21st Century FOD Prevention

Using RFID to automate FOD prevention, increase efficiency and drive cost savings

The Leader in Remote Asset Tracking

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One of the most dangerous threats to catastrophic aircraft failure comes from human error during the aerospace manufacturing and maintenance process. F-O-D are three of the most feared letters in the alphabet when it comes to airlines and aircraft operators. The idea that items may be left inside an engine, nacelle, wing, fuselage or other parts of an aircraft is known as Foreign Object Damage or Foreign Object Debris (FOD) and it is often a deadly mistake.

According to FODcontrol.com, "Foreign Object Damage hits the aerospace industry for a loss of $3-4 Billion annually…" not including lost productivity or fines imposed by the CAA or FAA[1] . There are safety implications that require attention and compliance but one thing many companies overlook is that a good FOD program brings a heightened level of efficiency and productivity to existing processes. In this white paper, you will learn how that is accomplished and provide data that took one airline process from more than four hours to under sixteen minutes.

Nearly all manufacturers and maintenance operations have entire staff dedicated to FOD prevention. Many times the CFO or Finance team view a FOD prevention team as drains on cash or productivity when in fact a FOD program is critical to the survival of an aerospace company. The question for the FOD team is how to make best use of automation to show that the FOD program is at the leading edge of efficiency and accuracy. –What tends to validate a CFO's fear is putting in cumbersome processes that slow production in a manual attempt to regulate FOD.

At the most basic level here is only one way to prevent FOD, and that is to account for and "see" every item that is on a shop floor when a shift starts and account for each and every one of those items when the shift is over. This requires a level of diligence and focus that humans are unfortunately not able to maintain. History has shown that counting on people to account for and maintain visibility on items like tools and parts is an imperfect solution. The only way to get true visibility and accountability is to give each item its own voice – automation through RFID. This has only become possible as a solution in the past six or eight months. Prior to 2010 RFID for FOD tracking really was not ready for prime-time.

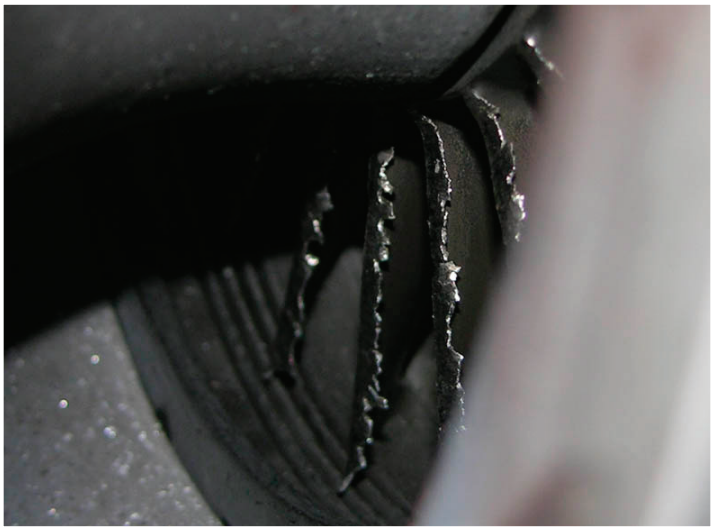

Figure 1: Turbine blade damage caused by Foreign Object Debris (FOD)

Radio Frequency Identification (RFID) enables fast non-line of site data transfer from many objects at once to fixed or mobile readers with relatively long read ranges[2]. 2010 was a breakthrough year for RFID, while the costs have been steadily decreasing over the past few years, in 2010 the costs have came down significantly while the performance of the technology improved dramatically. Many aerospace manufacturers validated the fact that RFID broke through the price/performance threshold in 2010 by moving FOD programs into production – companies like Airbus, Lockheed Martin, and others all expanded RFID programs in 2010. In addition, organizations like the Airline Transport Association (ATA) and International Airlines Transportation Authority (IATA) have agreed on standards for RFID.

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The aerospace industry currently is targeting nine primary areas for FOD elimination:

1. Aircraft and aircraft engines
2. Hardware and fasteners
3. Machined parts
4. Electronic assemblies
5. Sheet metal assemblies
6. Optical assemblies
7. Electronic components
8. Chemical, sealants and cleaners
9. Software and operating systems

In order to properly address the elimination or reduction of FOD, proper systems or what we at Quake Global refer to as catalytic mechanisms need to be in place. These can address the types of potential FOD and put the appropriate controls on the root cause area. If possible, technology needs to be employed to eliminate the possibility of human error.

The five controls that can be put in place are:

1. People controls
2. Tool controls
3. Parts controls
4. Specific controls
5. Area controls

People, tools, and parts are all opportunities for automation to take place and RFID to eliminate FOD. Many companies, like Pratt & Whitney, are using toolboxes that are "see-through" and enable a visual inspection of parts. This is not only time consuming but also predicates human involvement. At the end of a long shift, repeated processes can often be quickly scanned over causing small details to be missed.

There is well documented proof that RFID tags attached to tools increase process efficiency and prevent Foreign Object Damage. A well publicized project for Airbus in the UK has provided very compelling data for not only an increased level of safety but a Return On Investment (ROI) in just about twelve months from efficiency gains. That program brought great attention to the team because it is a safety program that saved the company money.

How does a safety program pay for itself in efficiency? Queuing to wait for tools from tool stores wastes workers' valuable time as they stand waiting unproductive. The same employees could be more productive if they were performing tasks instead of waiting in line. Effectively tracking calibration status of tools is also a critical part of maintaining safety validation. Reducing times spent waiting for tools, increasing calibration tracking, and removing a major source of Foreign Object Damage allows RFID Tool and Parts Tracking to achieve large ROI in a very short time.

Process Efficiency Improvement

In many manufacturing operations, more time is lost to workers queuing for tools to be delivered than any other single operation. Rather than use guesses and hyperbole, we decided to take the stopwatch into the field and see what impact automating the tool check in and checkout process would have.

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In one medium-sized factory (using approximately 3500 tools), Quake Global installed an RFID tool tracking solution which combined both passive and active RFID systems. What we found was over 7.5 hours total (or 450 minutes) was spent each shift to Check In and Out hand tools, locate and process calibrated tools, and Check In and Out and inspect kit carts and containers. With the RFID solution, just 62 minutes is spent each day on these tasks, a time reduction of 85%.

In additon to the time savings, errors and calibration exceptions were reduced by 98%, which means there was less likely to be an incident where an out of calibration tool was used, or where a part was left in the aircraft or engine. The automation and ability to locate a missing tool very quickly within a wing or fueselage is often worth the price of an RFID program. However, a CFO may not accept finding a missing tool as justification. To justify an RFID program a FOD manager needs to build a business case. A simple analysis would show a compelling business case.

At a fully loaded cost of $125,000 per annum for a typical engineering employee, the savings illustrated in Figure 2 would equate to:

- The FOD threat is greatly reduced and compliance is assured
- $125,000/40/52= $60/labor hour
- 388 minutes per day savings = 6.5 hours per day
- 6.5 hours/day X $60/hour X 52 weeks X 5 days/week = ***$101,000 annual savings per shift***

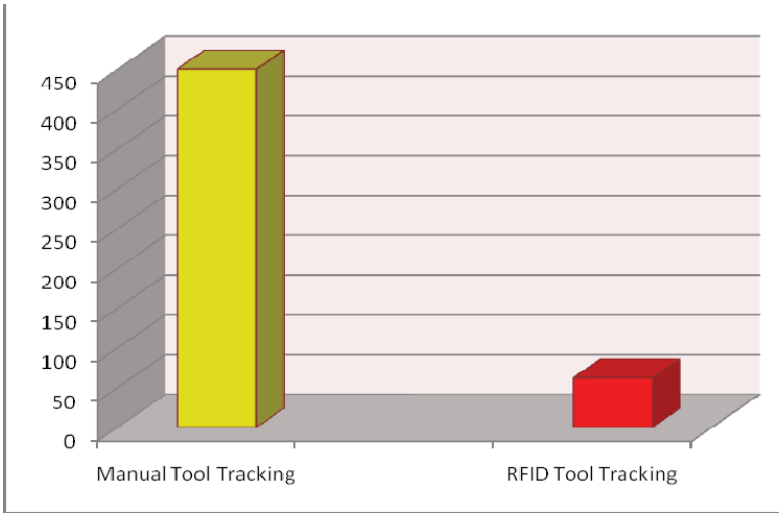

Figure 2: Labor Minutes spent per shift tracking tools

You can use your own internal numbers to determine ROI data but clearly what the numbers show is that even in a small/medium facility like the one described above there are two important outcomes:

- The FOD threat is greatly reduced and compliance is assured
- The savings pays for nearly another full-time employee; increasing productivity

Implementing an accurate RFID solution with very high visibility is predicated on two core tenets consistent with Six Sigma accuracy levels system:

1. Physics – accurate scientific testing to ensure the right choice of tags, readers, and configuration parameters requires an experienced lab and trained RF engineers and physicists.

2. A True RFID OS – an Operating System that puts intelligence on the reader and eliminates the need for middleware severs and a cumbersome enterprise application. This ensures the most value from the hardware and a cost effective, low maintenance solution.

Hand Tool Check In/Out

At the start of every shift, tools are "booked-out" from central tool stores to engineers who are required to return the tools at the end of their shift. In the facility mentioned above, 250 transactions occur each day (125 in & 125 out) averaging 5-10 specific tools per transaction. Prior to the RFID implementation, these transactions required 3.1 man-hours of work per day. An additional 123 minutes were wasted each day as the operators waited for their tools. The process flow below in Figure 2 describes the pre-RFID tool assignment protocol.

The RFID system described earlier uses a Quake Global EasyTable™ with a variety of specific RFID tags designed to be mounted on metal items which are then attached to each tool. EasyTable™ automatically reads every tool placed on the table and provides the Electronic Product Code (EPC)[3] to an SAP database which supplies the specific tool information. Tools are then automatically assigned to the Operator. This RFID tool tracking system reduced queue time at the checkout window by 66% and eliminated the two most time consuming steps for the Storeman – writing down serial numbers and entering the numbers into the database. The system also reduced a 10-12% error rate associated with the manual recording of serial numbers down to less than a one percent error rate.

Kit Inspection

Tool kits are widely used by operators in manufacturing operations. When issued, an operator has all of the tools necessary to complete a specific job contained within the kit. Kits can range from hand portable tool cases to carts packed with a variety of tools. These kits are often issued quite far from where the actual work on the aircraft is completed in an effort to centralize tool storage, calibration and management. Many times the process that a kit is being used for will take the better part of a full shift to complete. The problem or pain for the engineer comes when the kit has a part or critical tool missing and this is not discovered until the process is underway or they are at their work cell, often a great distance from the kit pick up location.

RFID provides an instant and accurate verification of each kit. An RFID reader scans the kit before issuance to an operator – the EasyTable™ can be used for the small cases and a a standard portal or handheld reader can be used for the large carts. A "parent tag" on the outside of each kit container determines what tools should be inside the kit. The "child tags" of each tool are read at the same time as the "parent tag" and are checked against the "parent tag" to make sure that the "parent" has all of its "children." Prior to this implementation, when a tool was missing, the operator did not know about it until he or she tried to use the tool and could not find it. When the tool was discovered missing, a very time-consuming

process of walking across a large hanger and filling out paper work to get a specific tool ensued. The knock on effect was that a process designed to take an entire shift was not completed. An RFID system eliminates this quality issue and keeps processes running on time.

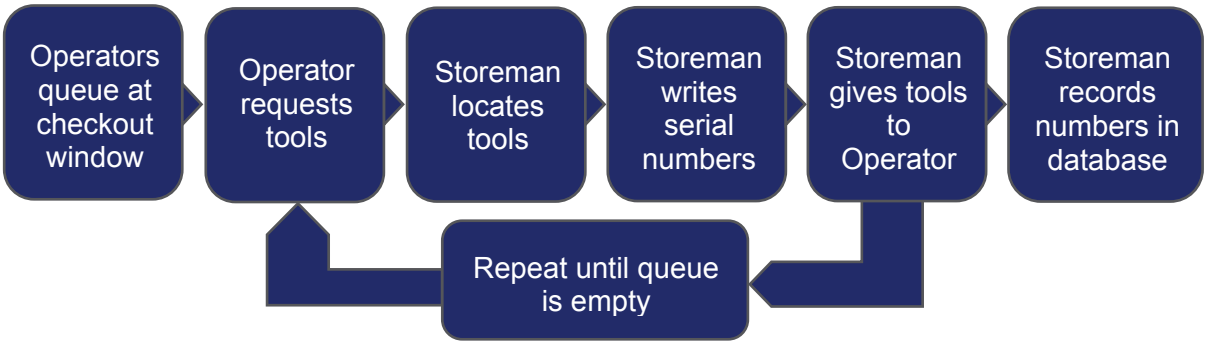

Figure 3: Tool Check-Out Process

Calibration Management

Properly calibrating tools is necessary to ensure correct and safe manufacturing. Using calibrated tools is not only the law it is imperative for aircraft safety as well. Any over tightened bolt or hole that is too small can lead to stress fractures which may destroy parts or require expensive repairs. Manufacturing companies are of course aware of these risks and have methods to prevent late calibrations, but the fact is tools are often still in use well after their calibration dates have expired.

A major culprit of out-of-calibration tools is the kit issuing process. Delivering a full kit can save time in the check out process, but means that calibration dates of each individual item are not checked when a manual system is used. In addition, if two workers with similar kits swap a tool, the calibration date information of the swapped tools will no longer be correct in the database, because the tool is often associated with the calibration schedule as part of a full kit. An RFID solution will check each individual tool so that no part misses its calibration date. If an RFID system is properly set up each time the tool passes over an EasyTable™ or through a portal the system will read each individual tag and look up the information in the database to check for calibration schedule. If the tool is due for calibration an alarm will stop the tool from being issued, or a light can illuminate preventing the entire kit from being removed, or a note can pop-up on a touch screen. All of this communication takes place automatically in a fraction of a second.

Just as in the tool check in/check out processes, a large amount of time is wasted tracking tools and entering serial numbers one at a time manually. An RFID

Quake Global recently published a SW White Paper describing the steps to ensure successful integration with existing SW infrastructure – as mentioned above, most companies already have systems to track calibration records; what they don't have is the hardware (namely, RFID technology) to track individual items. Adding hardware that is more sophisticated should not require adding more complicated software. In fact, a server or laptop has the best operating system (OS).The same can be said for the newer version of TFID (TFID 2.0). All that is required to make an RFID system work well with an existing SAP or similar system of record is an RFID OS.

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solution eliminates tools being used past their calibration due-dates and allows calibration setters to complete tasks more quickly.

During the tool check out process described above, calibration information populates a PC database the moment tags are read. If a tool is past-due for calibration, a warning alert goes off and the tool is not issued. Prior to this implementation, the Storeman would not check the database until after all operators had their tools. If he found that a tool issued was past due, he would then have to track down the user to re-claim and replace the tool. This often meant leaving the tool crib, walking across a large hanger, and leaving people waiting to be served back at the tool crib.

The Calibration Setters can also use handheld readers to aid the calibration process. A custom application installed on the RFID readers reads the RFID tag on the tool without needing to see or touch the tool. The application then displays the relevant calibration parameters of the tool. The setter can enter the specifications of the tool directly into the handheld application, which connects over Wi-Fi to a database server, and updates the information. Using a handheld reader allows the setter to bring the information with him as he uses different calibration stations and machines relevant to each step of the calibration process.

Improved Inventories

Better management of the Check In & Check Out processes naturally leads to more accurate inventories. In some factories, however, a tool store is not used. Instead, tool carts remain in the location where the tools are used. Even in factories that use tool stores, carts that do not contain calibrated tools are often employed. In these situations, Quake uses handheld readers spread throughout the factory or specialized toolboxes fitted with RFID readers. A user will take the reader and scan the cart's ID tag. Then he or she will scan each drawer of the cart and read the tags. Without RFID, a cart with 180 tools takes 45 minutes to fully inspect. An RFID system is able to read most of the tools in just two minutes. The remaining items are items such as ratchet bits and wedges that are either two small for a tag or have no place for a tag to be placed without compromising the function of the tool. Checking these remaining tools takes an additional 10-15 minutes for a total time of 12-17 minutes. This inventory provides the same benefits as the Kit Tracking use case in a tool store and does not require a user to leave his or her area and go to a dedicated tool crib.

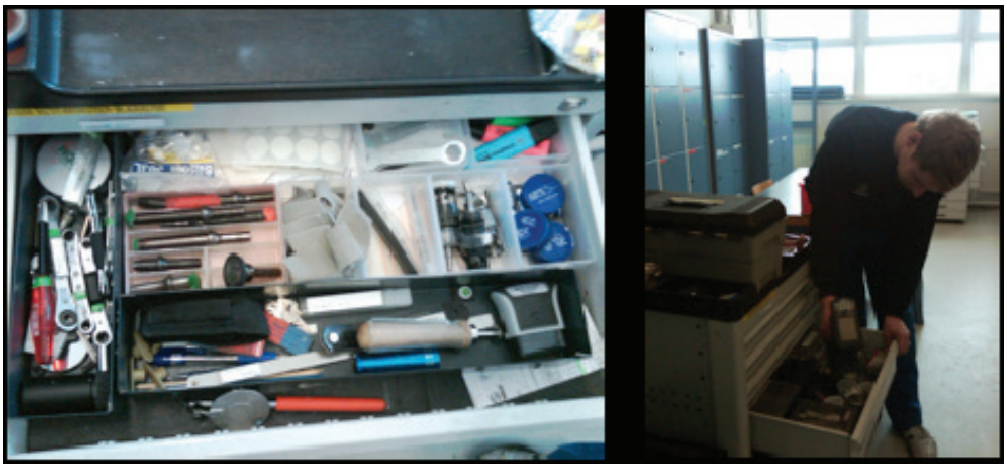

Figure 4: Tool Carts used with a Handheld RFID tag reader enable accurate inventory

As new waves of smaller tags are released, these smallest items will be tag-able and inventory times will be reduced further. There are also specialized tool cases that have built in RFID readers and can read every item in the toolbox without any human interaction. Companies like Boeing and Lockheed Martin have hundreds of these new RFID enabled toolboxes and are especially

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good at preventing people from putting multiple tools in a single slot. Mark Renser the most senior FOD executive at Pratt & Whitney told Quake toolboxes that need to be strategically placed in work cells often will have multiple tools in a cut-out designed to hold only a single tool. This is "insurance" for the workers who in case they lose a specific tool have a back-up. For a FOD prevention program however it is a nightmare. There are multiple tools that are not accounted for in each shift that could be left inside an engine or fuselage. Many companies like Pratt & Whitney are phasing out customized toolboxes and not allowing operators to change the tool boxes as they are assigned to prevent multiple tools.

FOD Prevention

Foreign Object Damage (FOD) is a very important concern for manufactures. FOD includes damage caused both by foreign objects left inside major component sub-assemblies (MCAs) as well as external damage from birds, rocks or hail. In response to the self-inflicted damage from tools or debris left inside an MCA, the CAA and FAA will impose fines on manufacturers up to grounding an entire fleet or closing a factory while the source of damage is determined and eradicated. One mistake can put a company out of business and has in the past cost major aerospace manufacturers hundreds of millions of dollars.

Multiple aerospace factories have been closed due to FOD investigations – one Airbus facility was closed for a full two weeks. Airbus estimates that the "cost of non-quality" is €400M per annum[4]. Self-inflicted FOD itself is, according to an Airbus executive, "notoriously difficult to calculate," but makes up a sizable portion of the €400M in rework prior to delivery and the very rare fines.

FOD Prevention is enabled through two methods. The proactive method of keeping better track of inventories gives warnings when tools are missing so that operators know when to search and what to search for. A reactive method uses RFID handheld readers to aid the inspection process of completed sections and find tools that cannot be found visibly. Speeding the Check In & Check Out times and automating full calibration tracking are use cases that have been achievable for quite some time. The newest generation of passive RFID 2.0 tags and readers have yielded smaller tags that can be read from further distances. These improvements have increased the effectiveness of the two previous use cases by allowing even smaller tools to be tagged but have also allowed entire new use cases to be developed, such as the reactive FOD Prevention tool searching.

Evolution of the RFID toolbox

The early RFID enabled tool boxes had RFID tags in the bottom of the tray where a tool was placed. The tools had cut-away padding so that only a certain tool type would go in its cut-away spot. Early RFID toolboxes worked by negative reads, if there were no tags read in a toolbox, you assumed that all the tools were in their spots; covering each RFID tags and allowing nothing to be read. But anything could be covering the tag not necessarily the right tool

RFID 2.0 is capable enough to actually tag items down to a single ratchet and read where the item is, not just if it's covering up a tag. Now you can wave a handheld in a wing and get a beep if any tagged tools are still in the wing. It is a quantum leap forward for the Aerospace industry.

RFID enabled FOD prevention leverages the same RFID tags used to enable the process efficiency improvement use cases discussed earlier. The use case is very simple – prior to fully closing access ports of an MCA and as part of the inspection process, a hand-held RFID reader checks for tools left behind. The inspector only has to "shoot" the RFID handheld reader in the general direction and listen for a beep from the reader indicating it is reading an RFID tag on something left behind. Then the inspector can use the RFID handheld like a Geiger counter to very quickly locate the left over part or tool. In one system Quake Global implemented for a major airframe manufacture over 360 trials using two

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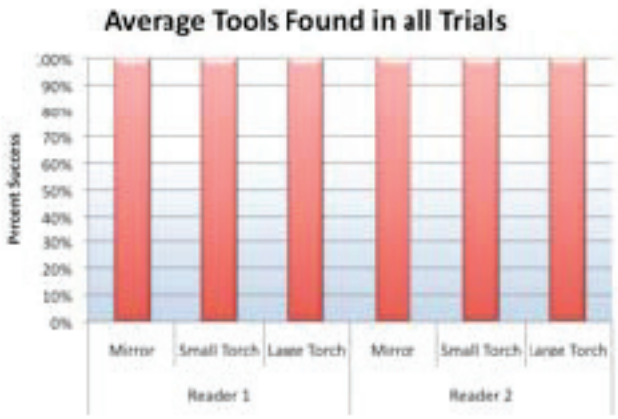
different handheld readers were tested on various parts purposely hidden inside an MCA. The result: the RFID reader quickly pinpointed 100% of tools left inside an MCA.

RFID Systems Costs

RFID systems can range from $100,000 to $10 million depending on the size, scope and level of integration. It is very difficult to pinpoint the costs without having deep expertise and a well-defined requirement. The good news is that total costs have decreased significantly over the last two years.

One of the biggest expenses of the RFID 1.0 era was dedicated RFID "middleware" that software providers tried to sell end-users for each location. These middleware applications would cost between $25,000 and $1 million per location depending on the vendor. They also required ancillary costs in the form of servers, network maintenance, hardware and software support. Fortunately that approach is history. The most successful of the second generation RFID implementations have taken an approach similar to new mobile phones (like the iPhone) – they put intelligence on the devices in the form of an RFID Operating System. This approach is significantly cheaper (usually $1,000 to $2,500 per RFID device depending on the vendor). The cost of an RFID Operating System is not only cheaper but it also leverages all the reader configuration parameters that results in higher read accuracy and lower maintenance.

The other benefit of using an RFID Operating System for your RFID Software is that it helps you get more value out of your existing enterprise resource planning application. If you have SAP, Baan, or similar system you have likely invested millions of dollars in those applications. You want to squeeze as much value from them as possible. The old RFID 1.0 Middleware tries to take the place of those systems for certain tasks and adds a cumbersome layer of additional cost. RFID 2.0 in the form of an RFID Operating System drives greater value for the enterprise.



Specialized RFID tags for the FOD process can range from $ .10 to $5.00 depending on the amount of memory required, if they are mounted on a metal item, or if there is specialty long read range required. A good average is $ 1.00 per tag for planning purposes.

The readers themselves also have a fairly wide cost range. The better RFID handheld readers will be in the $2,000-3,000 range. A dedicated RFID table will be around $10,000-15,000 and a typical portal will be around $10,000 when all is said and done. For fixed read points such as portals and tables make sure your analysis includes the cost of electrical if there is no service present in the location now. Connectivity can be either over WiFi or Ethernet Cable but that needs to be factored into cost as well.

The level of system integration will drive cost, but at all costs make sure that your system integration partner has extensive RFID experience. Aerospace is a very specialized industry that operates in an austere environment full of environmental challenges that test the physics of RFID. A vendor with deep physics expertise is the only way to ensure very high read accuracy and get the optimal ROI.

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Summary - Why Using RFID Will Get You Promoted

If you are looking for ways to cut costs and improve safety you need to use technology not people. A CFO will be hard pressed to approve new headcount in your next year's budget after everything the industry and economy has been through over the last two years. Technology that shows a compelling business case and improves safety is something that will get his attention.

RFID automates many steps in a sound FOD prevention program. If you adopt RFID and try a small, very well planned pilot, you may be able to prove the business case for innovation and a full company-wide roll out. This kind of innovative thinking and ROI-based decision-making is just what the aerospace industry needs right now. An RFID program shows the type of innovation and initiative with results that are worthy of a promotion in any company, or at least some favorable company publicity in Aviation Week.

The RFID use cases described herein drastically reduce time spent for a number of process flows and increase the safety and quality of finished products. 40-year-old barcodes cannot compete with the improvements offered by RFID technology. The Check In & Check Out and handheld inventory use cases rely on reading multiple tools quickly and being able to scan full kits automatically. The entire point of the FOD Prevention use case is to find tools that cannot be seen. RFID has made great strides in the past ten years, it is not only ready for prime-time it's ready for flight time.

If you would like to benefit from Quake Global's 500 successful RFID projects and ground-breaking work in aerospace give us a call. If you are willing to spend a little bit more to hire the best and make sure you get it done right the first time Quake Global can help you achieve the benefits described in this paper.

[1] Reference "www.fodcontrol.com/foreign-object-damage.html".
[2] For an overview of RFID technology, check Quake Global's (formerly ODIN) Ask the Experts page at http://odintechnologies.com/ask-rfid-expert.
[3] The Electronic Product Code or EPC is a unique number like a serial number for each tool. It points to a specific record in a secure database that can be either on-premise or in the cloud with the history and critical information about the tool.
[4] Author's note: "cost of non-quality" is an Airbus term, a more descriptive phrase is "cost of non-perfection," which supports the Airbus goal of zero defects.

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