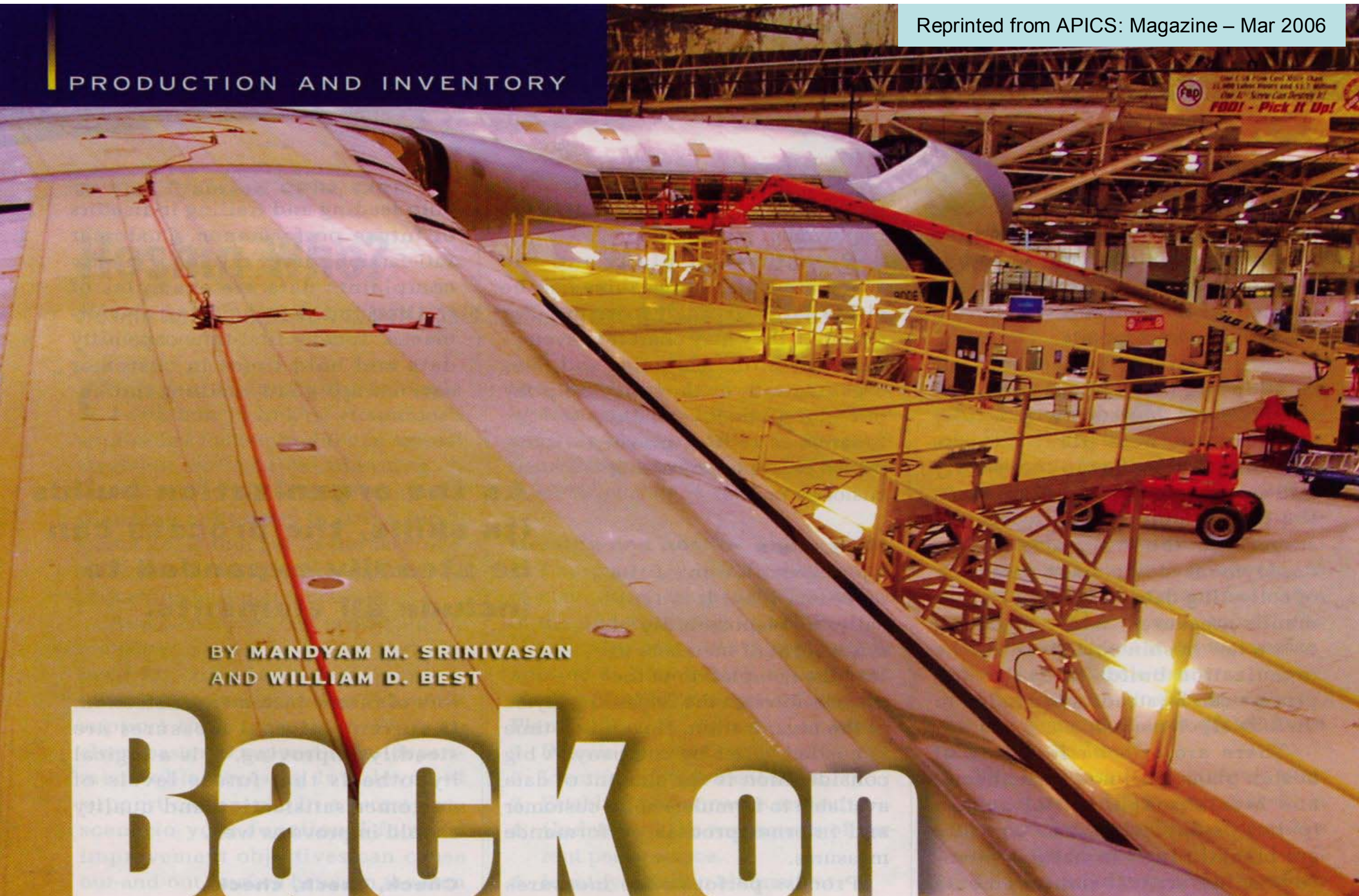

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Back on the Runway

The United States Air Force meets critical chain project management

Maintenance, repair, and overhaul (MRO) is a burgeoning business. According to AeroStrategy, a consulting firm in the aviation and aerospace industry, annual worldwide spending on MRO in the aircraft industry is approximately $96 billion. This is significantly more than the $75 billion estimated to be spent worldwide on new aircraft production every year. Spending in the military aircraft MRO market alone is estimated to be about $50 billion, with the United States driving approximately 40 percent of the spending.

To paraphrase the late Senator Everett Dirksen, "A few billion here, and a few billion there, and pretty soon we're talking about real money." With this level of resources being spent in this sector, it's good business to continuously evaluate techniques for managing MRO activity more effectively.

Consider aircraft repair and overhaul, a process that often takes more than three months to complete. From a modeling perspective, each aircraft can be considered a project consisting of a set of tasks that must be completed. Traditional project management tools such as CPM (critical path method) and PERT (program evaluation and review techniques), in use since the 1950s, provide a structured approach for managing the various tasks comprising such a project. However, while these techniques recognize uncertainties present in MRO activity, they have some drawbacks, the primary one being that they account for the uncertainties in the project *plan*, rather than provide a mechanism for dealing with uncertainties during schedule *execution*. Furthermore, they do not adequately address the uncertainties and resource contentions across multiple projects. Consequently, they induce and create waste during execution.

Critical chain project management (CCPM), introduced by Eli Goldratt in 1997, is a relatively new approach to multiproject management that has produced very good results in diverse settings such as new product development, software design, and MRO. It provides a systems perspective toward managing multiple projects within an organization and facilitates significant reduction in project completion times.

The C-5 at Warner Robins

The Warner Robins Air Logistics Center (WR-ALC), situated within the Robins Air Force Base in Georgia, employs about 3,000 people in its Aircraft Maintenance Group. It maintains four different types of aircraft: the C-5, C-17, and C-130 transport aircraft; and the F-15 fighter jets. The repair and overhaul activities on these aircraft take on one of two forms: program depot maintenance (PDM), which involves a complete overhaul and repair of the aircraft; and unscheduled depot level maintenance (UDLM), which is short-cycle maintenance done at the depot and takes anywhere from one to thirty days. Our focus here will be on the PDM activity at WR-ALC.

WR-ALC was assigned the responsibility for MRO activity on the C-5 transport aircraft when the Kelly Air Force Base in Texas was closed based on a recommendation made by the 1995 Base Realignment and Closure Commission. WR-ALC was required to compete in a public-private solicitation for the work. It won the bid, but did not receive the expected level of personnel transfers from Kelly Air Force Base.

WR-ALC thus inherited the C-5 aircraft under rather difficult conditions. The situation was compounded by the fact that the C-5 is an aging aircraft. Lockheed Martin produced and delivered the last C-5 in 1989. In addition, MRO projects usually have to deal with a lot of uncertainties. Typically, there are three types. There is the *known* work that must be performed on an aircraft. Then there is the *known unknown* work, consisting of work to be performed on some, but not all aircraft. For this category of work, while it is possible to arrive at statistics that provide the percentage of aircraft that require this work, it is usually hard to predict exactly which aircraft will need this work. Finally, there is *unknown unknown* work, due to damage caused by corrosion, stress, and the like, and this is quite unpredictable. Often there are no parts available to repair such damage, requiring that they be built from scratch. Sometimes, new repair techniques have to be developed by engineering to handle such unpredictable work.

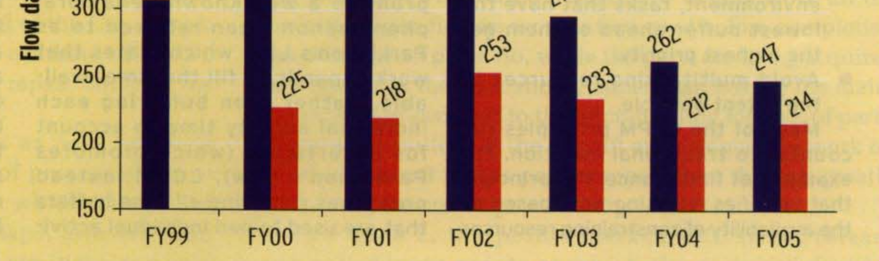
At WR-ALC, the resulting uncertainties—which included corrosion typical in aging aircraft, highly variable task times, parts shortages, funding delays, competition for resources, lack of fixtures, and new personnel unfamiliar with the C-5—provided many reasons for it to require long lead times to repair and overhaul these aircraft. Indeed, in fiscal year (FY) 2000, namely, the period from October 1999 to September 2000, WR-ALC was requiring around 390 "flow days" to repair and overhaul these aircraft. Almost all C-5s were delivered late, and costs almost always exceeded estimates by large amounts. Requests for schedule extensions were made on a regular basis.

Lean initiatives

To address these problems, WR-ALC undertook a series of initiatives between FY 2000 and FY 2005 to significantly reduce the flow days. It established cell teams; instituted standard work in all its cells; deployed production control boards, parts kits, and point of use material; and applied 6S (5S plus a sixth for safety) techniques and method sheets (clear job instructions). It instituted a mechanism to pull components from the back shops and worked on reducing travel times within the depot. These initiatives resulted in a dramatic reduction in flow days.

As shown in Figure 1, the flow days decreased from about 390 days in FY 2000 to about 240 days in FY 2005. While part of this reduction could be attributed to a learning curve as WR-ALC became proficient at repairing and overhauling the C-5, a fairly significant reduction in

Figure 1 Flow days for repair and overhaul of the C-5



flow days can be attributed to the implementation of lean principles to manage the MRO activity. These efforts led to the C-5 repair and overhaul operations winning the Shingo gold award in September 2005, which was the first time it was offered to the public sector. WR-ALC was the only public sector organization to win the gold award in 2005. The lean initiatives also resulted in a significant improvement in due-date performance. Just 25 percent of the aircraft were being delivered on time in FY 2002. In FY 2004 and FY 2005, the due date performance was 100 percent, and not a single aircraft was delivered late.

Pressure to perform

Despite the significant improvements achieved through FY 2005, WR-ALC was still under considerable pressure to reduce flow days. Management was aware that reducing flow days led to a corresponding reduction in the number of aircraft in the depot. Reducing the number of aircraft at the base was an important objective because there are currently only 114 C-5s in service. During FY 2004 and FY 2005, WR-ALC had between 11 and 13 aircraft in the depot at any point in time, in various stages of repair. These aircraft thus represented around 10 percent of the fleet unable to haul cargo for the military. A conservative estimate of the revenue generated by an aircraft hauling cargo was in the neighborhood of $40,000 per aircraft per day. Thus, every day the aircraft spent at the depot undergoing repair and overhaul represented a significant potential revenue loss to the government.

Decision makers at WR-ALC were well aware of the fact that reducing the number of aircraft in the depot would provide several side benefits. It would result in less competition for facilities, mechanics, and other resources. It would enable supervisors and team leads to focus on fewer jets at one time and focus management attention on fewer aircraft. Fewer aircraft in the depot would result in an increased speed of maintenance, resulting in increased throughput and promoting a cycle of ongoing improvement.

WR-ALC also was under pressure to take on additional work, such as UDLMs, which it was unable to do because of an apparent lack of capacity. Finally, it had to contend with a corporate mandate, an Air Force initiative to increase the availability of all weapon systems by 20 percent by the year 2011. This was a considerable challenge, especially for an aging aircraft like the C-5.

In December 2004, managers at WR-ALC decided to adopt CCPM to reduce flow days and thereby reduce the number of aircraft stationed at the base. They contracted with Realization Technologies, through LOGTECH Inc., to implement the CCPM management process at the center. A faculty member from the University of Tennessee's College of Business Administration provided guidance and oversight. The Realization Technologies Concerto software was used to implement CCPM.

The Structure of CCPM

Critical chain project management (CCPM) is based on a number of key principles.

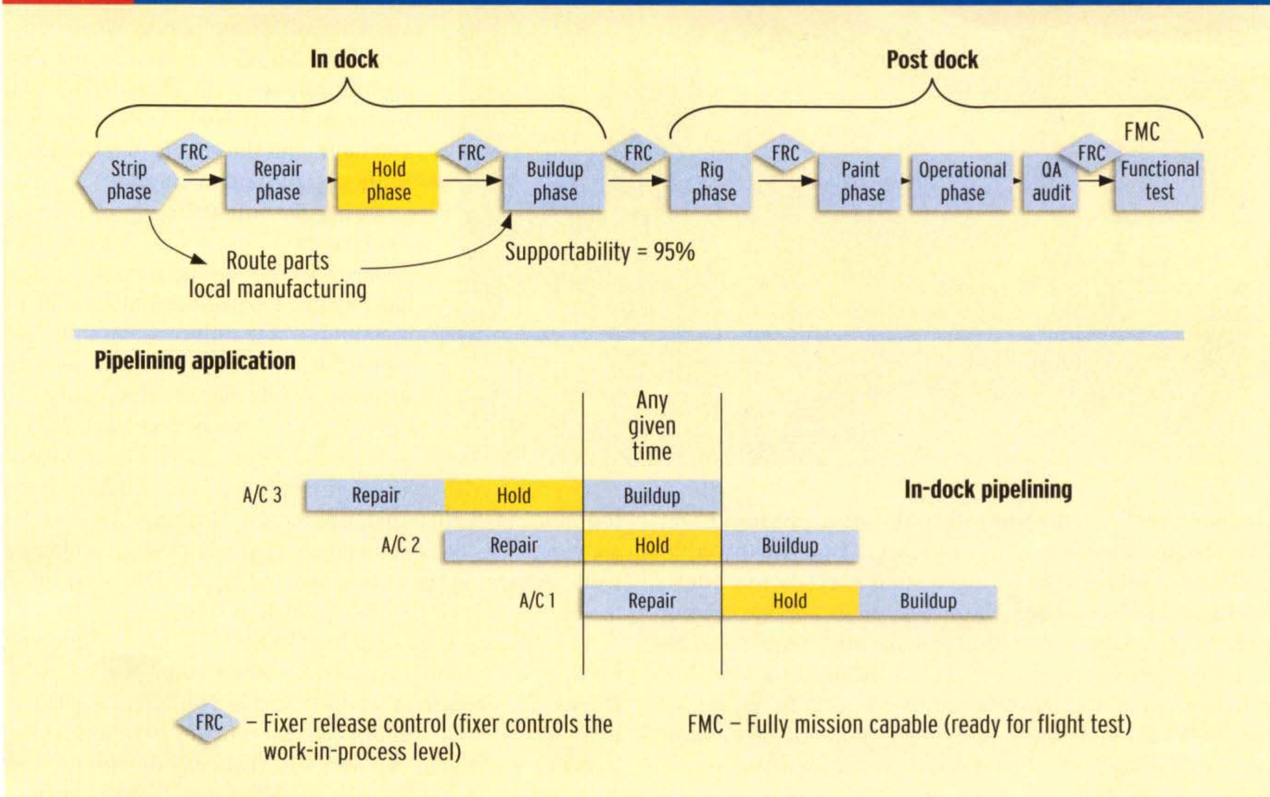
- Reduce the amount of work in execution by releasing work based on the availability of the most loaded resources as these constraining resources limit the amount of work that can be completed.
- Remove safety buffers from individual tasks and aggregate these safety buffers into a project buffer that protects the overall project.
- Do not create precise schedules for resources at planning time. Instead, set schedules during execution based on how much buffer is remaining. In a multiproject environment, tasks that have the lowest buffer ahead of them get the highest priority.
- Avoid multitasking resources to the extent possible.

Many of the CCPM principles run counter to traditional intuition. For example, at first glance, the principle that specifies releasing work based on the availability of constraining resources may seem to contradict an objective that aims to "complete work as soon as possible." However, releasing work prematurely into the system results in overloading already constrained resources and, thus, only serves to distract the focus on completing projects in a timely manner.

A distinguishing feature of CCPM is that it explicitly addresses such human behavior. As explained in the main article, the repair and overhaul of an aircraft can be viewed as a project—a project fraught with uncertainties. To buffer such uncertainties, activity times are typically inflated over the course of time. Inflating activity times, however, serves to promote a well-known behavioral phenomenon often referred to as Parkinson's Law, which states that work expands to fill the time available. Rather than buffering each individual activity time to account for uncertainty (which promotes Parkinson's Law), CCPM instead prescribes removing all time buffers that are used to pad individual activities. These buffers are replaced by a project buffer that protects the overall completion of the project.

Additionally, a key tenet of CCPM is displaying due dates or milestones. This promotes another behavioral phenomenon referred to as the Student's Syndrome, in which the importance of a task gains increasing prominence as the due date for the task draws near. CCPM measures progress against the plan using a method entirely different from the traditional approach, which uses Gantt charts and displays target due dates for various activities. The notion is that displaying due dates tends to promote Student's Syndrome. Instead, CCPM uses visual signals to highlight the progress of the project and the tasks that need attention, if any, without providing specific due dates. The project network is updated regularly, and tasks that can affect the project completion are highlighted so that the supervisor or team lead can address the problem immediately. Priorities are thus set accordingly.

Figure 2 C-5 repair process flow and dock pipelining



The first step in the implementation involved the formation of a dedicated cross-functional core team. The core team went through an intensive three-day workshop to understand the concepts underlying CCPM and how to apply them to the C-5 line. During the workshop, the core team reviewed the existing time standards for each activity in the project. The team arrived at a consensus goal of 160 days to complete the repair and overhaul activity—a 33 percent reduction from the existing standard of 240 days. Also, it was understood that, if a 160-day cycle time could be achieved, the number of aircraft in the depot would decrease from an average of 12 to 7.

Next, project templates were created to represent the new 160-day flow. The network was scrutinized by the core team and validated by other experts in C-5. The project plan finally ended up with a 105-day aggressive project completion time with an additional 55-day project buffer to protect the overall completion of the project.

Now the core team carefully mapped out all the activities involved in the repair and overhaul of the C-5 aircraft. As outlined in Figure 2, the repair and overhaul of the C-5 aircraft involve a series of phases: strip, repair, buildup, rig, paint, operation, and functional testing.

Figure 2 indicates that, as soon as an aircraft is brought in, it goes through a series of process steps or phases. First, it enters a strip phase, at which time all the parts that need to undergo repair—flaps, ailerons, tail, and so on—are removed. These parts are inspected, and a work scope is undertaken to determine the extent of repair involved. A number of parts now are routed to the back shops for repair and rebuild while orders for other parts are placed with the logistics center for procuring replacement parts.

At this stage, the CCPM implementation results in a rather counterintuitive process step. This step, denoted as the "hold phase" in Figure 2, has the aircraft stay in the hangar for about 20 days without any activity performed on it, even as parts are being repaired in the back shops or are being procured by logistics. This practice was initially met with skepticism because the notion was an anathema to members of management, who viewed idleness as a key factor in increasing flow days.

With CCPM, activity on an aircraft is not necessarily viewed as representing progress, especially if it results in a lot of interruptions. Working on an aircraft that does not have all of its component parts available only aggravates the situation. The maintenance crew begins work on the aircraft only to find its work interrupted before completion due to a lack of parts. So, while the parts are being acquired or repaired in the back shops, rather than having the maintenance crew assigned to the aircraft idling for lack of parts, everyone is pulled off the aircraft and assigned to work on another aircraft that is parts-supportable, thereby greatly increasing the crew's productivity.

In Figure 2, the points marked FRC (fixer release control) denote points at which the manager decides

whether to release the aircraft to the next phase. These points enable a better control of the work in process (WIP): Work is not released until the system is ready to undertake the next phase. Thus, the aircraft does not move from the hold phase into the buildup phase until 95 percent of the parts have been returned. In addition, these control points maintain the right amount of pressure on the workforce to complete tasks, reducing any tendencies toward Parkinson's Law, which states that work expands to fill the time available.

The aircraft moves quickly through the buildup phase, following which it is rolled out of the hangar, and power is restored to the aircraft. The aircraft is now routed through rigging, flight controls, paint, and eventually on to the operational and functional test phase.

Figure 2 shows that, at any given time, there is typically one aircraft in the repair phase, one in the hold phase, and one in the buildup phase. Such a method of "pipelining" the aircraft ensures that each phase has exactly one aircraft on which to work. Pipelining the C-5 effectively eliminated the tendency for the maintenance crew to multitask, a tendency that prevails if multiple aircraft are present at each phase.

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Results

WR-ALC quickly implemented CCPM. The contract was signed in February 2005 and the project went live in April 2005, eight weeks from the contract date. The flow time for the first aircraft delivered using CCPM in October 2005 was 171 days. This result was achieved without violating first-come-first-served (FCFS) priority for aircraft already undergoing MRO activity.

At the start of implementation in April 2005, there were 13 aircraft in process. To achieve the flow-days target of 160 days without violating FCFS, WIP had to be flushed to 7. This was one of the most significant challenges faced during implementation. Yet it was achieved without incurring additional overtime or using additional labor. While flow days were cut to 171 days for the first aircraft released under critical chain, the target for the next several aircraft is 160 days, and the goal is to reduce this further by the end of 2006.

Using revenue figures projected by the U.S. Air Force, a very conservative estimate of the annual revenue generated by the five additional aircraft in operation is $40 million (assuming 210 days of operation a year at $40,000 in revenue per aircraft per day). This is a quantifiable savings that already has been realized from the implementation. These aircraft provide an additional 180 ton-miles of airlift capability for the Air Force. The results are remarkable considering they were achieved on an already well-performing operation, one that had just been awarded the Shingo Prize Public Sector Gold Award.

A challenge that remains for WR-ALC is a reluctance on the part of many employees to let go of project milestones (for de-dock, fuel leak check, paint, and so on). It is management's opinion that all references to milestone dates in meetings, reports, and tracking sheets need to be eliminated. It has been observed that, unless reliance is placed solely on buffer management, people have a tendency to put more thought into meeting a due date. This is tantamount to succumbing to behavioral affects such as Student's Syndrome and Parkinson's Law—the very effects that CCPM strives to eliminate.

The implementation of CCPM effectively enabled WR-ALC to move away from cell-level cycle times to one cycle time for the entire aircraft. This was a significant change for the better. Future plans for WR-ALC include extending CCPM to the three other aircraft, the C-130s, C-17s, and F-15s. Work is, in fact, already underway on implementing CCPM for the C-17s, with the goal of reducing its WIP from 25 to 15 aircraft.

Added Update-May 2, 2006:
As a result of this project "Streamlining Aircraft Repair and Overhaul", Warner Robins Air Logistics Center received the Franz Edelman Award for Operations Research Excellence.
http://www.informs.org/article.php?id=1186

TOC and Critical Chain:
Critical Chain Project MGMT is a Theory of Constraints (TOC) method. Created by Dr. Eliyahu M Goldratt, It is based on TOC continuous improvement logic. Additional information can be found at www.eligoldratt.com.