Proceedings of the 2005 Winter Simulation Conference
M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, eds.

TOWARD EFFECTIVE DEPOT TRANSFORMATION: LEVERAGING SIMULATION TO ENHANCE TRANSITION PLANNING

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ABSTRACT

The goal of depot transformation is variability elimination over the production life-cycle. Forced to "ride the bike while we fix it," the depot must transform the current batch and queue production style to a lean, cellular paradigm. Major challenges include transforming the infrastructure, work force, facilities, and supply chain. Further, unlike manufacturing production where the "work content" in a production item has been engineered from the ground up, work content for a repair item is highly variable and creates a ripple effect across the production system. This paper describes depot-MRO transformation according to a series of carefully designed transitions that mitigate variability and provide the modeling needs and requirements that, if met, would enable effective modeling and analysis of MRO production scenarios, providing engineers with a Transformation Design Assistant [TDA] for designing and testing production control strategies. TDA components are currently employed at OC-ALC, NASA-KSC, and within UH-60 MRO programs.

1 INTRODUCTION

The first part of this paper describes the nature of the Maintenance, Repair, and Overhaul (MRO) domain, and describes the core facets of MRO that make modeling its behavior essential. The second part of this paper maps these essential MRO facets into a set of needs and requirements for system simulation constructs that, if developed, would enable computer modeling of the MRO environment and assist in the transformation design by allowing the transformation team to study the system performance of various transition scenarios over time.

There are two major themes discussed in the first sections of this paper focusing on how simulation and modeling technologies can be extremely useful and beneficial to the MRO community. The first theme is the challenge of transforming of the depot from its initial state, the AS-IS, continuing through a series of facility, resource, and process changes [interim states], and progressing to the final and complete transformation: the TO-BE. The second theme is the challenge of depot maintenance workload: what is the unique nature of the Maintenance, Repair, and Overhaul in the military depot? This subject was first discussed in a paper given at the Winter Simulation Conference 2002, "New Perspectives Towards Modeling Depot MRO," and is revisited in this paper (Boydstun et. al. 2002).

The final section of the paper leverages the insights and issues described previously to outline the needs and requirements for model and simulation constructs that are effective in both understanding and improving the overall depot-MRO production system.

The subject matter of this paper is developed from the experience of performing simulation modeling at the Oklahoma City Air Logistics Center at Tinker Air Force Base (AFB), who are transforming all of their production shops into world-class production operations by applying state-of-the-art production principles (e.g., lean, cellular manufacturing, etc.).

2 TRANSFORMATION CHALLENGE

The first theme of this paper is the challenge of designing and planning for a series of small system changes that *transition the depot from batch flow to a lean-cellular system*, resulting in the complete transformation of the depot. The motivation behind transformation is the need to move the depot away from traditional ways of doing business and toward modern methods of achieving minimum production cost and time with high quality results. Implementing lean and cellular manufacturing strategies in a depot has two broad challenges. The first is getting the design of the interim states correct for the dynamics of depot production discussed in the second theme of this paper. The second challenge is updating and refurbishing the infrastructure, much of which dates back to WWII. These two challenges and the three aspects mentioned earlier create a situation in which simulation modeling is a potentially valuable activity. The transformation challenge requires a precisely phased and coordinated sequence of production changes that divide the transformation into smaller steps, so that production can continue in parallel with transformation.

2.1 Infrastructure Challenge

What is the nature of the infrastructure challenge? Over time, the depots have become the one of the lowest priorities for investment strategies. Consequently, many production facilities are obsolete and inadequate, especially by modern standards that support cost efficient and time effective production methods. This means moving from a batch and queue mass production philosophy to the modern philosophies of lean and cellular manufacturing, with single piece flow and point-of-use resources. The transformation challenge involves not only the processes, but all the resources as well. Perhaps the most extreme resource challenge is Building 3001, the primary production facility at Tinker AFB. B3001 has about 2.5 million square feet of production space that was built in 1943 according to that era's electrical, lighting, plumbing, heat, and air standards for industrial facilities. Modern production methods require facilities with at least a magnitude more of each of these facility infrastructure components. This is not hard to accept if one pauses to think of the differences in current electrical equipment, human safety and ergonomics, and environment protection measures and standards that did not exist during WWII. Two facts that exemplify the magnitude are (1) increasing from two electrical power loops to five, and (2) increasing from a primary chilled water backbone of 16" pipe to 24" pipe. Both of these are more than doubling the previous historical capacity of the facility infrastructure component. The transformation of B3001 is being done with the "Ten Phase B3001 Revitalization Plan" which must be coordinated with the production transformation.

2.2 Swing Space Challenge

In order to maintain production while transforming the depot, portions of production must be relocated so that the vacated production space can be refurbished and made available for reallocation. These reallocation spaces are referred to as "swing spaces," or some call them "staging areas." The basic principle is to clean out a space and then move a shop into that space and maintain production. The space vacated by the original shop is then refurbished and perhaps another shop is located there or the original shop is moved back into the newly refurbished space. One of the objectives in reorganizing production is to break up functional islands of similar equipment operating as shared resources and re-allocate that equipment to the specific product line it supports. Groups of production equipment that are currently shared resources will be dissolved and migrated into new roles as dedicated resources. In utilizing the swing space concept, the challenge is to maintain production throughput and coordinate work piece movement while dissolving each functional island. The calculation involves not only how much equipment is needed for the final state, but also how much equipment is needed for each step of the transition. Another aspect of this moving target is the routing of components and delivery of parts. This becomes not only a planning and scheduling issue, but also a communication issue.

Two strategies that can benefit from simulation based design and analysis experiments are to (1) work overtime for previous periods and accumulate excess production, then shut down the shop and try to refurbish and bring the shop back on line before the excess is consumed; and (2) use the refurbished shop, which should be more productive in its lean cellular configuration, and try to catch up with production quotas before the downstream shops are starved for input.

2.3 Nine Docks Two Doors

One of the infrastructure challenges peculiar to B3001 is the configuration of the docks and doors in the aircraft production area. Originally, B3001 (see Figure 1) was built to assemble the classic Douglas DC-3, or its military cousin, the C-47. The C-47 was a very significant component of military cargo capacity in both WWII and the Berlin Airlift during 1948-49. The production concept employed a moving assembly line from one end of the building to the other, far end, about ¾ miles away. Much of the "high bay" assembly area is now filled with jet engine and aircraft commodity overhaul workload. Further, the far end of the building is now used for the programmed depot maintenance of the KC-135 four engine jet. In addition, the amount of support equipment, stands, and tooling required around the airframe is much greater now than was necessary in the C-47 assembly days. One door is situated at the extreme end on the first dock (south end of B3001). The other door is about halfway up the series of docks, between Docks 5 and 6. Normal paths for aircraft are that Docks 1 and 2 go out the south end door. Docks 4 and 5 go out the mid-way door. Dock 3 goes out the door that is more convenient. Docks 6, 7, 8, and 9 always go out the mid-way door. This condition is colloquially called 'blocking.' The aircraft are blocked by each other from having direct access to the hangar door. Not only are the aircraft blocked, but the width of the

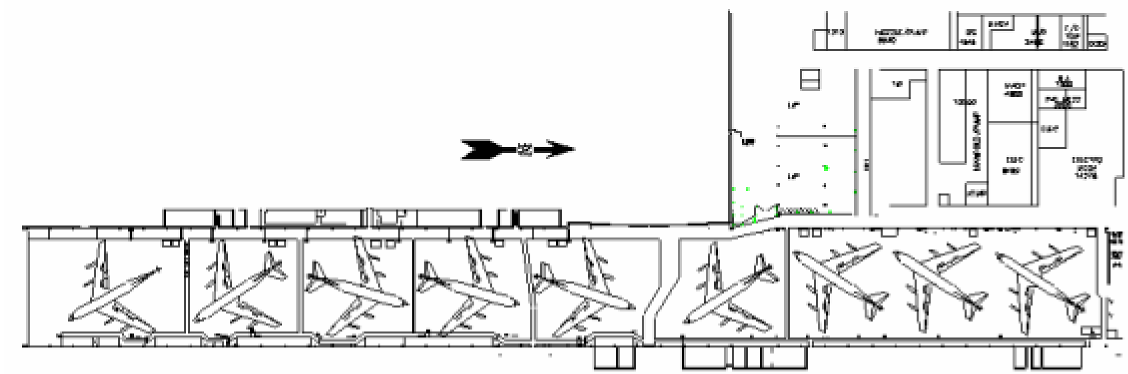

Figure 1: B3001 Layout Schematic

building is also narrow. All equipment, stands, parts, tools, etc. must be moved out of the way to allow aircraft to move to the door. The policy question is whether to move all the aircraft when the first one is ready (interrupt on-going production to accommodate single piece flow), to wait until all the aircraft are ready (batch-movement), or some other in-between policy contingent on the state of the aircraft involved. For example, do not move an aircraft on jack stands if it is within 2 days of completing its overhaul. Whatever policy is chosen, it is still more costly and time consuming than each dock having a hangar door. Plans are in place to modify the building and put extensions and doors for each dock on five of the docks. This situation, when analyzed using a simulation model, raises two challenges: (1) How do you model the blocking, the policy, and the penalties for that policy? (2) How do you model the construction process and identify a space plan that will enable meeting production schedules?

2.4 Cultural Challenge

It is worth noting that as part of the transformation, but perhaps not directly related to a simulation modeling task, is the cultural aspect of transforming the workforce mindset. While the resource challenge of B3001 was called extreme, the transformation of the workforce will probably be more challenging, though not from an engineering and probably not from a simulation point of view. The workforce has been doing work a certain way for decades. Now, at the end of the next five years, this workforce will be expected to do work another, radically different way.

2.5 Funding Challenge

The magnitude of this transformation challenge is reflected in the primary funding. A transformation contract has been issued to Team Battelle to plan and execute the production realignment. The contract has a ceiling of $500M and the first five years of funding is programmed at $50M per year. The B3001 Revitalization is programmed in ten phases, every other year, at a cost of $20M per year. The depot workload revenue is about $2.3B per year, from 7.5M man-hours of effort. Depot transformation is a big task for a big operation. Funding adds another challenge to successful transformation and another reason to utilize simulation modeling of the transformation process. What are your options for moving forward if a portion of the funding decreases or increases? In fact, this question is one most likely to be dealt with during management meetings, where the funding profile may be only a few months from becoming a reality.

2.6 Process Change Challenge

The transformation will be performed in small, incremental (transition) steps. After the final lean, cellular manufacturing state has been defined, how do you get there? And while transitioning, how can you keep up with production quality, cost, and schedule? Obviously there are many interim states to be defined by evaluating and identifying which pieces are easiest to do first, which pieces are most beneficial, which pieces are most critical to success, and, finally, which pieces will be the most difficult to achieve? What is a good strategy for breaking up the functional islands of shared resources into dedicated resources for each business unit or product line? Which island should be broken first? All of these questions represent an ideal application for simulation modeling. The simulation model will have to invoke a dynamic logic for the transitioning production process hybrid (batch, single piece, and cellular flow), travel distance, and resource type assignment, to work type by a calendar. Should the simulation be composed of a meta-model with a group of smaller simulation models that are called according to the state of the model? Or should it simply be developed as a group of independent models? The process change will encompass all the engine, commodity, and aircraft production. As an example, for the nine-dock two-door scenario described previously, the current process is constrained by space limitations for resources. Consequently, the work is divided, and segments of the work are performed in different types of docks in various locations, with some of the work being done outside on the ramp. After the conversion of the first dock to the "One-Dock One-Door" configuration, that dock will basically be a One Stop Dock capable of doing all the dock work in one dock and much of the current work done on the ramp as well. In essence, two different processes will exist simultaneously, and require coordinated management, for performing the same work. For the B3001 docks, how many docks should be shut down for door construction at one time? What is the best sequence of dock conversion? How will this be scheduled and resourced before, during, and after all the dock conversions?

3 DEPOT MRO WORKLOAD CHALLENGE

Tinker is one of three Air Force maintenance depots. Depots perform the most radical and invasive maintenance, repair, overhaul, and modification tasks on Air Force weapon systems. Tinker performs depot level maintenance on large body aircraft, jet engines, common aircraft commodities, and aircraft software.

The primary objective of the depot is to reverse the wear-out trend of the weapon system. This is normally achieved through MRO of the entire system and its subsystems, down to the individual nuts, bolts, and washers as needed. In addition, because of the expertise available in taking apart and putting together the weapon system, the depot is often tasked to modify the system, changing its configuration either to add to the functions to meet some need of the warfighter or to improve the reliability and/or maintainability of the system and thereby reduce the total cost of ownership.

The large complex array of processes needed to perform depot MRO began during WWII, which also gave birth to many other types of large scale operations and their management tools and methods. Over the decades, the depot has been extremely successful in providing the frontline defenders of our freedoms, those devoted souls who live at the tip of the spear, with reliable weapon systems. However, while the rest of the world has been driven by global competition to improve their processes, the depots have been driven by other forces to largely preserve their system of providing weapon systems. In recent years, there has been an increasing effort and determination -- from Congress down to the shop floor -- to apply the cost cutting and time saving methods developed in private industry to the depots. The objective is to reduce the cost of depot MRO and harvest that benefit for the sake of the war fighter as well as the tax payer. It is a very large undertaking in at least three aspects. One is the magnitude of the organization being changed, some 7 million man-hours per year. The second aspect is the magnitude of change attempted: the entire organization and every shop will be drastically affected by the complete rearrangement of the shop infrastructure, layout, and processes. The third aspect is similar to the analogy "We want to ride the bicycle while we fix it!" This aspect means that transformation of the depot MRO will not include shutdown of any duration that causes a loss in the bottom line production. The Oklahoma City Air Logistics Center's 76th Maintenance Wing will meet all its production commitments while transforming its production processes to globally competitive methods and practices.

3.1 Depot Found Work

The single most significant difference between depot workload and manufacturing, and likely true of *diagnostic systems* in general, is the nature of what we might call "found work." Long range planning estimates for the cost and schedule of doing MRO on a weapon system. After the induction occurs, the system is opened up, investigated, and evaluated, and the detailed list of work really needed for that particular unit is determined. The work content continues to be "found" or identified as the system goes through the stages of depot maintenance. Analysis of history in the depot indicates that anywhere from 20% to 60% of the man-hours on a system will be identified and defined after the induction of the system into the production shop. How will this level of variance play havoc with the transformation plans generated so carefully in the preceding section? How will it play with the swing space plan? How will it play with the One Dock One Door plan?

3.1.1 Nature of Found Work

There are three characteristics that describe the nature of found work. The first characteristic is that a task of found work is not like any other task of found work. Each instance is unique in terms of its resource requirements. The easiest example to illustrate this is corrosion removal. While the corrosion may be on the same part in the same location, each is corroded more or less severely. The removal of each instance will take more or less time to remove, and maybe more or less skill to remove; because of the particular amount of that corrosion instance. While corrosion is chemically the same, the removal of corrosion is not the same from a resource requirement perspective. While this may seem somewhat trivial to the reader, corrosion removal on an aging weapon system can be significant. Consider a planned level of 3,000 hours of corrosion removal for each of fifty aircraft, which is actually very low for a large body aircraft. This plan requires 150,000 hours, or corrosion work for about seventy people per year. The historical variance of twenty-percent to sixty-percent mentioned gives a probability low of 180,000 hours, up to a high of 240,000 hours. The seventy employees for corrosion work will be working between 400 and 1300 hours of overtime in one year! This unique aspect of found work by instance is consistent across many of the tasks, including hydraulic, sheet metal, electrical, landing gear, etc.

The first characteristic, the unique nature of each instance of found work, drives the second characteristic of found work: the organizational level of experience for that task. The experience level can be qualified in three grades: mature, developing, or new. Found work can be a mature task that has been performed several times, is very well known, and is easily quantified. Found work can be a developing task that has been performed a few times but that has not been performed long enough to be completely and definitely known or documented. Found work can also be a first time new failure. A new failure is not covered by the technical orders and repair procedures and, therefore, requires engineering approval from the system manager.

The third characteristic, describing the nature of found work rests in the belief that *the work will always be found*, including new failures. It is logically impossible to determine everything that is actually wrong with a system until that system is "completely" evaluated. In many remanufacturing situations, this unknown has been bypassed by simply making a 100% disassembly and 100% replacement of parts and only reusing the core itself, which is either accepted or rejected at the collection point. This method of 100% invasive disassembly is impractical for large body jets. The nature of found work involves unique tasks even when the tasks are defined similarly. Each task has a level of experience associated with it, or a learning curve context. Depending on the resources assigned to a task, unplanned work may or may not be discovered or found. Moreover, the trend of found work cannot be planned out of the work package. This means that in depot MRO, each unit of the workload is entirely unique from every other unit inducted and worked. A task to be performed may have been performed hundreds of times previously by the same mechanic, but the identical task does not mean identical work.

3.1.2 Impact of Found Work

The primary objects impacted are the planned resource requirement and schedule. The historical variance of 20% to 60% of the man-hours on a system being identified and defined after the induction of the system into the production shop, is really a statement concerning the impact of found work on the labor resource. This level of task variance causes a corresponding variance in the other resource requirements. It includes variability in the direct hours, indirect material, direct material, back-shop workload, engineering support, and indirect hours attributed to supply, scheduling, and planning. The facilities, the equipment, and even the people, all to a certain level of duration, can simply be put on overtime and run 24 hours a day, 7 days a week. However, parts cannot be put on overtime. In depot MRO, the critical resource is always parts. This is especially true for the impact of new failures. At the Oklahoma City Air Logistics Center, the aircraft production shops are routinely replacing parts that were never originally intended to be inspected during the useful life of the airframe, much less replaced! The ripple effect of found work variability on the resource requirement, when compared to new manufacture variability, is more like a tsunami from the ocean compared to a pebble on a pond.

3.2 Salvage of Parts

One of the other unique characteristics of the depot is the availability of parts from inducted systems. Often referred to as cannibalization or "canning" and sometimes referred to as "rob-back," it is the acquisition of parts from an inducted work-piece instead of from prescribed supply or a back-shop sources. This practice has often meant the difference between success and failure in delivering a reliable combat ready system to the war fighter. Canning negatively affects accurate supply requirements. What is canned today will not be bought tomorrow if there is no record of its demand in the ordering system. Theoretically, then, it is possible to have fewer of a certain critical part in the inventory than there are weapon systems that require that part. This is because there is a work-in-process (WIP) of non-available weapon systems at the depot. Just one more thought on this peculiarity: the limit of the difference is equal to the amount of the WIP at the depot minus one. The root cause for canning has two components. One is that the part requirement was not known until the work was found. The second component is the lead time for weapon system parts. They are not readily available at the local hardware store, and the procurement process is significantly more involved if the part is not already covered by an existing contract.

One of the strategies for dealing with the issue of "lead time to acquire parts" is to keep condemned parts. While the part may originally be condemned for cost of repair versus buy new, when production is at a work stoppage and the field needs critical components, fixing one part quickly and expensively is preferred to buying a new one slowly and cheaply. Engineering may be required to again look closely at tolerance variances or approve new repair procedures, but the product goes out the gate.

4 IMPLICATIONS FOR SIMULATION MODELING

In this section we summarize the specific challenges faced during transformation (as discussed in the previous sections) and relate these challenges to (simulation) model-specific needs. The goal is to provide a simulation capability that will allow the transformation team to study the impacts of various transition strategies prior to initiating facility modifications and possibly compromising production opportunities. Given the transient nature of the MRO system under transformation, many of the modeling needs are focused on the ability of the modeler to declare dynamic decision strategies that mimic the decisions of the shop-floor supervisors. A system plagued by excessive variability in its key performance indicators is indicative of decision policies that are ineffective in controlling the influences of the transition step changes during the transformation. Hence, a useful way of modeling the MRO system is to isolate the production control logic from the production process logic that it supports. In doing so, the modeler can more easily specify the decision logic necessary to deal with cases of found work – for example, without worrying about how the decision logic will be executed by the simulation engine. The question then becomes, How must the underlying simulation engine operate in order to integrate the two components back together?

The table below summarizes key challenges inherent in the MRO transformation and the key transformation design question facing the transformation team. The final section outlines the simulation technology requirements to addressing these system simulation needs and dealing specifically with the challenges described previously for an MRO system undergoing transition.

Table 1: Implications for MRO Systems Simulation

Specific Transformation Challenge	**Design for Transformation questions**	**Simulation Need**
Tinker AFB is planning on updating and adding on further maintenance capacity for the KC-135 and other aircraft maintenance. Key to this is the transition from the current method of multi-site phased maintenance (i.e., aircraft moves to new area for next phase of maintenance activity) to single-site phase maintenance (the aircraft is located in one dock space through out the entire maintenance cycle (not counting pre and post dock work)).	• At what point in the transition should the cellular approach to aircraft maintenance be implemented into the system? • Is it more efficient to switch all aircraft to a cellular approach simultaneously or should some aircraft continue working through the phase maintenance cycle even after other aircraft have begun the cellular approach?	• Simulate the transition period, where the user can set dock shut down and start up dates. Using this calendar function the user can indicate when docks will come online and other docks taken offline for construction. The tool's calendar also needs to be able to account for weekends and holidays and permit the user to make weekends work days.
Door accessibility is a major problem with the current dock configuration at Tinker AFB. Within building 3001 there are currently nine docks available for work, but only two doors are available to bring aircraft in and out.	• Given a set of aircraft in different stages of repair, what is the optimal method for moving these aircraft in and out of the building to complete the assigned work?	• Tool functionality should include the capability to simulate constraints on dock accessibility to bay doors. In some cases an aircraft must move thru another dock to access a door. To this end the tool must handle this blocking constraint and present an option to the user about how to deal with the constraint in a type of policy choice prior to running the tool. Blocking also necessitates that tasks be dynamically added during to the simulation run to mimic the need for preparing the aircraft to move, etc.
Tinker is constantly altering their policy for when to move a blocking aircraft.	• Is it more efficient to move aircraft every time it is blocking a completed [finished] aircraft • Does maintaining one constant policy make a difference in aircraft flow times?	• Concerning the move policy the tool should give the user at least three options for moving aircraft that are blocking other complete aircraft. 1. Pre-empt the aircraft and the return them to the same dock once the move requirements are satisfied; 2. Pre-empt and reshuffle the aircraft so that the aircraft with the longest remaining time is placed the furthest in the "hole;" and 3. Do not move the aircraft until all the blocking aircraft are finished with their work requirements.

Table 1 (continued): Implications for MRO Systems Simulation

Specific Transformation Challenge	**Design for Transformation questions**	**Simulation Need**
When an in-phase aircraft is blocking the movement of another aircraft and the decision is made to pre-empt the work on that aircraft and move it to release the completed plane there is a “movement” penalty associated with preparing the in-phase aircraft for movement and for setting it back up after the move.	• Under what circumstances should an in-phase aircraft not be moved to release a completed aircraft? • At what point does it make the most sense to move an in-phase aircraft to release the finished aircraft behind it? • Once released what is the best way to reorganize the aircraft being put back into the docks?	• The tool must have the capability for the user to set a basic move chart that establishes the penalty time associated with moving an in-phase aircraft to release blocked aircraft and setting it back up after the move. It should also be able to let the user establish certain times within the in-phase aircraft’s repair cycle that the aircraft cannot be moved due to the extent of the work performed. • A formula should be established to determine whether an in-phase aircraft should be moved to release ready, blocked aircraft (i.e. what is the go, no-go strategy?).
Typically older aircraft are given the highest priority, but this is not always the case. Therefore, we need a way to assign priority to each aircraft.	• If an aircraft falls behind in its maintenance schedule is it more efficient to bypass the aircraft and focus on the others?	• The user should also be able to assign differing priorities to the aircraft so the simulator can pre-empt certain low priority aircraft with other higher priority ones.
As a part of the Transformation plan, Tinker will be closing docks and reopening them with new configurations. One of the new configurations includes outfitting docks 2-5 in 3001 with dedicated doors [“one-dock one-door”].	• What is the best method for shutting down the docks, performing the work and then reopening them? • Does it make more sense to close all of the docks at once or close them one at a time? • How will these decisions affect production? • If doing one dock at a time, is it more efficient to start from the North or South side of 3001? • Identify the Additional dock requirements at a point in time that would have prevented queuing. • What is the Optimal sequence of building modifications to reduce the impact on the production schedule?	• The tool must have the ability for the user to define some future date, using a calendar function, that when reached after a user-defined, construction shut down period, new doors are added to designated docks easing the blocking constraint.
Currently, aircraft are moved to different docks depending on the maintenance phase it is preparing to enter. Under the new paradigm, all of the maintenance phases will be performed in the same dock. The tool must handle both of these methods for aircraft repair.	• Which maintenance plan is more efficient considering dock availability, manpower and support equipment/tooling?	• The simulation application must be capable of simultaneously simulating single-site phase maintenance (Cellular) and multi-site maintenance activities (Phase).

Table 1 (continued): Implications for MRO Systems Simulation

Specific Transformation Challenge	Design for Transformation questions	Simulation Need
Tinker will continue to maintain the current aircraft workload and hopes to lure more new workload from the Air Force and Navy. Currently some docks are capable of working different types of aircraft.	• Given a set number of aircraft and a streamlining of their current process, will Tinker ever be in a position to consider introducing different or more workload into the system?	• The tool should allow for the assignment of aircraft types to specific docks and limit the ability of aircraft to move to docks not assigned to that aircraft type. Facility constraints in tool must be able to restrict particular aircraft types to certain dock types.
Currently, there are four weapons platforms repaired at Tinker AFB, the KC-135, B-1, B-52, and the E-3. For the most part each aircraft is repaired in its own set of repair facilities, but in certain instances the same facility is used for different types of aircraft. Under the Transformation scenario this concept of using the same facility for different aircraft types is set to expand.	• Given a set of conditions for each facility (i.e., type and number of aircraft that can be worked in it) and a production schedule for each aircraft type, what is the best utilization rate for the available facilities?	• The simulation application must be able to address multiple aircraft types (e.g., KC-135, B-1, B-52, E-3, etc…), multiple phase maintenance schedules (Schedule for B-1 v Schedule for KC-135) and multiple phase maintenance schedules across same aircraft type (Maintenance Level-1, Level-2, Level-3 for the KC-135).

5 OVERVIEW OF SIMULATION-BASED TRANSFORMATION DESIGN ASSESSMENT TOOL REQUIREMENTS

Enhanced design of OC-ALC depot processes will lead to the rapid deployment of *cost-effective* and *high-performance depot processes*. Transformation is inevitable, but the transition path itself must be selected to allow for the minimal disruption of resources. Moreover, the transient nature of MRO necessitates the study of variability and its impact throughout the transformation as the planned transitions proceed. A few important simulation-based transformation design assessment tool requirements that may be derived from the needs described in Section 4 are summarized in this section.

5.1 Future State Modeling

Transformation Design Assessment (TDA) simulation tools must provide the capability to model and simulate (1) the current world state (based on actual data about the facility, equipment, aircraft, etc.), (2) multiple *planned* and *predicted* future states. Future states are often determined through the execution of the simulation model of the processes at the depot. The simulation tool must allow for dynamic update of the current world state, and, at any current state, allow for the simulation of multiple possible future states.

5.2 Transition Process Modeling

TDA simulation tools must allow for the modeling and simulation of different transition activity types. For example, the tool must provide the ability to plan different types of dock modification activities such as the dock reopening aircraft with different phase schedules and configurations for multiple types of aircraft. During such modification periods, the dock becomes inaccessible to aircraft, and, therefore, may not be used as a resource in the MRO process. Once a dock modification is complete, it becomes active and is available for use in the MRO process; after dock modifications are completed, the dock may open with a different "configuration" (i.e., different physical characteristics of the dock and the type of work that can be performed in that dock space).

5.3 Flexible, Multi-Site Work Policy Modeling

TDA simulation tools must be capable of simultaneously modeling and simulating single-site phase maintenance (Cellular) and multi-site maintenance activities (Phase). For example, under the current policy at Tinker, aircraft move to different facilities for each phase of the repair process: Pre Dock, performed on the ramp; Inspection/Structures, performed in designated inspection/structures docks; PDM, performed in designated PDM docks; and Post Dock, also performed on the ramp. Under the new maintenance paradigm, all maintenance activities except small portions of Pre and Post Dock activities will be performed in a single dock.

5.4 Modeling Complex Constraints

TDA simulation tools must provide the capability of modeling a variety of physical and logical constraints imposed by the requirements of complex and dynamic MRO activities. For example, the tool must provide the capability to simulate the physical constraints on the accessibility of aircraft to bay doors. In some cases, an aircraft must move through multiple docks to gain access to a door. To this end, the TDA simulation tool must enable the creation of such "blocking constraints" that would allow end users to make policy decisions about how to adequately address the depot performance limitations imposed by these constraints.

5.5 Multiplicity of Workload Packages and Types

TDA simulation tools must be able to address the requirements imposed by multiple aircraft types (e.g. KC-135, B-1, B-52, E-3, etc.), multiple phase maintenance schedules (Schedule for B-1. vs. Schedule for KC-135, etc.), and multiple phase maintenance schedules across same aircraft type (Maintenance Level-1, Level-2, Level-3 for the KC-135). The tool must also be able to accommodate *work variability* requirements – that is, the ability to model and simulate work *discovered* or *found* on the aircraft during the maintenance cycle.

5.6 Advanced Experiment Management

TDA simulations tools must provide sophisticated simulation experiment management capabilities. For example, the tool should have the ability to save experiments, to re-initiate/recreate the state from which the simulation was run, and to re-run the simulation using the original status information. These tools should also have the capability to save simulated (possible) world states and load them as the "current" world states.

In summary, this paper has outlined a number of key facets that delineate depot or MRO production from manufacturing production. In doing so, our focus has been on describing the problem domain well enough to understand what facets of MRO have the greatest impact on production and, therefore, should be included in models used for designing and studying the transition based designs necessary to achieve the end state of the transformation.

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