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RFID/RTLS Application to Remanufacturing Operations in the US Department of Defense

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by

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Abstract

The most efficient use of the DoD's network of remanufacturing depots is an important concern because of the extensive requirement to recapitalize the military equipment used in Iraq and Afghanistan through product recovery. In this report, we consider the use of radio frequency identification (RFID) technology in improving remanufacturing efficiency. We first provide a framework for understanding the choice between permanently tagging components with passive RFID versus using RTLS for the temporary identification of components in the remanufacturing process. We then report the results of simulation model that analyzes how RFID/RTLS creates value within the remanufacturing operation. We find that the simulated gains from using RFID/RTLS are quite modest, and propose alternative justifications for the major benefits seen in practice.

Keywords: radio frequency identification, remanufacturing, process improvement, framework, simulation

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1. Introduction

In this report, we study how RTLS (real time location systems)—a form of radio frequency identification application—may generate value in remanufacturing operations in the Department of Defense (DoD). The DoD has remanufacturing capabilities in 19 depots across the US that are able to recover aeronautical, automotive and naval equipment, in addition to a variety of electronic instruments (DoD Maintenance Depot Capabilities and Services, 2003)). Examples of such depots include the F A-18 remanufacturing operations we recently toured at North Island Naval Air Station, San Diego, or the naval and aerial radar recovery facility in Tobyhanna, PA. The DoD also has numerous partnerships that involve outsourcing remanufacturing activities to industry sites that might also benefit from RFID technology—one example would be the Bradley armored personal carrier remanufacturing program, which includes final assembly, integration and testing at BAE Systems facility in York, PA.

The timing for this study is opportune for two main reasons. First, the DoD's prospective demand for remanufacturing operations continues to grow with the long-term operational demands placed on its equipment in Iraq and Afghanistan. The Government Accountability Office (GAO) has addressed the "recapitalization" topic at length in recent reports (2007, 2008). This increased level of demand places a premium on the optimal use of remanufacturing facilities and personnel available in the DoD system. Second, RFID technology continues to evolve at a rapid pace and its diffusion in supply chains is becoming rather widespread, including within DoD environments. With the technology becoming more widely understood and integrated within DoD infrastructure, it is the right time to analyze its effectiveness in a range of other applications.

This report proceeds with a quick overview of some of the important literatures on remanufacturing and we provide a concise appraisal of what has been learned in past studies of RTLS in DoD remanufacturing operations, which sets the scene for the rest of the report. In section 3 we analyze the process of selecting RTLS in a remanufacturing environment and the alternative choice of directly tagging components with passive RFID at the beginning of their service life. We argue that this choice is largely driven by the feasibility of passive tagging and the VOI (value of information) gained through monitoring the tag during its operational period. Some of this information may be useful for remanufacturing operations, such as sorting components prior to remanufacturing. Section 4 reports the results of a simulation model that helps analyze the narrower issue of how RTLS (or passive RFID) creates value within the remanufacturing job shop. Our results suggest that the direct gains are relatively modest. A brief conclusion follows.

2. Remanufacturing: A Brief Literature Overview

Remanufacturing closes the materials cycle and provides the basis for product recovery and re-use in supply chains. It focuses on value added recovery, rather than just materials recovery, that is, recycling. An old estimate indicates that there were more than 73,000 firms engaged in remanufacturing in the US, directly employing over 350,000 people (Lund, 1983). Twenty-five years later, this number must have increased with new classes of products that are regularly remanufactured, such as electronic and computer equipment, and new markets that depend on remanufactured products. Remanufacturing has been described as:

> [A]n industrial process in which worn out products are restored to like-new condition. Through a series of industrial processes in a factory environment, a discarded product is completely disassembled. Useable parts are cleaned, refurbished, and put into inventory. Then the new product is reassembled from the old and, where necessary, new parts to produce a unit fully equivalent—and sometimes superior—in performance and expected lifetime to the original new product. (Lund, 1983)

Remanufacturing is therefore distinctly different from repair operations, since a product is completely disassembled and all parts are returned to as-new condition before reassembly.

There is substantial literature on remanufacturing dealing with tactical, operational and strategic questions. Several authors have argued that current manufacturing technologies, practices and processes can and should be used in support of remanufacturing operations (Giuntini & Andel, 1995). Thus, in many ways, remanufacturing has the same broad goals as manufacturing, such as quality, speed, flexibility and cost. Therefore, the transfer of relevant best practices between these different operational settings is an important issue.

Also, many authors see remanufacturing as a process of growing importance in the overall product lifecycle. There are several reasons for this, including product take-back laws that mandate manufacturers bear the burden of disposal at the end of a product's useful life (Mangun & Thurston, 2002), and the profitability/cost-effectiveness of remanufacturing in some circumstances. In short, remanufacturing may make good business sense, with producers recovering a profit from remanufacturing that offsets some of the costs of take-back policies instituted in various communities. The key point is that, in every organization, it is useful to conceptualize remanufacturing as a profit-enhancing or cost-reduction activity. For this reason, we see many organizations seeking profitable opportunities via remanufacturing.

A third point is that often remanufacturing may incorporate component upgrades to add new features to the product or to improve compatibility with newer systems. (Ayres, Ferrer, & van Leynseele, 1997). This point is particularly important for the DoD, which is frequently engaged in refreshing its stock of hardware with new and improved upgrades. Excellent examples of this include numerous examples in the US Army (i.e., Bradley and Abrams armored vehicles upgrade programs), the Marines' Harrier upgrade programs, periodic updating of the Navy's aircraft carrier fleet, and numerous examples in the USAF (including the recent B52 and KC135 tanker fleets, both of which were originally built in the 1950s). The authors know of no formal models of the upgrade decision and note that this topic clearly warrants further study in the military context.

In the context of job shop operations, the remanufacturing literature remains limited. The main difficulty in this research stream is to model the job shop in a meaningful, generalized way. Guide, Srivastava, Spencer and Kraus generated a series of articles related to regular and expedited schedule, inventory buffer and capacity planning in simulated scenarios based on Naval Aviation Depots (Guide, Srivastava & Spencer (1996), Guide & Srivastava (1997), Guide, Kraus & Srivastava (1997), Guide & Srivastava (1998), Guide, Srivastava & Kraus (1998)). These studies generally recommended best approaches to schedule the disassembly-repair-reassembly sequence considering the uncertainty of the remanufacture process. Since then, very little work has been done to understand the remanufacturing job shop. Interesting exceptions are the graduation theses by students of the Naval Postgraduate School at the Army's Tobyhanna depot. We turn to their work next.

Tobyhanna Army Depot in Pennsylvania is the largest, full-service electronics maintenance facility in the Department of Defense (DoD), providing design, manufacturing and remanufacturing services for satellite terminals, radio and radar systems, electro-optics, night vision and anti-intrusion devices, airborne surveillance equipment, navigational instruments, electronic warfare, and guidance and control systems for tactical missiles. The Army designated Tobyhanna as its Center of Industrial and Technical Excellence for communications-electronics, radar, and missile guidance and control, while the Air Force has designated Tobyhanna as its Technical Source of Repair for command, control, communications and intelligence systems. The variety of jobs undertaken by Tobyhanna clearly classifies this facility as a job shop, with all the challenges that a typical job shop would face.

In early 2004, Tobyhanna conducted a pilot program incorporating Radio-Frequency Identification (RFID) technology into its radar remanufacturing operations. The program resulted in a payback of less than one year and measurable improvements in average repair cycle time and direct labor-hour per job, enabling higher throughput and more reliable lead-time promises (Forrest & Miertschin, 2005). To further leverage the RFID technology, managers at Tobyhanna extended the program for three more years (Phelps & Rottenborn, 2006).

Phelps and Rottenborn (2006) found that, thanks to the use of RFID technology, the remanufacturing process in Tobyhanna experienced an improvement in six performance measures. Three relate principally to customer-orientation:

- Lead time accuracy: The ability to make good estimates about lead-times is a valuable service to customers that was improved with the system.

- Job visibility—Response time: The ability to assess the status of a job in real-time was improved.
- Cycle time: Better scheduling reduced wait time between tasks, thus reducing cycle time.

A further three measurable impacts relate more to remanufacturing efficiency. These are:

- Labor-hours per job—Non-value-added work—Overtime labor: Workers did not have to waste time looking for parts lost in the shop floor, eliminating the need for scheduling overtime work.
- Resource utilization—Scheduling: Greater visibility enabled better scheduling of resources and improved asset utilization.
- Shrinkage and theft: Better visibility eliminated material loss in the shop floor.

Clearly, Tobyhanna’s experiment with RFID was an operational success, which begs the question: should RFID be adopted in all depots in the Department of Defense? If so, what type of RFID should be used? When should components be tagged at source (using passive RFID), and when should they be tagged only within the four walls of the remanufacturing site (using RTLS)? Within remanufacturing operations, what characterizes a job shop that would benefit from using RFID to track parts and components movement in the shop floor? In what follows, we address these questions.

3. A Framework for the Choice between Passive RFID and RTLS

In this section, we analyze which kinds of RFID tagging are most appropriate in various situations. The choice we consider is the choice between tagging a component with a passive RFID tag, which will be used to track its whereabouts over its lifetime (as Boeing and Airbus are reportedly doing with certain aircraft parts) or tagging components using RTLS while they are in the remanufacturing process. There are distinctly different reasons for tagging components.

1. Regulation or policy. Some systems are subject to regulation that requires keeping all components together as a kit, never cannibalizing parts among different systems. In some cases passive RFID tagging may be an efficient method of accomplishing this. This is particularly the case when errors are relatively expensive (i.e., cost of rework or cost of errors to users are high), when testing is relatively expensive (to check conformance of the reassembled original components), and if the error rates and costs of the alternatives to tagging are high. Moreover, regulatory policy may encourage passive RFID tagging at source for safety reasons, i.e., it may be necessary to record major events in the life of certain components and follow their use, degradation, repair and reuse until they are discarded. To complete the system, the tag should be associated with the part's serial number or UID (unique item identification), and the data would be recorded in a digital system (Obellos, Colleran, & Lookabill, 2007).

2. Usefulness or value. Passive RFID tagging may generate valuable information by recording the part's history. This information may facilitate the execution of timely maintenance of expensive items. In some systems, such as aircraft engines, components are required to follow a cycle of inspection and refurbishment after a pre-specified number of flight hours, or after exceptional operating conditions are registered by an RFID tag (such as temperatures outside normal operating ranges). There may also be value in information generated about a component during its operational life for its disassembly as it goes into remanufacture.

In the situations described, either there is a regulation requiring records of the history of the part, or there is a benefit in tracking the history of the part over its lifetime. Tagging the part with passive RFID may facilitate the process.

A different reason for using passive RFID or RTLS is their value within the remanufacturing process itself. Remanufacturing operations often have low economy of scale, and the DoD's depots are no exception. Considering the standard product-process matrix classification, the DoD depots are job shops because of their process-oriented layout, high product variety, high demand variability for each product and low volume associated with each job. Hence, they cannot benefit from some of the efficiencies found in a line flow (human-paced or machine-paced assembly lines), such as steady demand and considerable economies of scale. Hence, jobs in military depots naturally face a jumbled flow, which makes it very difficult to schedule work orders and to keep track of all jobs as they progress, a problem that leads to inefficient operations with unpredictable deadlines, low resource utilization, and high incidence of delays, defects and rework. To reduce uncertainty in the job shop, floor managers try to track the jobs using simple paper and pencil methods, with all the risks associated. Clearly, the use of a reliable tracking technology would be more appropriate in this environment. Better job shops make a consistent effort to be lean, and the use of RFID to track parts may be a useful tool to achieve this objective. In fact, if lifetime tagging is not necessary, and the benefit lies in tracking the process, one may consider RTLS tags, eliminating the need to tag the components themselves. RTLS uses active tags that have their own power-source to emit a continuous beacon indicating the location of the part. A set of three of more readers strategically located in the job shop identifies the precise location of the part using simple triangulation, which helps tracking the component's progress in the remanufacturing process.

Following the movements of individual components in the job shop while the product is being remanufactured can be difficult, due to high propensity for some parts to lag behind in the process and delay final re-assembly. Moreover, if the shop is large enough, busy enough, or if the items are similar enough (where *enough* is introduced subjectively), tracking the location of individual parts using some automated system, such as RFID/RTLS may simplify decisions and allow the parts to speed from station to station until all processes are complete. This suggests three situations in which RFID/RTLS is useful in the job shop:

1) Some shops repair a large number of similar items at the same time. The variety of items may overwhelm even the most experienced scheduler, or the most talented worker, making it difficult to enforce even the simplest first-come first-serve policy.

2) Some repair processes are complex, requiring the parts to follow various operations in multiple workstations. The typical process-oriented layout found in most job shops would force the part to travel in a non-linear fashion in the shop floor, increasing the scheduling complexity. This complexity would further increase with the general complexity of the site layout, the number of different workshops onsite that components are dispersed among, and the number of offsite subcontractors used for outsourcing specific remanufacturing processes. These more complex arrangements are not untypical and result in a loss of visibility of components. The scheduling difficulties created are magnified when there is high variability in component processing times.

3) Some items go through several remanufacturing cycles during their lives, each time burdening the repair shop with the same scheduling and tracking challenges listed in cases 3 and 4, above.

At least one of the five scenarios described must occur to justify the adoption of an RFID system to tag the parts that belong to complex remanufacturable items or systems in the repair shop. However, RFID tagging is expensive and is sometimes technically challenging, so the decision to adopt it requires evaluating the trade-off between benefits and the complexity of execution. Figure 1 shows our suggested framework for making this decision:

As Figure 1 shows, once the value of RFID is identified, the next step is to evaluate the implementation cost by answering two questions:

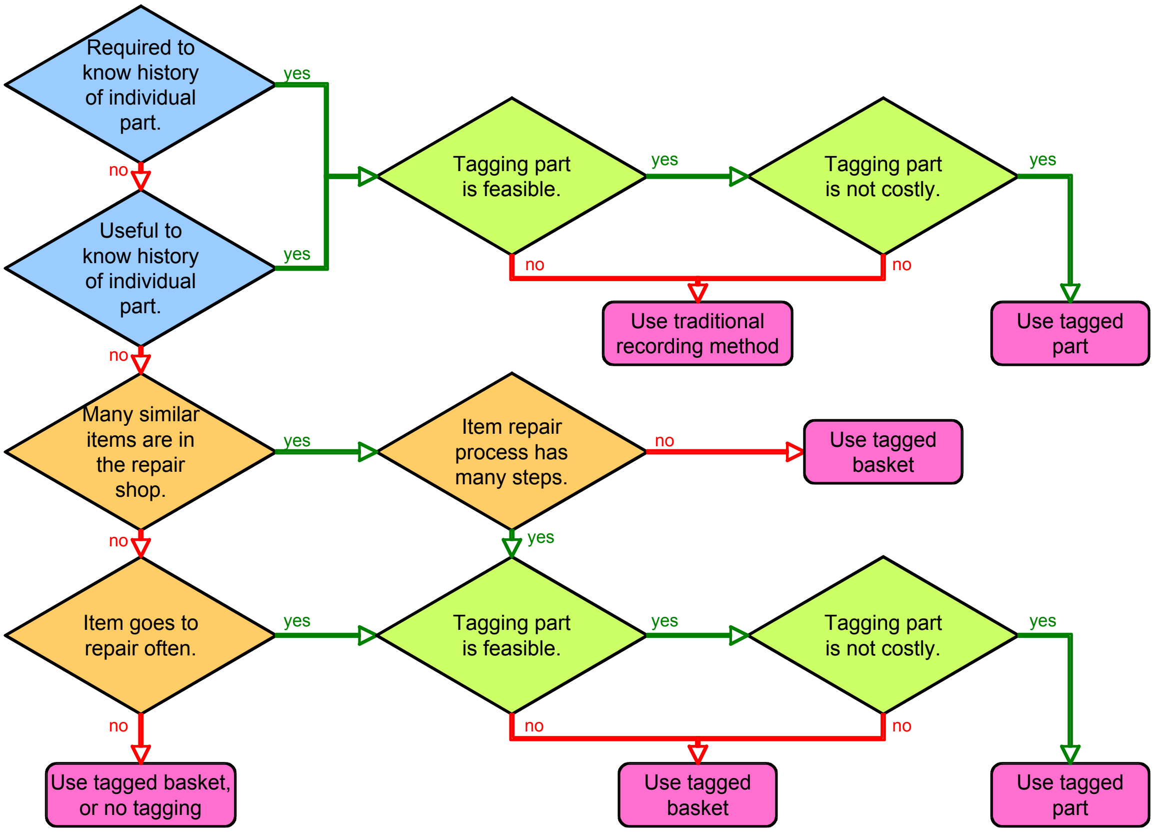

Figure 1: Framework for the Adoption of Passive RFID or RTLS in Remanufacturing

- Can the part receive an RFID tag without compromising the part's function? This assessment must include:
  - The effect of the tag on the component's functionality during its normal operating cycle.
  - The ability to effectively read the tag in various operating environments.
  - The tag's resilience to the remanufacturing process (perhaps requiring replacement).
  - The effect of the tag on the efficiency and effectiveness of the remanufacturing process (potentially requiring removal or replacement).
- Is the cost of tagging the individual part acceptable? The answer to this question requires assessing:

- The cost of the tag itself and whether to install it on the component.
- The cost to replace it during the component's lifetime.
- The cost of additional hardware and software in the system.
- The cost of managing the process.
- The cost of not having an RFID-type of system, using an alternative tracking method, or not tracking at all.

If the answer to these questions is positive, then the parts should be individually tagged with RFID, preferably associated with the part's serial number encrypted using UID.

If the answer to either set of questions is negative, the alternative depends on the purpose of tagging. If the value lies in the knowledge of individual part's history (specifically, if it is a regulatory requirement) then a traditional recording method must be adopted, with all its inherent weaknesses. However, if the value of the tagging process lies exclusively in improving the material flow during remanufacturing, the tag could be located in a basket or bin that will be used to carry individual parts or kits of parts through the process. With a little discipline to ensure that baskets and parts are correctly associated in the system and that the parts stay in the same baskets until the process is completed, the same benefits can be obtained by RTLS tagging using baskets (the system used at Tobyhanna Army depot) or directly tagging individual parts with passive RFID tags (we analyze this issue in the next section of the paper).

One further alternative rationale for passive RFID tagging at source is worth mentioning here. In some circumstances, passive RFID tagging may create valuable information for the pre-remanufacturing process of disassembling components. Two articles have recently addressed this issue (Kulkarni Ralph, & McFarlane, 2007; Zikopoulos & Tagaras, 2008). These analyses suggest that since there is a high level of uncertainty about the quality of components entering the remanufacturing process, RFID-derived information can be valuable in helping sort components wherever it provides an alternative to manual inspection and sorting processes. Thus, information about the history of the component might help lower costs in the remanufacturing process. Key findings are:

- VOI (value of information) from passive RFID tagging increases with potential variability in component quality. If variability is high, then information on component history has more value, which favors passive RFID tagging of components. This may be true for parts that are sensitive to maintenance quality or use/abuse/environmental factors (e.g. officials at North Island Naval Air Station told us that FA-18 aircraft entering the remanufacturing process vary greatly in how many hours of work they require, largely depending - in their opinion - on the maintenance practices of the sites from which they operated). Moreover, some components may be malfunctioning when they enter the remanufacturing process; at the extreme, some parts are completely missing. Early identification of this aids the remanufacturing planning process. Using passive RFID-enable data it may also be possible to presort and prioritize components based on their history: some parts can be fast-tracked, some parts may not need disassembling, some may not be suitable for remanufacturing (and hence must be replaced).
- The value of presorting using passive RFID-enabled data is contingent on several factors. One is disassembly costs (if high, component tagging is more valuable, as this may enable the assessment that component may not need disassembling). If holding costs are high, passive RFID data may have value by enabling faster sorting and routing compared to manual inspection processes. The costs of manual sorting and testing also influence the value of RFID tagging: where manual costs are higher, RFID may be a better choice. Finally, the accuracy of alternative sorting and testing procedures, and the cost of errors in sorting and testing has to be considered.

Next we take up the question of the value of RFID/RTLS for improving the material flow during remanufacturing using a simulation model.

4. Simulation of RTLS in a Remanufacturing Shop

The decision-making process shown in Figure 1 seems plausible but needs to be corroborated. In this section of the report, we use the results of a simulation model to provide a better understanding of how RFID/RTLS may generate value in remanufacturing operations.

When the remanufacturing process requires that parts coming from the same core be reassembled together, the use of RFID is expected to reduce the complexity of the parts handling operation, thereby reducing or eliminating errors in the reassembly sequencing. In the absence of RFID, as a part exits a repair step, it is routed to the next step in which it may or may not be sequenced in the order that it arrives. The typical jumbled process seen in most remanufacturing job shops makes it difficult to maintain a discipline that ensures all parts arrive together at the reassembly station, creating delays and increasing the queue ahead of reassembly.

We propose a simulation that compares two situations: one that ensures first-come first-serve in every repair station and another that allows parts to be repaired in random order at each workstation. We believe that, in a busy job shop, it is difficult to ensure that all jobs are executed in the scheduled order if there is not a control system such as RFID tracking in place. From a simulation viewpoint, there are different ways to implement a random sequence of parts in the workstation, as expected in a RFID-less job shop. We assign the travel time between workstations according to a random distribution, which delays some parts and speeding others in the subsequent workstation. Thus, the queue in front of each workstation will not reflect the order in which the parts left the previous repair operation.

The proposed simulation works as follows: Cores from *m* products arrive in the system according to a Poisson process at a rate of λ cores/hour. They are immediately disassembled into *p* distinct parts and proceed to execute *s* distinct steps in a job shop containing *w* distinct workstation, after which they queue in front of the final station where they are reassembled as soon as all parts from the same core join the reassembly queue. In all scenarios, the time to execute the repair in every workstation is drawn from the same exponential distribution, regardless the step or the part; in other words, all workstations in each simulation have a capacity of μ cores/hour. In all scenarios we adopt the same value of $\lambda = 4$ cores/hour, and we select a value of μ such that the utilization level in each workstation is either 0.8 or 0.9. To prevent confounding factors to influence the simulation, the time to disassemble or to reassemble each product is set equal to 0. If the job shop uses RFID to manage material flow, the transportation time from one workstation to the next, and from the last workstation to the reassembly station, is constant and equal to τ. If the job shop does not use RFID, this transportation time is drawn from the uniform distribution with range $(0 : 2\tau)$. Hence, any benefit from introducing RFID stems from ensuring a first-come first-serve discipline in every workstation. We perform *R* replications of each scenario, lasting the equivalent to *N* days of continuous operation, shown in Table 1. A sample material flow showing the different path taken by each part appears in Figure 2. Each replication in the simulation is equivalent to the continuous production of several thousand remanufactured products. Although process times and arrival rates are measured in minutes or hours, it does not affect the generality of the simulation, since all parameters can be easily scaled to arrival rates or process times measured in days or weeks. However, the results would change significantly if the utilization rate (the ratio between arrival rate and the process capacity) is substantially different from the target values used.

Table 1: Simulation Scenarios

Scenario 1: $m = 1$ product, $p = 3$ parts, $w = 3$ workstations, $s = 2$ steps, $R = 20$ repetitions, $N = 30$ days, $\mu = 10$ parts/hr, utilization (ρ) = 0.8 and $\tau = 6$ min

part A: first repair step in workstation 1, second in workstation 2
part B: workstations 2 and 3, in this order
part C: workstations 1 and 3

Scenario 2: $m = 1$, $p = 3$, $w = 3$, $s = 3$, $R = 20$, $N = 30$, $\mu = 15$, $\rho = 0.8$ and $\tau = 4$

part A: workstations 1, 2 and 3
part B: workstations 2, 3 and 1
part C: workstations 3, 1 and 2

Scenario 3: $m = 1$, $p = 4$, $w = 4$, $s = 3$, $R = 50$, $N = 60$, $\mu = 15$, $\rho = 0.8$ and $\tau = 4$

part A: workstations 1, 2 and 3
part B: workstations 2, 3 and 4
part C: workstations 1, 3 and 4
part D: workstations 1, 2 and 4

Scenario 4: $m = 3$, $p = 2$, $w = 3$, $s = 2$, $R = 50$, $N = 60$, $\mu = 20$, $\rho = 0.8$ and $\tau = 3$

product I: part A (workstations 1 and 2); part B (workstations 2 and 3)
product II: part B and part C (workstations 1 and 3)
product III: parts A and C

Scenario 5: $m = 4$, $p = 3$, $w = 3$, $s = 4$, $R = 50$, $N = 60$, $\mu = 40$, $\rho = 0.9$ and $\tau = 1.5$

product I: part A (workstations 1, 2 and 3); part B (workstations 2, 3 and 4); part C (workstations 1, 3 and 4)
product II: part B, part C and part D (workstations 1, 2 and 4)
product III: parts A, C and D
product IV: parts A, B and D

Scenario 6: $m = 5$, $p = 4$, $w = 5$, $s = 3$, $R = 50$, $N = 60$, $\mu = 53.33$, $\rho = 0.9$ and $\tau = 1.125$

product I: part A (workstations 1, 2 and 3); part B (workstations 2, 3 and 4); part C (workstations 3, 4 and 5) and part D (workstations 1, 4 and 5)
product II: part B, part C, part D and part E (workstations 1, 4 and 5)
product III: parts A, C, D and E
product IV: parts A, B, D and E
product V: parts A, B, C and E

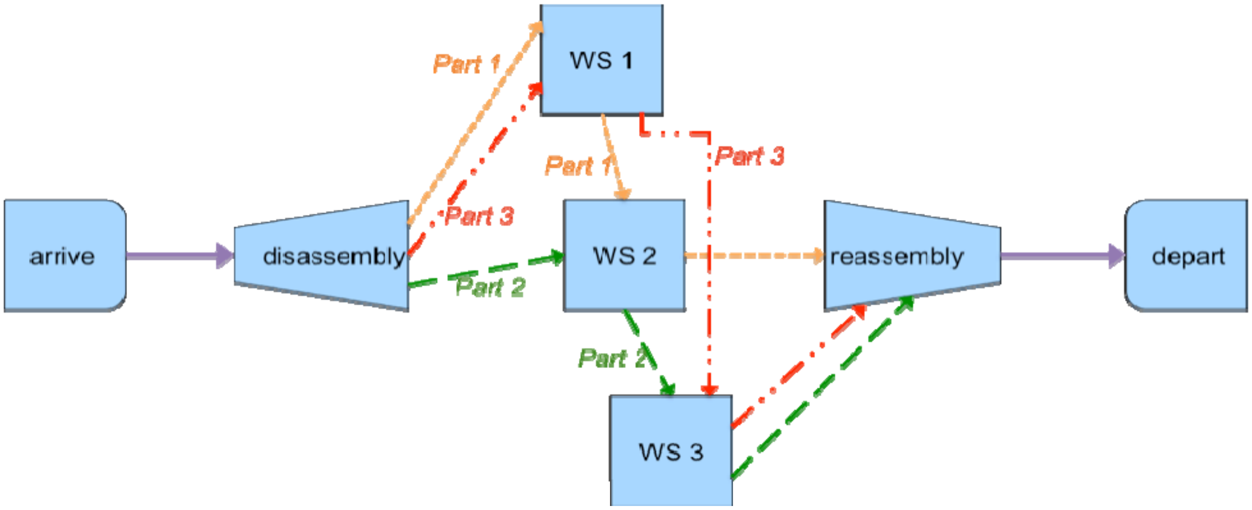

Figure 2: Material Flow in Scenario 1

Table 2: Simulation Results

	Reassembly Queue Length			Reassembly Queue Time			Cycle Time			
	All Reps	Min Avg	Max Avg	All Reps	Min Avg	Max Avg	All Reps	Min Avg	Max Avg	Worst Case
m = 1, *p* = 3, *w* = 3, *s* = 2	0%	3%	10%	1%	2%	6%	-3%	-1%	5%	15%
m = 1, *p* = 3, *w* = 3, *s* = 3	13%	10%	11%	14%	13%	13%	1%	0%	-1%	13%
m = 1, *p* = 4, *w* = 4, *s* = 3	7%	14%	0%	7%	11%	1%	2%	4%	-1%	-5%
m = 3, *p* = 2, *w* = 3, *s* = 2	5%	6%	2%	5%	6%	2%	0%	1%	-1%	22%
m = 4, *p* = 3, *w* = 3, *s* = 4	2%	6%	4%	2%	5%	4%	0%	2%	1%	-3%
m = 5, *p* = 4, *w* = 5, *s* = 3	1%	6%	9%	1%	6%	8%	-1%	4%	2%	3%

The scenarios vary from the simplest (one product, three parts, two repair steps per part) to the more complex (five products, four parts per product, three repair steps per part). The results appear in Table 2, showing the reduction in total cycle time (the total time that the product stays in the system, from disassembly to reassembly), queue length and waiting time at the reassembly stations with the adoption of an RFID-based control system. In all cases, RFID reduces the length of the reassembly queue, as well as the time that parts wait in line. However, the reduction in cycle time was not as consistent. For example, in the scenario in which there are three products, each made of two recyclable parts that are repaired in two out of three workstations (scenario 4), the average queue length was reduced by 5%. Comparing all 50 replications, the replication with lowest queue length average was 6% shorter, and the replication with the largest queue length was 2% shorter with RFID. Similar improvements were found with the time that each part stays on queue. However, the cycle time did not have the average reduced. Comparing all replications, the replication with shortest average cycle time had a minor improvement (1%) and the replication with the longest cycle time showed a worse performance with RFID than without. It seems that these minor differences (up or down) result from the simulation itself and should be ignored. On the other hand, it seems that RFID has a major positive impact against the worst-case cycle times, providing double-digit cycle time reduction in half the scenarios analyzed.

The simulation only evaluated the impact of improving the control of the material flow in the job, which explains the relatively small performance improvement. However, this is only part of the RFID benefit, which also includes better housekeeping and faster process recovery when parts are effectively lost in the system. Simulating the impact of RFID in this type of event is outside the scope of this study.

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5. Conclusion

In this report, we have shed some light on two key issues pertaining to the use of RFID technologies in DoD remanufacturing operations: when to use passive RFID tagging of components throughout their lifetime versus using RTLS tagged baskets in a remanufacturing process; and what about RFID/RTLS generates value in the remanufacturing process? It turns out that neither of these questions is quite as easy to answer as it seems.

Passive lifetime RFID tagging is beginning to happen for some components in the commercial aircraft industry but is not yet embraced by the DoD. Given the contingencies we highlight in our proposed decision framework, at the moment we see a fairly limited scope for applying passive RFID to components in the DoD. Although we do not analyze the economics of this decision, we suspect that most of the value from lifetime passive tagging will be generated in maintenance programs, or is to be had because passive RFID is an efficient way to meet mandated safety or security policies. In addition, passive tagging may improve the efficiency of the remanufacturing process, but we believe these are probably secondary considerations.

This leaves the question of why and how RFID/RTLS generates remanufacturing benefits at all. It is quite clear that substantial savings were garnered by introducing an RTLS system at Tobyhanna. Yet our simulation results suggest that the efficiency gains from using RTLS in remanufacturing operations are relatively small. Comparing the simulation results with the Tobyhanna results suggests one of three things might be going on.

One possibility is that the relatively modest gains in remanufacturing efficiency translate into dollar savings that are still large compared to the cost of implementing RTLS at Tobyhanna. This would explain the quick payback at Tobyhanna.

A second possibility is that the largest savings from implementing RTLS within remanufacturing do not come from improvements in the material flow that we address in our simulation. This assumption suggests that the big dollar gains occur because RTLS creates information that prompts managers to address issues such as overtime, scheduling, shrinkage, etc. It is possible that such inefficiencies could have been eliminated without the use of technology, but the arrival of new technology focuses management attention on their processes and therefore encourages improvements. This raft of improvements is responsible for generating a strong payback of the new technology being implemented. Ultimately, the point here is that implementing new technologies can have spillover effects by prompting general process improvements.

A third possibility is that the implementation of RFID in the remanufacturing process requires substantial housekeeping and reorganization effort, which can only be obtained with unrestrained commitment from top management. This housekeeping benefit is the same catalyst that is often observed during the implementation of Just-In-Time or Lean Six Sigma programs. It is often described as the 5S approach (Simplify, Sort, Shine, Standardize and Sustain) introduced in Toyota. In order to be able to introduce RTLS in the shop and track the movements of components, it was necessary to remove excess inventory, tools, bins and other staples from the working area to allow for a smooth material flow. In doing so, the job shop achieved the whole potential of the process improvement through component tagging.

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