Guidance on Introducing

Radio Frequency Identification (RFID)

Into Airline Maintenance Operations

International Air Transport Association Safety, Operations and Infrastructure

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RADIO FREQUENCY IDENTIFICATION (RFID) INTO AIRLINE MAINTENANCE OPERATIONS

TABLE OF CONTENTS

1. Introduction

Over the last few years, a number of airlines have started seriously exploring RFID Technology in their Technical Operations. Additionally, Airbus has announced that they will progressively incorporate RFID tags in all current production aircraft and Boeing has been marketing aftermarket solutions using RFID for a number of components. It appears that RFID technology will soon be widely available in commercial aviation for maintenance operations.

IATA believes that the industry needs to act collectively and quickly on a number of issues affecting RFID technologies, including:

a) Uniform and broad acceptance of the technology worldwide

b) Dissemination and incorporation of industry standards to eliminate some of the complexities that

the new technology will undoubtedly add to current aircraft operations

c) Interoperability and higher data security requirements that will maximize efficiency and minimize costs to the operators and other users.

As solutions are already deployed, it is urgent that IATA takes the lead to facilitate and provide a forum to move the industry forward quickly in a wellcoordinated manner. IATA sees that the RFID implementation case can be one of the critical technology pillars that will enable the industry to track and trace aircraft parts and their maintenance records quickly and accurately. This is very similar to the eticketing solution that IATA and the industry mandated to simplify the business.

This paper is intended to offer practical information and guidance on how to make the best use of RFID technology in the airline technical operations and maintenance arenas. It will focus on passive UHF RFID technology defined in the aviation industry standards. It will not cover battery-assisted passive (BAP), active, real time location, or GPS radio frequency technologies.

1.1 Scope

Why RFID?

a) The Pros and Cons approach

RFID may be a great technology, but if it doesn't provide a Return on Investment (ROI) in our challenging aviation environment, why bother to get started? A highlevel value proposition will be presented as well as more specific use cases in our operations and maintenance environments. In addition, both the pros and cons of this technology will be presented so that the reader can avoid the standard 'marketing spin' and gain a realistic understanding of where the primary benefits may lie in their operation.

b) The State of Technology approach

RFID has been a mature technology for a number of years. It has been used extensively in logistics as the technology can provide access to data and information quickly and accurately. The industry needs to be quickly aware of this technology's potential and take advantage of what it can offer. The major airframe OEMs (Airbus and Boeing) have already committed and have entered programs introducing RFID on aircraft parts. It is imminent that RFID technology will be widely deployed on new aircraft parts. As such, airlines will have to be ready if they want to fully utilize it.

c) The Compliance approach.

RFID technology ensures that parts will be accurately identified, therefore providing an alternative means of meeting regulatory needs. In addition to easier facilitation in meeting regulatory compliance, aircraft parts and their maintenance records can be quickly accessed and assessed to simplify aircraft transfers and meet aircraft leasing as well as other commercial requirements (e.g. participation to aircraft parts pooling).

Once the reader has a realistic perspective of use cases, this paper will go on to describe how the technology works and the pros/cons over bar code technology. Further discussion will be held on the RFID tag requirements, and the differences of high memory versus low memory tags. Technology readiness will be discussed from the perspective of the aviation supplier, the airline, and the technology suppliers' performance of meeting airline industry needs. This section will also present how aviation has been able to go beyond the logistics use case and accomplish more than other industries.

Next, the global interoperability issues and security requirements will be presented. The software requirements, industry standards and regulatory guidance will be discussed, covering the use of RFID technology on aircraft and on the ground. Finally, RFID training and intellectual property issues will be presented for consideration.

1.2 Purpose

The purpose of this white paper is to provide a realistic overview of where RFID technology can be used, and is being used, in the aviation business. Many RFID pilot projects have been started and completed, and few companies are using this technology in production, meaning they have committed to moving forward after the completion of pilot programs. The technology has tremendous potential, but it is just a tool and like any tool must be used in an appropriate way to gain advantage of its potential.

The expectation is that the reader will acquire an understanding of the benefits RFID technology can provide to aircraft operations. They also will understand the challenges faced in implementing this technology properly. The goal is to enable the industry to move ahead quickly and safely in a coordinated way to the benefit of all the players.

It is also important to understand the purpose the aviation industry taskforces have in defining an RFID specification in the first place. The purpose was not to benefit one company or one segment of the industry (e.g., airframers vs. component OEM vs. airline operators vs. MRO). The purpose was to benefit the entire industry by storing a minimum set of key data on the part and using industry standard, non-proprietary methods for reviewing that data and making business sense of it. An example of the industry benefit may be in identifying a chronic / rogue unit – a component that tests OK on the bench but repeatedly fails when installed on an airplane. Such a unit creates extra costs to the airline, hurts the dispatch reliability of the airframer’s fleet it is installed on, and damages the reputation of the OEM who manufactured the part. It is to everyone’s benefit to identify those units and remove them from the system as quickly as possible. To do so requires the sharing of pertinent data between all the players involved, and using RFID for part marking purposes is the easiest way to do that.

Finally, the purpose of this paper is to increase the awareness of the RFID Technology and its potential for the commercial aviation industry. It is a matter of urgency that the industry works together towards achieving maximum benefit while minimizing complexity. The window of opportunity to synchronize industry efforts is relatively short. Newly produced aircraft will be equipped with RFID tags and aftermarket solutions have been successfully deployed and will expand exponentially as critical mass is achieved. Various suppliers will create integrated solutions that may not be able to “talk” to each other. An airline may have to utilize several solutions in the absence of common standards and a common platform. It will be better to be in a position to drive technology rather than be driven by its complexities.

2. Industry Use Cases and Value Proposition

The airline industry has been working formally on RFID since 2003, starting with the first meeting between Boeing and the FAA to understand what requirements the FAA would have for the industry to move forward. By then, it was felt that the EPC RFID technology standards were sufficiently mature and gaining enough worldwide acceptance to warrant the aviation industry to join the effort. Many individual company efforts to use RFID had been successful, but for global interoperability across the airline industry much more explicit guidance needed to be addressed with regards to business and regulatory standards.

As is befitting the safety-consciousness of the aviation industry, a decade was spent talking, evaluating, and getting ready for RFID to be deployed. Now is the time as the first commercial airplane will soon be delivered fitted with thousands of RFID tags on various components. The supply side of the industry has invested significantly in the benefits they expect from using RFID technology. The airline side, however, is not yet in a place to take advantage of what will be available to them at the time of the aircraft delivery. It is hoped with further reading through this paper more airlines might be inspired to take advantage of the potential use of this new technology.

The industry use cases can be defined in two large categories:

1. RFID use cases that effect ***flyable parts*** and/or the airworthiness of the aircraft

2. RFID use cases used ***on the ground and within the confines*** of an airline's own operations

Category 1 is where the FAA/EASA and other National Aviation Authorities (NAAs) have established criteria and rules that parties need to abide by. Category 2 is where all the early RFID success have been in aviation and for which there are hundreds of use cases that can be successful. Category 2 involves defining a new business process using RFID technology and then following these rules in your daily operation (basic ISO 9001 criteria). With parts and processes that stay on the ground, companies have significant freedom to determine where and how they can utilize the technology. The Category 2 use cases are essentially closed-loop processes where one company has total control over the parameters. For example, Airbus has been using RFID internally since about 2005 for multiple business processes, such as logistics identifying and tracking the expensive jigs used to transport aircraft components to Toulouse or kits tracking from logistics areas to Final Assembly areas, or tools tracking or even automated production progress tracking.

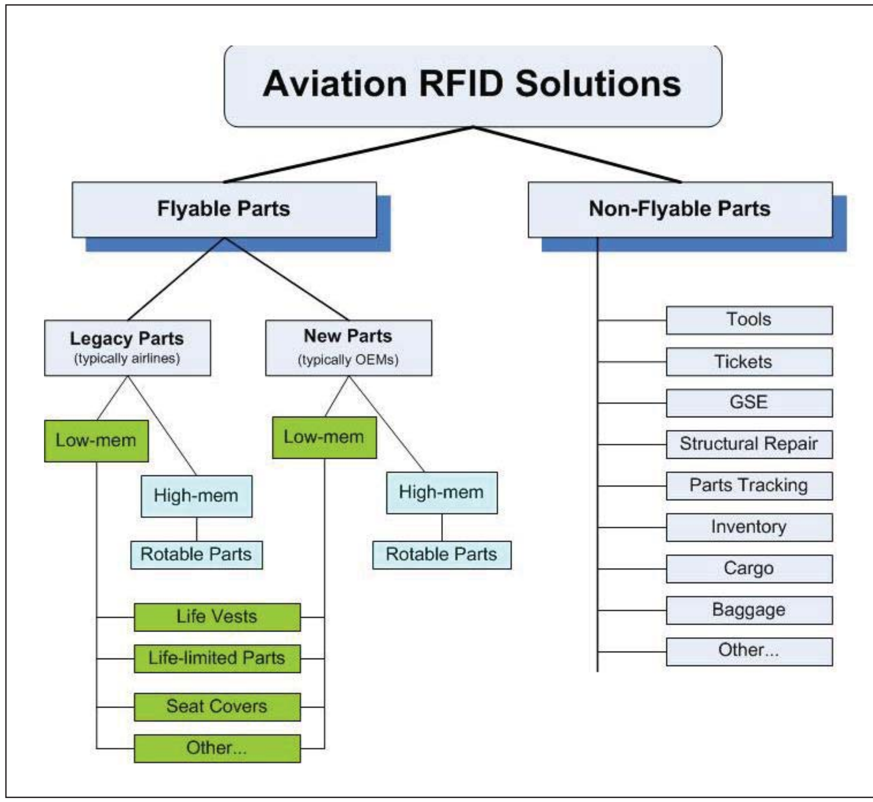
Airbus has seen clear ROI in their use of RFID technology. Lufthansa Technik was the first to develop a RFID Chemical Cabinet to ID and track life limited chemicals that worked very well. In both the OEM and airline examples, the business processes affected were internal and easily controllable, which was key to the initial success with this technology and probably most technologies that touch the real world.

The Category 1 use cases that touch flyable parts and/or airworthiness issues are where significant challenges currently lie, but also where significant ROIs will eventually be achieved. Boeing and Airbus started on these challenges in 2004 by working together and conducting a dozen Global Aviation RFID Forums around the world to explain to airlines and suppliers alike what could be achieved with RFID by working together. Boeing took the initial thrust to establish RFID on parts on 787 aircraft. Airbus has decided to equip new A350 aircraft and has signed an agreement with MAINtag to provide tags for a number of components. Major suppliers have also seen the benefits of obtaining data on parts returned for repair – data that is difficult to obtain currently. For several years, some airlines have been tagging life limited parts - oxygen generators, life vests, security seals that stay within their control and are seeing tremendous ROIs. Labor savings is in the range of 80 % for life limited part expiration date checks, presence checks (e.g., under seat life vests), and security checks.

In both the Category 1 and Category 2 areas there are further branches of opportunity to address your business problem using either low memory RFID tags or high memory RFID tags. The definitions of low/high memory and the differences and opportunities will be discussed more in a later section, but there is more than just one solution for an airline's particular business challenge. The picture below provides a high level glimpse of the opportunities ahead for the industry:

The basic value proposition for using RFID lies in two main areas for the industry:

- A unique identity for each tagged item, but with a common data format
- Better visibility of each item because the data collected via RFID can be done



More will be discussed on both these topics in later sections. Suffice it to say that the largest benefit in the near term will come to the industry from simply making items more visible to the average worker. Eventually, the industry will mature and get more sophisticated with this technology and we will see broader benefits addressing more business problems, but that should not be the near term expectation. The aviation industry operates globally, 24x7, in an open loop flow of people, parts, and processes (e.g., part loans, borrows, exchanges, parts pooling, power by the hour, etc.). It is too complex to imagine the many things that could be automated, but striving for simple visibility will provide the initial ROI benefits the industry needs to continue down this path.

Implicit in this approach is hidden the benefit of moving more of the part tracking and record keeping from the paper and pencil analog approach of last century, to a digital approach that is appropriate for where we are in the 21st century. Here again, simple visibility of the digital data provides huge benefits because digital data can be corrected, viewed, and utilized by many people simultaneously. For Best Commercial Practice systems, this means gathering the data from the source via digital formats (e.g., RFID, barcode or other Auto ID Technology), transferring the data in digital formats, and storing the data in digital formats so it can easily be retrieved again. These systems also reuse the same data in other systems and for other purposes all while avoiding a human typing a wrong number, which makes good data useless for the rest of its life. Sometimes bad data can be identified as invalid (i.e., a part number that cannot be recognized), but it is a much bigger problem to determine what the correct answer should have been (e.g., which Serial Number was installed on that aircraft?).

Another key aspect of making data visible, and therefore the parts, is providing more information to the front line people who need it. Historically, data has been a one way flow into the computer and it may eventually come out as a paper report to a manager. With the advent of digital data, laptop computers, tablets, handheld computers, WiFi, etc., there is a totally new paradigm about who needs the data when, that needs to be thought through again. Putting useful data on the RFID tag and giving the mechanic a handheld reader is part of this process to provide front line people with more information to do their job. Alternatively, a part can be identified with its unique ID via the handheld device that may have the required information preloaded or allow establishing the link with the airline IT system that keeps the records.

Value Proposition Highlights:

- *Two major use cases are using RFID tags on flyable parts and non flyable parts*
- *Initial ROI will come where there is a higher density of RFID tags to read in a particular environment or a high value object to be tracked in order to improve availability and usage rate*
- *Near term ROI can be achieved by tagging legacy parts in airline inventories, particularly where the item is crucial for safe operation (life vests), has on expiration date (O2 Generators), or requires frequent, labor intensive checking*
- *Longer term ROI will be achieved from high memory tags containing data that is shareable across the rotable supply chain*
- *Initial success will come with projects where one company controls most of the parameters and/or the parts lifecycle (closed loop applications)*
- *Simply making parts and data more visible to people who need this data can result in significant improvements in airline operations.*

2.1 Operations

In the airline operations arena there are many uses for RFID technology to play a major role in cost reduction and efficiency. Several of these use cases have had large industry pilot projects implemented to prove these benefits and IATA has had a major hand in spearheading these efforts. If interested, contact IATA for more information on the results of those studies. Shown is a list of a few of the RFID opportunities in the operational area:

- Baggage handling
- Catering
- Cargo handling
- Ground Service Equipment
- Passenger Ticketing
- Employee badges
- Security Process

2.2 Maintenance

The aviation maintenance arena also offers many opportunities to use RFID to improve efficiency and lower costs, and provides a number of use cases and value propositions that the industry will take advantage of. The primary area of focus is RFID Part Marking. This is the area that Airbus and Boeing have concentrated their efforts regarding their new fleets. This will return savings in the long term as the industry learns to share and use data embedded on the parts. There are also significant benefits that airlines can realize in the short term by marking their legacy parts already existing on their aircraft and in their stockrooms.

The value proposition for RFID part marking again lies in simple visibility and record keeping of each important part. The Maintenance & Engineering (M&E) functions rely on knowing exactly which item was installed at which location on which aircraft by exact serial number – not just a part number. RFID can quickly, easily, and correctly identify that serial number from a tagged part with no human mistakes to invalidate the data. Such data is currently stored in the airline's official System of Record, but with the advent of industry standards and high memory, RFID tags this data, which can also be stored on the part as a portable traceability record. The value then comes from sharing key data between all the parties interested in that part – the OEM, the installer, the remover, the repairer, the engineering department (reliability, root cause analysis), maybe the airframe maker, and certainly the next potential user of that part.

Many people across many companies can make better decisions if they have more data about what breaks, and how often these breaks, occur on their existing parts. Such information feeds directly into dispatch reliability numbers for aircraft and fleets that affect the airline operation, the fleet reliability numbers, and the OEM's reputation. More data, gathered correctly and easily, solves problems quickly to the benefit of all the players in the industry. Finally, certain aircraft lease requirements on parts and aircraft records can be easily and accurately monitored.

Operation & Maintenance Highlights:

- *Operational benefits often involve multiple parties which complicates the ROI. If a critical mass of tags across a defined environment can be achieved, these projects can save millions of dollars for companies involved. The reading–oftags density must be kept high to achieve benefits.*
- *A closed loop operational RFID project kept within one airport may work as a good pilot project for operational RFID*
- *Maintenance benefits within airlines have been in use for at least 2 years, checking for the presence and expiration dates on various emergency equipment types in the aircraft.*
- *Maintenance benefits come from visibility factors, starting with each part having a cradle to grave Unique ID so every company over decades of life is identifying the part by the same name, regardless of Part Number roll.*
- *Further maintenance benefits are accrued by providing front line people (e.g., mechanics) more and better data they need for their job. A computer report the next day or at the end of the month is virtually useless.*
- *There are at least 3 ways to consider benefits: 1) Process improvements; 2) Technical advantages of RFID technology (fast and errorfree data capture); 3) Compliance with regulatory needs and commercial entities.*

2.3 Costs and Benefits

When new aircraft are equipped in production with RFID tagged components, the initial cost that an airline may incur results mostly from the RFID reader, interface and software solutions that will be implemented to link it to the airline's IT systems. Therefore, in this case, it is highly expected that any RFID related cost will be absorbed under the initial investment covering the introduction of the new fleet.

A cost benefit – ROI analysis is important when new and aftermarket RFID solutions are sought. This would seem to be a key question to be answered, but it is first important to determine what problem you are trying to solve. Complete configuration control of an aircraft, an entire fleet, or would you just like to know that all your life vests are under their seats? Costs and benefits are always of high interest to the industry because our profit margins are so slim we can't afford to waste any effort chasing unlikely solutions. If the problem is global baggage tracking, the costs will be quite high and the benefits will be distributed across all the players. The good news is the aviation industry has learned from the logistics use case of the early adopters (Wal-Mart, P&G, Gillette, etc.) as well as selected use cases and has designed solutions that are far less expensive by avoiding the massive costs of a fixed readers and infrastructure cabling. Many, if not most, of aviation's RFID applications currently being deployed can use a handheld RFID reader so the computer/reader can be carried to where the job needs to be done rather than carrying the job to the computer. Airlines are using existing applications where life limited parts like oxygen generators or life vests are tagged on the aircraft and then tracked for presence and expiration date issues. The software, hardware, and tags can be obtained for tens of thousands of dollars, and the benefits can be in the hundreds of thousands of dollars per year, so the ROI is measured in months. The hardware and software are not the only items to consider, as there may also be expenses related to process reengineering, employee training, regulatory acceptance, system integration; analytics tool development, system design and installation, system maintenance, etc. This improvement in processes will be driven by the RFID implementation. Most likely, it will act as a catalyst in a similar way that e-ticketing acted for the seamless passenger travel.

An essential criterion for determining what the costs, benefits, and ROI of a system might be is to estimate:

1) Density of RFID tag reads

2) Price of the asset you want to follow

3) Criticality of its usage.

If tag density is low, e.g., tags are being read infrequently because few items are RFID-tagged, then the benefits will also be quite low. A better scenario may be where the RFID tag density is high and lots of information is being gathered on every read. An example would be if all the life limited parts in the aircraft cabin are RFID-tagged – hundreds of life vests, dozens of oxygen generators, dozens of other types of emergency equipment, and hundreds of seat covers. When the tag density is much higher, a single 60 second data read down the center aisle yields a wealth of information in one pass.

This information enables multiple management decisions about equipment status, may reduce the cost of keeping the airline in compliance, and provides current data to both maintenance planning and purchase planning people. Similarly with OEMs, if they are manufacturing six different part numbers on a given production line but only applying RFID tags to one of the part numbers, then the system utilization is low and the benefits are unlikely to appear any time soon. There needs to be enough RFID ‘critical mass’ to create a ‘benefits reaction’ within your business.

A second method of determining value is to determine which are first order benefits (e.g., direct), and which are second or third order benefits, which may be harder to obtain and/or prove to your accounting department. They typically ask very direct questions: “If this will reduce inventory, can we reduce the budget for that component next year?” Thinking through those answers will provide a realistic understanding of the actual benefits to be achieved. Based upon existing experience by airlines, if a task needs to be done on every airplane (e.g., check presence of life vests) and RFID can reduce the labor time significantly, the RFID benefits and ROI can be proven quite simply, especially if dealing with outsourced labor that is billing for that task.

The other side of that question is to know what your current costs really are surrounding a particular component or process. This determination may help sort out which business problem needs to be worked on first. “How much expense and waste was there replacing life limited components that still had significant life left in them?”

This question often goes unanalyzed because the costs of doing business the existing way are usually ‘lost in the overhead’ – they are taken for granted. This is a common (and very expensive) problem that continues decade after decade, which can now be solved with RFID solutions providing better data.

In summary, the costs and benefits question can only be answered within the perspective of a selected business problem and the current costs, both direct and indirect (e.g., delays caused by lack of parts, lack of information, etc.). The typical thought process of most companies is based on RFID solutions that are brought in house based on proven, first order benefits. Experienced companies see beyond the obvious and know that the collateral benefits - fast, easy, accurate and transparent data collection – provides immeasurable benefits, not the least of which is having decision making data where none existed before. These can easily exceed the initial, obvious benefits. Better information can replace inventory and avoid a lot of wasted labor expended checking things again – and RFID can provide better information to your people. Nevertheless, this will trigger a retrofit process that has to be defined.

Cost & Benefits Highlights:

- *There is no generic technology cost or benefit that can be determined apart from the business problem trying to be solved.*
- *Knowing what your costs are for different components and processes will help determine where your focus should be. Afterwards, the appropriate use of technology can be considered to enable a new solution.*
- *RFID benefits will be related to the density and frequency of RFID tags being read*
- *Using RFID handheld readers (vs. fixed RFID infrastructure) will deliver quicker benefits for most aviation business problems; costs will be significantly less*
- *First order benefits will bring the technology in house initially; other collateral benefits will soon be more significant to the business.*
- *RFID allows for automatic data collection without touching each item. The RF reads through boxes, seats, overhead bins, etc. saving significant checking labor.*

3. Technology Overview

There are many technologies that use “radio frequency” and this has led to a lot of confusion about what RFID (**R**adio **F**requency **I**Dentification) technology can and cannot do. GPS technology in your car utilizes radio frequency waves from satellites in space to locate your position. Cell phone towers miles away can pick up your signal, and even active RFID tags can be read from hundreds of feet away with special equipment. But all those solutions use different radio frequencies and different amounts of power to accomplish their task and they do not interoperate with each other. The technology discussed in this paper uses passive UHF RFID tags where there is no onboard power source, and because of that the tags could last indefinitely. The other RF technologies that may be useful in your operations (active RFID tags, BAP tags, Real Time Location Systems (RTLS)) are beyond the scope of this paper, but they are worth investigating to solve specific problems.

Passive RFID technology is one of many AutoID (Automatic Identification) technologies along with 1D and 2D (dimensional) bar codes, voice recognition, biometrics, magnetic stripe, smart card and others. The primary advantage of using any AutoID technology is to improve the speed and accuracy of data collection. For bar code technology, the speed increase for 1D barcodes is about a factor of 10X over a person typing, but the accuracy increase is 100,000X more accurate. A proper perspective would be to ask ‘How much does a mistake cost your business, and could AutoID technology save many of those mistakes?”. RFID technology is even faster and more accurate than bar code technology and has the added advantage of reading and writing, plus being able to see hundreds of tags per second.

3.1 Technology Description

Bar code technology in industrial environments has been around for 50 years and has proven itself to be inexpensive in general. However, there are examples, such as applying a bar code on a metal plate, that are much more expensive than any RFID tag you’ve seen. The 1D bar codes (e.g., ABC123) operate like an optical Morse Code of ONs and OFFs when the light is reflected back to the reader. There are numerous 1D bar code symbolizes and, for general usage, the aviation industry is focusing in on Code 128 for its higher data density and builtin error checking. 2D barcodes (e.g.,) are similar but an imager (camera) is needed to take a picture of the ON and OFF dots and then decode what the dots means. 2D has a number of advantages, including 5-10X higher data density for the same space requirements, robust error correction if part of the symbol is damaged, and the ability to print low contrast symbols using Direct Part Marking on metal parts. 2D DataMatix is the preferred symbology in the aviation world for part marking applications.

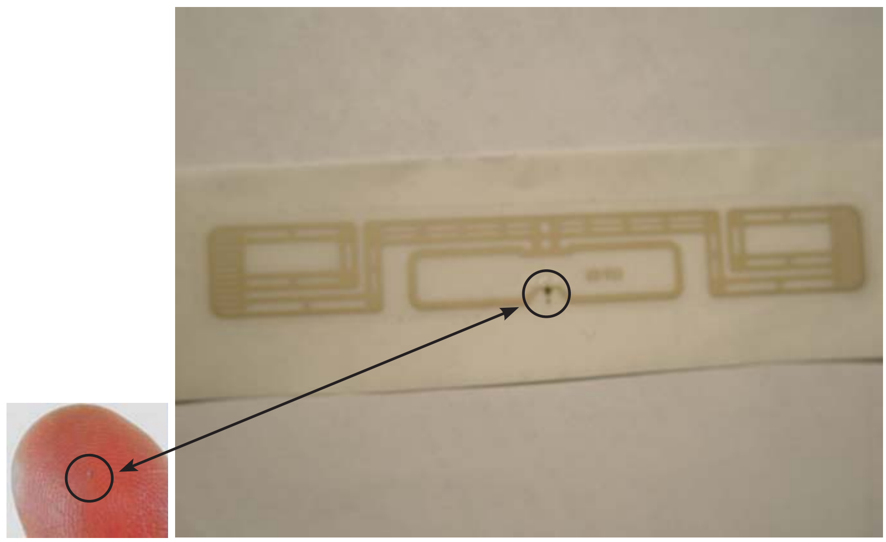
Both 1D and 2D bar codes suffer from the same limitations, however, of 'read only' technology as no new data can be added to the existing barcode, and all bar code technology requires a visual line-of-sight in order to work. While RFID technology moves beyond those limitations, it can often be used to great advantage in conjunction with bar code technology to get around RFID's limitations.

RFID technology is the latest AutoID technology to come into broad acceptance across multiple industries, including aviation. It brings wonderful benefits beyond bar code technology, plus a new set of challenges to 'focus' the benefits appropriately. Where bar codes need light to transmit and receive data, RFID uses radio waves to transfer data to/from the RFID tag. The magic specific function of these radio waves is that they go through, around, in, under, and behind objects to reach a tag that you may not be able to see. The technology can also see hundreds of tags per second, so it appears to gather data instantaneously. That enables an entirely new set of opportunities for the airline. Examples are, in quickly determining if every airplane seat has its life vest hidden underneath, or if security has been breached on any life vest boxes. Other examples include, reading if any oxygen generator that is still closed up in the Passenger Service Unit will expire in the next month, or if all the medical kits are still sealed. This functionality is currently being used in production by a major US airline by taking a 30 second walk down the aisle with a handheld scanner. A European airline has been using it for 5 years.

The handheld portable RFID readers usually come with the capability to read bar codes as well as RFID tags. This is extremely useful to use both technologies in conjunction with each other. It is recommended that the bar code scanner be capable of reading 2D bar codes – those will also read the 1D but not vice versa. The reason why the bar code capability is so useful is that the initialization process of applying a tag to a part requires some singulation, a direct way to associate an item to that particular RFID tag (an RFID reader could be pulling data from any tag in the vicinity). Using an appropriate bar code on the RFID tag makes that a simple thing to do.

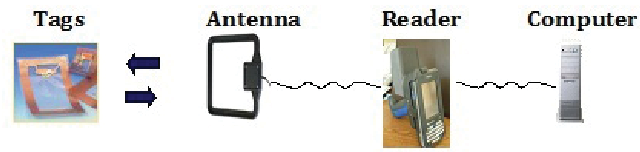
However, specific reading of the all RFID tags within its range can also be a curse in that the reader may also be reading tags that were not supposed to be read, such as tags on the other side of the wall, or tags 20 feet away that were not a part of the task to be accomplished. So, this technology brings the challenges of data discrimination, of knowing what you want to read and ignoring the items you don't want to read. There are functions (e.g., EPC filter bits) builtin to the technology to provide some help with that aspect, but it also requires a tighter business process surrounding the task to be accomplished. Here is where the combined use of bar code and RFID technology can work together to avoid the limitations of both and deliver a greater benefit.

The RFID technology itself is quite impressive. Shown below is an example of an RFID chip. The larger RFID tags include this little chip plus a (relatively) large antenna and the appropriate packaging for the intended purpose and environment of the tag.



But inside the tag, this chip - the size of a speck of pepper - does amazing functions: converts the radio wave into DC power, converts a radio-frequency (RF) signal to useful information, stores data in four separate memory banks, handles sophisticated communications with the reader, checks error codes on every communication, decodes passwords, and other specialized functions. If the reader sends out a signal strength of 1X, each tag can only ‘harvest’ a little bit of that energy and then answers back to the reader at 10-6 (one millionth) of that power – and the reader has to listen for those tiny signals from hundreds of tags! Each tag ‘listens before it talks’ so as to avoid talking when other tags are answering the reader. If two tags do start talking at the same time, they both back off a random amount of time and then try to answer again. All this happens in milliseconds, allowing the reader to send out an initial query and then read responses from hundreds of tags in a single second as well as handle all the error corrections that may be needed from each communication.

A complete RFID system requires several components: an RFID tag (chip + tag antenna), an antenna to send out and listen for radio signals, a reader connected to the antenna to decode the digital signals, and a computer system to control the process and store/use the data from the tag.



Major Components of any RFID System

Such a system can be as simple as a handheld RFID reader/computer such as shown below,

or as complex as an RFID portal with multiple antennas in a surrounding array, sorting out duplicate reads and antenna interference, while trying to read every tag that goes by at every dock door of a distribution warehouse.

As mentioned previously, selecting the right business problem to solve has a huge effect on the costs and the benefits returned.

Other AutoID technologies – Mag Stripe, Smart Cards, Biometrics, CMB's

Other AutoID technologies also fit into the aircraft maintenance. These technologies are magnetic stripe readers, 'smart cards' using NFC (Near Field Communications), fingerprint and iris scanners, and the like. Most of these technologies are used in personal identity and security areas of the operation. Employee cards have long had bar codes and/or mag stripe technologies on them to automate the ID process. Those same cards are now being replaced with smart cards that carry an embedded NFC chip in the card. The NFC chip is harder to counterfeit, is quicker responding for access control, and allows reading from and writing to the chip so it is much smarter. Much of the technology that the aviation industry uses is still dependent on logons and passwords. That approach is surprisingly labor intensive as systems require password changes every few months and people lose or forget their password on a regular basis. This process delays the original transaction to be accomplished and maybe that transaction never gets logged at all. Although LDAP technology (Lightweight Directory Access Protocol) has been available for 20 years to enable a Single Signon capability, using it effectively means modifying every legacy system that requires a password. A better resolution for this personal identification problem will likely be the use of biometric scanners for fingerprints or irises. Many business laptops already come with fingerprint scanners built in, and with the vast improvements in camera technology now found in cell phones, iris scans or even facial recognition will be a better method of establishing your personal identity.

3.2 Technology Readiness

Technology readiness can be discussed at several levels – is the hardware technology ready to work in the industrial world? Are the standards ready for implementation across the global world we work in? Are the aviation applications ready? And is your company ready for this technology? Let’s discuss each one briefly, and several are discussed again in later sections of this paper.

RFID technology from the hardware perspective is certainly ready for work in our aviation world. Four years ago this wasn’t true, but it is true in 2013. Likewise, the technology and business data standards are all in place. The GS1/EPC and ISO standards are well defined and have been adopted in all developed countries of the world. There are different frequencies allowed in the US, Europe, and Asia, but this is not a problem as the tags can be read across all those frequencies. The data format standard for the tag header for use in aerospace and defense sectors was officially approved by EPC in the Tag Data Standard 1.6, September 2011. The ATA Spec 2000 Chapter 9, describing the structure and content of user memory was published in 2009 and a major revision is going to be released imminently.

Are aviation RFID applications ready? This is a bit more difficult to answer. There are COTS (“Commercial off the Shelf”) products available that solve some business problems from end-to-end, from tag to reader to user interface to business data for management decisions. These solutions particularly reside in the less expensive, low memory RFID tag areas being used by a range of airlines. Delta Air Lines in cooperation with TechSolutions and Aerospace Software Developments has been tagging oxygen generators for 2 ½ years and is expanding into life vests as well as two dozen other pieces of emergency equipment on their 777 fleet. Alaska Airlines has been working with Boeing and Futjitsu on equipping life vests and other components with RFID tags. Also Etihad, Air France, Austrian Airlines, Turkish Airlines, Singapore Airlines, Lufthansa Airlines are implementing RFID projects. Other airlines and suppliers have developed end to-end solutions, but only for their internal needs and are not commercially available. There are also applications (particularly in the high memory tag area) that are a piece of the whole solution, but until they are integrated with your business processes they are really just a tool to accomplish some limited tasks of reading/writing to the tag and could not be considered a solution by themselves. Thus, the middleware integration between the reader and each company's business systems is something that needs to be customized for each system. Some ERP suppliers look into developing the RFID module integrated in their main IT product. However, currently they look into this as additional data port without profound understanding the process behind it. For proper integration, MRO IT providers should be closely introduced to ATA Spec 2000 and be able to analyze and offer users clear benefits.

What will it take for your company to be ready for RFID? That depends on your company. For the high memory business case, Airbus is making RFID the traceability tool for all its aircraft progressively (A350 is half way equipped, seats and lifevest just announced for A320/330/380 and more to come). Airbus is supporting airline specific requests at this stage (consulting mode). Boeing is offering retrofit solutions for specific scope or use cases.

For the lowmem business case, a dozen airlines are purchasing life vests, rafts, slides, oxygen generators and other items tagged with lowmem RFID tags supplied by several manufacturers. Some of these airlines are tagging their own components with RFID tags to gain the benefits sooner. These airlines also have solutions in place to make use of the RFID data they are gathering.

The hardest question to answer is does your company have the readiness to make use of RFID solutions? The answer for the technical side of hardware, software, and tags is clearly "Yes", but each company needs to start with the correct business problem to solve. The difficulty comes if the selected business problem chosen also requires significant changes in your business process – that will be 10X bigger than any technology problem encountered. More will be discussed later, but problem selection is a key parameter for successful RFID implementations.

Technology Highlights:

- *Bar code and RFID are both AutoID (automatic identification) technologies*
- *Bar codes are generally less expensive than RFID systems but have limitations:*
    - *Line-of-sight required*
    - *Each item must be read individually*
    - *Cannot write more data to bar codes – read only*
- *Parts marking standards in aviation exist only for using GS1/EPC Class 1 Gen2 UHF RFID technology*
    - *This is the global, mainstream, RFID technology used around the world*
- *RFID uses radio frequency waves that go through and around objects to read*
- *RFID has many advantages:*
    - *Does not need line-of-sight*
    - *Can see hundreds of tags per second and return ID data*
    - *Can read from 3-6 meters away, depending on environment*
    - *Can read, write, and change data on tags*
- *RFID can be utilized counting items – need good business process; e.g. using a prepopulated list in specific cases*
- *Handheld, portable RFID readers are cost effective vs. fixed readers and infrastructure*
- *Several high memory RFID tools are available but a complete solution must be integrated with your business process*
- *Several low-mem RFID applications provide an end-to-end solution for airline decisions*
- *The RFID tools are all in place to use, but selecting the correct business problem to apply them to is crucial to success.*
- *Middleware, applications and project management can represent 80% of the cost of the project, when RFID and readers can represent 20% of the total cost.*

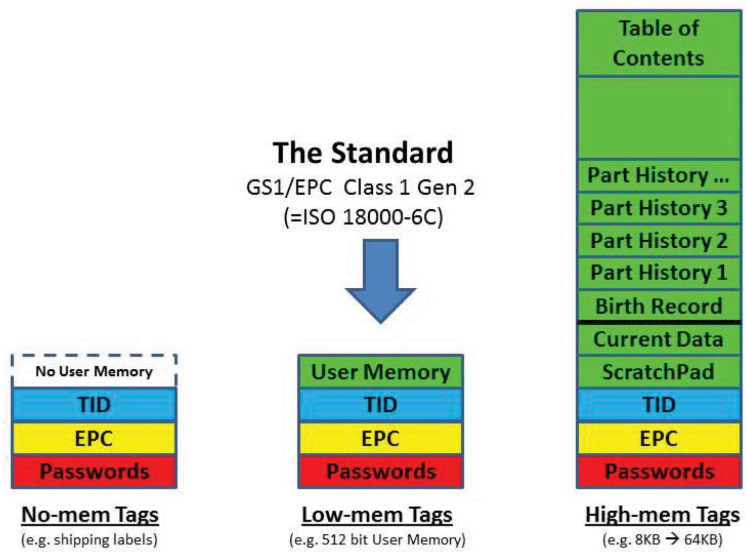
4. RFID Tag Specification

There are a number of RFID standards used for different purposes, but in the mid-1990s a number of industries came together to create an RFID standard that would be good and affordable enough to be used in the supply chain arena. Primary criteria for this new standard were: read distance, data transfer rate, and cost. This standard was dubbed the Electronic Product Code or EPC standard. This RFID standard was meant to supplement the existing UPC standard of bar codes on individual items. Initially, the EPC RFID standard would be applied to pallets and cartons, and eventually get down to tagging individual items. As further refinements were made to the standard, a revised version was released called EPC Class1Gen2 and that is the current standard aviation, military, retail, and most other industries are using. This standard covers the frequency ranges from 860 MHz to 960 MHz. This allows all countries around the world to find an unused band for their country to specify for their transmitting antennas without interference. The RFID tags are designed to respond to the whole frequency range so they are more universal. There will be more on this subject later in the report.

The good news is that aviation standards are right in the mainstream of the GS1/EPC standards used by all the retail giants (Wal-Mart, Metro, P&G, Coke, many others) around the world, as well as by the US DoD for shipping label standards. These are the market sectors that have driven the adoption of RFID as fast and as broad as it has come so far. Retail is a huge sector that drives standards, equipment suppliers, and tag manufacturers to respond to their needs. When aviation adopted the same standards, we got the benefit of standard hardware from multiple suppliers, standard tags, and lower prices. Proprietary solutions end up being very costly in the open, global marketplace we all have to work with these days. The aviation RFID taskforces have successfully avoided any proprietary tags or other hardware.

That said, the FMCG (fast moving consumer goods) world had different business drivers than aviation, primarily the goal of a USD 0.05 RFID tag because so many millions were going to be used as shipping labels on cardboard boxes for a week and then discarded. FMCG only needed to track pallets and cartons of relatively cheap items, but they had millions of them to track. Aviation, on the other hand, is more concerned with tracking much fewer, high value, long lasting parts. We needed to track each serial number to know where that item had been, how many flight hours it had, and when that item was last overhauled – a completely different business problem than the consumer goods world. Many of our very expensive rotable parts will last decades as they are continually repaired, upgraded, and put back into useful service. Aviation needed a tag that looked more like long term, permanent part marking than a 2 week, cheap, throw away tag.

The shipping label and part marking worlds settled on the same basic tag standard (called EPC Gen2), but aviation made full use of the Gen2 capabilities (User Memory) where shipping labels just used the minimum amount to keep the tag cost down. Below is shown a diagram of the three different categories of the Gen2 tag, including the ATA Spec 2000 high level formats for the user memory:



The diagrams above carry a lot of hidden, technical information, but most standard, Gen2, RFID readers on the market will be able to read a nomem, a lowmem, and a highmem tag just the same. The difference between the tags lies in the size of the EPC/UII (Unique Item Identifier) block and in the amount of User Memory present on the tag. This table compares the differences between the tag types:

Parameters	No-Mem	Low-Mem	High-Mem
Cost (highly quantity depend-ent)	<$0.20/tag	~$0.20 – 2.00/tag	~10– < $80/tag
Size of EPC	96 bits	<160 bits	<242 bits
EPC Data Format	Binary 1s & 0s	ASCII*	ASCII*
Size of User Memory	None	512 – 2kbits	8 KB – 64 KBytes
User Data	None	85 - 300 characters	10,000–85,000 char
Life of the Data (estimated)	2 weeks	10+ years	20+ years
Primary uses (typical)	Shipping labelS	Part Marking of Life-Limited Parts	Rotable Part Marking
*- ASCII - American Standard Code for Information Interchange			

In 2005 commercial aviation started developing their data structure on top of the standard EPC Gen2 tag design after observing the cost and difficulties other industries were having implementing the technology. With the industry's focus on permanent part marking, through the ATA e-Business Program aviation developed these features:

- Store key data on the part, as well as in the System of Record. For low-mem it will be just a minimum set of data. Highmem tags allow a full Birth Record, Current Data Record, a Scratchpad Record and multiple Part History Records to be located on the part like a portable database.
- Network access around the world is not ubiquitous to enable the lookup of binary data in a remote data base, so write all data on the tag in ASCII data (human readable) formats so they could be understood at point-of-use.
- The EPC/UII data is the globally unique identifier for that tag, and aviation uses ATA Spec 2000, a 22 year old standard to identify parts with a cradle-to-grave 'social security number' and write that data into the EPC/UII block. The RFID tag unique ID on the tag represents the actual data plate of the part it is attached to – no more meta data or lookup tables that caused technical and inter-business difficulties between companies.
- These decisions have allowed aviation to implement RFID for new business use cases, not envisioned in the FMCG companies.

RFID Tag Highlights:

- *RFID tags used in aviation all follow GS1/EPC (ISO 18000-63) global standards*
- *Tags come in two general sizes: Low memory (512 bits – 2kbits) and high memory (4 or 8 KB – 64 KB).*
- *Lowmem tags can cost from $0.20 to $2.00 depending on memory size and volume*
- *Highmem tags can cost from ~$10 to < $80 depending on memory size and volume*
- *Highmem tags are all metal mount tags, that will also work on non-metal items*
- *Lowmem tags generally are not metal mount, but can be made so*
- *ATA Spec 2000 Ch 9-5 defines data formats in both low and highmem tags; the CSDD specifies the definition and format of each piece of data, and Spec 2000 Appendix 11 describes the physical formats of the user memory.*
- *The EPC Tag Data Standard 1.6 specifies the Aerospace & Defense format of the header, which allows RFID tag header to use the actual part's identity without the need for lookup tables.*

4.1 Performance Requirements

All of the technical performance requirements are contained in the EPC Gen2 standard so that any reader or tag that is compliant will perform at an acceptable level. Technical performance standards have improved greatly in the past decade, and they will continue to improve as the hardware suppliers find better, faster, cheaper ways to make this wonderful technology work. Performance improvements have come in the areas of faster communications between the tag and the reader, better filtering when multiple readers are present, and just faster processors in the reader hardware. There are still improvements to be made, for sure, as some handheld computer readers were unable to read tags, beep for each read, and change the display at the same time, but the technology is more than adequate for today's business.

From a business perspective, performance requirements often means RFID tag read and/or write performance – what distance can the reader detect and read the tag? The SAE AS5678 standard has 3 categories for classifying RFID tag read performance when the tag is mounted on two different surfaces, metal and nonmetal:

Tag Performance Grade	Metal-mount (conductive surface)	Non-metal mount (non-conductive surface)
0.15 meter	A	D
1.50 meters	B	E
3.00 meters	C	F
Note: These are minimum distances, not maximums, which may be double this.		

Because the metal affects the sensitivity of the RFID tag antenna, they will not read from as far a distance as the same tag mounted on a non-metal surface. On metal, any tag will need a small amount of insulation material between the antenna and the metal surface to work at all. Tags will be designated as "metal mount" tags and the tag packaging includes that insulated, standoff space from the metal. Four meters is the furthest you can expect to read a tag on a metal part, and it will probably be less (depending more on the reader than on the tag!). As to the carbon fiber, which is also a conductive material (like aluminum), if the tag is inside/under the carbon fiber it can't be read.

Non metal mount passive RFID tags are expected to read at least 3 meters with claims up to 10 meters. There are many factors that will affect the read range (both shorter and longer) in the real world, so the technical folks have developed standardized tests in an anechoic (radio frequency echofree) chamber. Those give standardized results for comparative purposes as specified by AS5678, but it is the real world tests that are of more interest. Radio waves are both reflected and absorbed by different materials so it is very difficult to determine ahead of time where they will bounce to and where they won't. For applications inside an airplane, it is fortunate that the waves are reflected again and again so there is a greater chance enough power will be received by a tag to respond from quite a distance. Inexpensive, lowmem RFID tags regularly read 6m in these environments.

Another parameter that affects the read performance of any tag is how efficient the particular RFID chip is designed to be. Also related is the amount of user memory an RFID tag has – the more memory the more power it takes to energize that memory and the less power is left over to send back the desired data. Calculating all that is left to the academics, but you can do a practical, effective comparison with a handheld reader in your particular environment. While doing such a test, note that the orientation of the tag and the reader antenna have a significant affect. If the tag is turned 90o to the antenna orientation it can reduce the read range by 50% or more! Lots of reflections will minimize this effect, but it also explains why some tags may not get enough power to respond to the reader. Some readers are also available that have an omni directional antennas that send waves out in multiple orientations. These provide more flexibility to read different tag orientations, but they also do not read as long a distance – always trade-offs! Likewise, some tags are available that offer omnidirectional antennas or linear antennas that read well 'headon' as well as from the edge of the tag.

Regarding write performance, for both metal and nonmetal mount tags the write distance is approximately ½ the read distance for the typically EEPROM tags. The RFID tag needs more power to write data into its memory so the power source (reader antenna) needs to be much closer to provide more energy.

The Global Interoperability section below will also discuss the effect of regional power limitations and frequency ranges on tag performance.

With all the seeming limitations presented above, the technology still does a great job, but it is good to understand what the technology does, and does not, do. Like automobile gas mileage or any system in a complex environment, "your results may vary", so an actual test in your environment will yield more performance information than any analysis accomplished from reading technical specs.

The challenges for aviation RFID won't be in the performance arena, per se, but in the area of business process redefinition, now that this technological tool is available. The technology can read hundreds of tags per second, so the problem becomes finding the particular item, or exception, the mechanic is looking for out of all the incoming data. This is where more of the effort needs to be focused.

Performance Highlights:

- *SAE AS5678 is the standard that defines how RFID tags in aviation are to perform*
- *Nonmetal mount tags may read 2x – 3x further than metal mount tags*
- *Low mem tags will read further than high mem tags*
- *Most RFID tags have a linear design and are sensitive to reader antenna orientation*
    - *If the linear tag is 90o from the reader antenna, expect smaller read distance*
    - *This rule can be mitigated by special tags or lots of wave reflections*
- *Readers will have either of two kinds of antennas:*
    - *Omnidirectional antennas are less sensitive to tag orientation but send less power in any one direction, therefore shorter read range*
    - *Linear antennas send more power in one direction, reading further, but are sensitive to tag orientation*
- *Tags with shorter antennas will have shorter read distances (less power intake)*
- *Tag with more User Memory will need more power to just ‘turn on’, providing less power to respond back – thus shorter read ranges*
- *For all tags, write distances will be approximately ½ the read distance*

4.2 Security Requirements

Since 2004, industry taskforces have been considering the security aspects of having data stored on tags and what the appropriate amount of security is. Password protection is available on every Gen2 tag, but in the open, global marketplace of aviation industry there is no practical way to manage passwords across hundreds of companies around the world. Parts go on airplanes in one country/company, come off in another country/company, and get routed to a third country/company to be repaired. Controlling passwords by all those parties is currently impossible and would stop the use of RFID part marking across the industry. Individual companies could control their own passwords, but nobody else could use the data, negating the very purpose the industry is aiming for.

The digital security schemes that have been considered take up too much space in the very limited memory of the RFID tag – and that hasn’t been a workable solution for the industry yet.

Today, what is workable for our business case is an EPC Gen2, read-only, locking mechanism called Permalock. This allows any company to write the necessary data to the tag and Permalock it, so it can never be changed. This met the goals of the industry to allow every company to read the Birth Record and Part History on the tag, but no company can change a previously written record, therefore protecting that data.

Security Highlights:

- *The data on the tag is meant to be shared across this open, global industry.*
- *The data on the tags is designed to be read by any party in possession of the part. There are no passwords or security surrounding the reading of data.*
- *Important data (EPC Block containing unique ID, Birth Record, Part History Records) can be written by the appropriate party and the data is then permanently locked (Permalocked) so it cannot be changed by another party.*

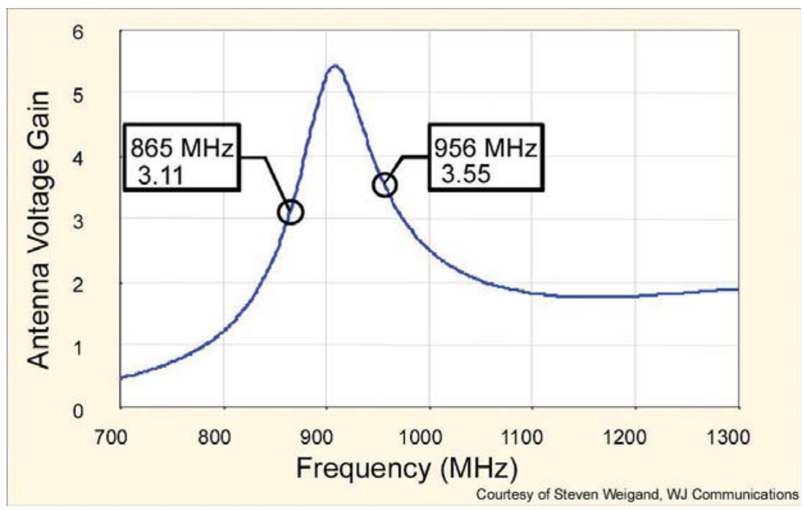
4.3 Global Interoperability

Driven by common business goals of an outsourced, open sourced, global supply chain, the technology industry worked hard to develop a standard that will work around the world. Because RFID technology needs to work in the same frequency spectrum used by cell phones, cordless phones, microwave ovens, police radios and dozens of other kinds of equipment, the global interoperability problem is akin to wanting a radio station with the same frequency in every country of the world, even if that frequency was already in use. Using the exact same frequency in every country of the world was impossible to achieve, but they designed the reader and tag technology to be flexible enough to work across three separate frequency bands that were adequate for global commonality:

Region*	Frequency Band	Power Rating
Europe & Africa	865-868 MHz	3.5W EIRP
US, North America	902-928 MHz with 915Mhz being the center frequency	4W EIRP
China	920.5-924.5 MHz	2W EIRP
Japan	916.7 - 923.5 MHz	4 W EIRP
*The full listing for every country: http://www.gs1.org/docs/epcglobal/UHF_Regulations.pdf		

These frequencies and power ratings are what the readers are limited to, because they cannot be allowed to conflict with other devices in those regions that use similar or adjacent bands. The tags, on the other hand, are the items that move from one region of the world to another and must be read everywhere. Some tags are designed to perform better at certain frequencies, but most tags today are designed with a broadband response so they can perform fairly well across all the frequency ranges around the world.

The graph below indicates the loss of power from the peak possible when a reader is transmitting at a different frequency than the tag is tuned for. The technology still works just fine (quickly, accurately, with standard equipment for that region) but the reader may not get the maximum read distances seen as when everything is exactly tuned the same.



The good news is that various countries and their approved RFID frequencies are coming more into alignment, as it has taken time to sort through the costs and benefits by each country. As of July 25, 2012, Japan has given approval to use the 916.8 to 923.4 MHz range, which is much more aligned with peak range shown above, so progress is being made in the right direction to get maximum use from these UHF RFID systems.

Interoperability Highlights:

- *The technology is flexible enough to work across a range of frequencies, from 856-868 MHz in Europe, to 902-928 MHz in the US and in Asian countries.*
- *More countries are trying to carve out a frequency spectrum closer to 915 MHz in order to gain making benefit (read range) from RFID.*
- *Tags are generally designed for the 915 MHZ but work in the 860 - 960 range with only a small drop off in power and therefore read range*

5. Software Requirements

Software requirements to make use of RFID technology are driven from two different levels, technical and business data. Almost all of the technical software requirements come built-in with the readers and tags that are tested for being EPC Gen2 compliant. In addition, the EPC organization has granted the aerospace and defense industries their own header number ("A&D Indicator" or ADI) to better distinguish aerospace items from all the consumer items that are being tagged. The ADI indicates to the software that a particular data format follows. As discussed above, the A&D format also changed the previous RFID paradigm of unique but random binary numbers on the tag, to unique RFID numbers that are identical to the company and Serial Number of the item to which the tag is attached. This unique ID of the part was established in aviation in 1990. The A&D format allows the industry to move closer to the permanent RFID tag being the actual data plate on the part, making it easier to get to a useful business solution.

Software requirements on the business data side are well developed with only relatively minor issues yet to be refined. The previous discussion on the RFID Tag Specification alluded to the User Memory section of the tag where business data resides. Aviation software would need to read the business data formats for both low memory (low mem) and high mem tags. The details of those requirements for each tag are too detailed to be included here, but they are all defined in ATA's Spec 2000 Chapter 9-5. Much more effort has been focused on the high mem, new part marking efforts due to the Airbus requirements for their suppliers, but there are a few companies that provide software for the near term ROI that comes with marking the millions of legacy parts airlines already have in their inventory.

Software Highlights:

- *All the really technical RFID software (RF communications, error checking, etc.) is taken care of automatically by the industry standards and the hardware companies that are certified by those GS1/EPC C1G2 and ISO 18000-63 standards.*
- *The business data standards are defined by ATA Spec 2000 Chapter 9-5*
- *High memory software tools are available from several companies, but then using that data in your business process is an individual company development effort.*
- *For low memory tags (life vests, O2 generators, security, etc.) several companies offer complete business solutions providing actionable data to the business for presence and expiration dates.*

6. Standards

In terms of standards, the first to be considered is the GS1/EPC Class 1 Gen2 (=ISO 18000-63) technology standard that allows the RFID tags and the reader/writers to all talk to each other in the Ultra High Frequency (UHF) spectrum. A subset of the EPC standard is the section that defines the A&D header (Aerospace & Defense) format. Next is the business data standard that defines the required data and data formats, found in ATA Spec 2000 Chapter 9-5. An example of the kind of business data found in each tag is included here:

Low mem tags - Manufacturer's CAGE Code, Part Number, Serial Number, Date of Manufacturer are all expected data, as well as such other data that is appropriate and will fit into memory, e.g., expiration date, location on aircraft, maintenance station code, current part number, current mod level, etc. These tags will have multiple uses across different areas of the business – life limited part tracking on plane and warehouse, tool tracking, inventory tracking, GSE, seat covers, cargo, etc.

Dual Record Tags – these tags will have a memory are that can be permanently locked for critical Birth Record data as well as another part of memory available for lifecycle data that enables read/write functionality.

High mem tags – these are more complex data structures that yield significant business data for the part they are attached to. Such data was only available previously if a company had data sharing agreements with the OEM, MROs, and repair agencies that might have handled the part. The software must handle a wide range of data in each of the following record types:

- Birth Record Data (Record Type 1) – A number of separate data elements found in the Birth Record as programmed and locked by the OEM at 'birth', including items such weight, hazmat codes, customs commodity codes, , air worthiness certificate number, etc.
- Current Data Record (Record Type 2) – Over time, these expensive, rotable airplane parts get modified and upgraded, changing the Part Number, mod level status, and other data that is crucial for the aircraft maintainer to know quickly, so this Current Data Record holds a few pieces of key data and is quickly accessible. If a Part History action rolls the part number, then the software would need to automatically update the Current Data Record as well.
- Scratchpad Data Record (Record Type 3) – This last record type is similar to an electronic sticky note, allowing a mechanic to add whatever information seems pertinent, e.g., "item was hot when removed from aircraft" which could be helpful for a bench mechanic to know 3 days later to perform a proper diagnostic.

- Part History Records (Record Type 4) – Multiple such records are allowed on the RFID tag and show who did what to a part and when. This provides information of when the part was installed, removed, from which aircraft, by which company; when/where/who repaired/overhauled the part, if it was bought/sold from another company and if it was exchanged with another part. The expectation is that part traceability will be found on the part to every player's advantage across the industry.

Part marking benefits are built on a ATA Spec 2000 industry standard for uniquely identifying parts that have been adopted by Airbus, Boeing, and many major aviation suppliers. This approach gives every serialized part a globally unique 'social security number' that will uniquely identify that part from cradle to grave. More information about this industry standard is in the ATA Spec 2000 Chapter 9 that included bar code, RFID, and Traceability data standards in one place. As of 2004, the US Department of Defense has also adopted this approach with their Unique ID (UID) Policy for marking every part that costs over $5000.

Continuing with the business data aspect, several companies provide COTS software products than can be purchased for low mem and/or high-mem tags. Many more OEMs, particularly suppliers for Airbus' A350 parts, have developed their own internal software, or have purchased one of the high mem COTS software tools and are integrating it into their production processes to create a complete business solution. It is really the airlines that have the greater challenge in this software area in that reading/writing data onto an RFID-tagged part is a significant change in their current business process. It is the airlines that have the key operational data that will be most helpful to the whole industry – e.g., data when parts were installed and removed from the aircraft, what aircraft were they installed on, etc.

For their A350 RFID part marking requirement, Airbus, as well as Lufthansa Technic Logistic has created an Interoperability Test Lab to insure that the data on the tags is all compatible with the industry standard. This has been a QA check for the entire industry to know that the data will all interoperate before it gets into a production status. GS1/EPC also certifies that software meets their standards and there is only one company in the aviation field that has passed that certification level.

For use of RFID tags and readers on the aircraft, there are additional guidelines related to the robustness and reliability of the RFID tags themselves found in SAE AS5678. This standard discusses the safety, testing, and performance expected from the RFID tags to insure they meet the industry's flammability specifications and they retain their data after a battery of "shake'n'bake tests" (a subset of the full RTCA DO-160G standard). The ARINC 673 Report adds RFID tag attachment standards so tags do not fall off and become FOD, as well as other useful information.

The FAA also has guidance on the use of RFID tags on the aircraft, found in Aircraft Circular AC 20-162. As shown in the guidance of FAA AC20-162, the use of passive RFID tags is considered a “Minor” change. Nevertheless, the guidance still requires the due diligence to show compliance to the airworthiness requirements of FAA 14 CFR Parts 21, 25 and 121.

This includes an engineering evaluation and safety assessment to show compliance to 14 CFR Part 25.1301 and 25.1309 to show that demonstrate that the normal operation, failures, or malfunctions will not have greater adverse impact on the aircraft, especially the mounting integrity. It requires the use of RFID tags that meets the requirements of SAE AS5678.

When using the RFID tag for limited life part or component part marking, it must comply with the requirements of FAA 14 CFR Parts 45.14 and 45.16.

If the RFID tags are used as an alternate means of compliance to collect and maintain data for maintenance tasks and inspections, the operator or modifier must submit a plan to the applicable civil aviation authority to show how the technology will be integrated to their regulatory approved aircraft maintenance program, including how the data will be used to show compliance to the requirements of the OEM approved Instructions for Continued Airworthiness (ICA). This plan must address how the data contained in the RFID tag is secured and not prone to tampering, and how the data is transferred to the maintenance computing backend system for configuration control of the aircraft.

To date, EASA has followed the FAA’s lead in this RFID area and has not provided differing regulations or guidelines to follow. For other foreign civil aviation authority approvals, the operator may submit an incorporation and integration plan for airborne use approval of RFID technology that is consistent with the intent and guidance of FAA AC20-162.

7. RFID as an Alternative Means of Compliance

RFID technology is a good enabler of inventory management and component visibility, but the ultimate advantage is non-line-of-sight configuration management for the purpose of compliance with instructions for continued airworthiness.

As stated above, FAA AC20-162 is a document which offers guidance to the end user for the installation of RFID systems on aircraft and for the use of that RFID data as an ancillary (non-authoritative) source of information for the purpose of inventory management.

Another significant value comes when the RFID system can be the “authoritative” source of data for the accomplishment of specific aircraft inspections and configuration management.

In April, 2012, the FAA Avionics Branch AFS 360 accepted Boeing’s comprehensive RFID-based maintenance program implementation package which when integrated with an airline’s current maintenance program allows the operator to use RFID as an alternative means of compliance with instructions for continued airworthiness.

These are some of the elements of the framework of the Boeing RFID-based maintenance program which may be considered a simple baseline to follow:

- Maintenance process engineering and configuration management requirements
- Maintenance document management system requirements
- Task card authoring / re-authoring requirements
- Maintenance program integration requirements
- Maintenance program bridging requirements
- Aircraft system installation methods, instructions and quality management requirements
- Hardware qualification, testing and reliability requirements
- Airline general procedures manual (GPM) interface requirements
- User training and qualifications
- Data integration, security, synchronization and management requirements
- Continuing system quality oversight and regulatory surveillance
- Hardware maintenance program requirements
- Software configuration management requirements

- Supply chain management requirements
- Continuing compliance with industry standards
- Business continuity / system failure recovery requirements
- Periodic system performance check requirements

There is interest in what the military is doing with RFID as that is also a very large market sector to contend with. The military's RFID policy is very similar to the retail shipping label business case. The US DoD is requiring that shipments to certain distribution centers contain RFID shipping labels. They are using a phased approach over a number of years to extend this policy to more commodities and more distribution centers. More information can be obtained at:

http://www.acq.osd.mil/log/rfid/index.htm

The DoD is also using radio frequency technology on their large shipping containers that go overseas. This is actually a proprietary system using very large, expensive RF transmitters attached to the metal shipping containers, and is closer to a GPS system than traditional RFID systems.

Standards Highlights:

- *Technology for readers and tag governed by GS1/EPC Class 1 Gen2 standard (= ISO 18000-63) operating in the 860-960 MHz frequency spectrum around the world.*
- *Aviation data standards based on ATA Spec 2000 Chapter 9-5*
- *Aviation only using tags that have user memory.*
    - *Lowmem tags are in the range of 512 bits to 2 kbits (85 to 340 characters) and a simple data structure; can be metal mount or not*
    - *Highmem tags are in the range of 8KB to 64KB (10,000 to 80,000 characters) with a complex data structure; all are metal mount*

- *Birth Record (locked) – key data elements at birth of part*
- *Part History Record (locked) – important events in the life of a part, e.g., installed, removed, repaired, overhauled, inspected, etc.*
- *Current Data Record – key data (e.g., current part number, mod level) stored together for quick access and keyed off Part History actions*
- *Scratchpad Record – an electronic sticky note for any free form comments*
    - *SAE AS5678 is the environmental standard that aircraft-mounted tags have to meet; ground-based tags not required to meet.*
    - *ARINC Report 673 – provide general implementation guidelines*
    - *FAA AC 20-162 approves the use of passive RFID tags on the aircraft*
- *They have no impact on airworthiness*
- *Tags applied to existing certified parts do not need to be recertified and do not require a part number roll.*
    - *The ‘standards’ listed above are guidance, not regulation, and companies with FAA Part 121 or 145 authority can choose alternate methods*
    - *EASA generally follows FAA recommendations and has no specific regulation*
    - *The military community is requiring low-end RFID tags to some distribution centers. They also use active RFID on their sea-going metal shipping containers. They are not currently considering RFID part marking.*

8. Training Requirements

There are two primary areas where training will be valuable – practical experience with RFID technology and training in the industry standard business data (Spec 2000).

The practical experience is best and most economically gained via the use of a handheld RFID reader, various sample tags, and appropriate software. The handheld computer is portable and can easily be taken into different environments to better understand how RFID works in those environments. You can easily isolate the tag you want to read as well as take the reader/computer to where the job is and not vice versa, e.g., airplane, cargo bay, warehouse, toolroom, receiving dock, etc. The sample tags allow you to try tags on paper documents, cardboard, plastic, wooden pallets, and metal items to see if and how they perform. You will easily be able to determine read distances, tag and reader orientation issues, and really get a feel for how the technology does and doesn't work in your environment. This kind of training is far more valuable than all the book learning you can absorb. Once you have questions from your practical testing, specific questions can be researched and/or answered by consultants or technology providers.

The second area of training is to understand the advantages of Spec 2000 business data defined by this aviation industry standard. Many problems in our own organizations occur because we incorrectly believe that our business needs are 'special' and not like anyone else's'. Decades of research have shown that only the details are 'special' and that 85-90% of our processes are fairly common and generic (i.e., "standard"), even if we call them by different names. Add to that the outsourced and interconnected supply chains of today's world and the need for a common set of core data becomes obvious. That is where ATA Spec 2000 data standards come into play. The industry works off some core data like Part Number, Serial Number, and Date of Manufacturer, but even the most important data of Part Number is easily confused across the industry as it often is not clear whether it is the OEM's Part Number, the manufacturer's Part Number, or the airline's internal Part Number that they create for interchangeability reasons. ATA Spec 2000 has a complete Common Support Data Dictionary where thousands of pieces of data are already defined. Each piece of data is self defined by the Text Element Identifier (TEI) so there is no confusion as to whose Part Number is being referenced across the supply chain. Spec 2000 also defines how a cradle-to-grave 'social security number' is assigned a new part or a legacy part (Chapter 9-4), and how this unique identity can then be used for traceability (Chapter 9-6) across the supply chain and over decades of time and multiple part upgrades that change the Part Number. Aviation RFID is based on the Spec 2000 data standard and any other approach is proprietary and will not "play well with others", thus increasing your cost of doing business.

Training Highlights:

- *Recommend rereading this IATA white paper, noting any questions*
- *Recommend obtaining a handheld RFID reader, software, and sample tags to begin experimenting how and where the technology does/doesn't work in your own environment.*
- *Understanding the benefits/constraints of Spec 2000 data and RFID processes found in Chapter 9-5 and the Common Support Data Dictionary (CSDD)*

9. Intellectual Property Protection

The RFID hardware and RFID tags are all standard items that can be obtained from a number of reputable manufacturers certified to meet the GS1/EPC Class 1 Gen2 standard. There are several other RFID software tools that are known. Each of those software tools interfaces to/from the data on the RFID tag, but they would be integrated into a larger system that the airline would develop to use the data in the business process.

From the technical side (GS1/EPC standards) as well as from the business side (Spec 2000 data standards), all participants have agreed to contribute non-proprietary knowledge to the standards setting efforts. The aviation industry has striven to avoid any proprietary hardware solution that is controlled by one company, and this has been achieved. A few companies in aviation have applied for patents related to RFID methods. The entire technology was developed in the open standards bodies, so that RFID tags could be applied to items and read by standard readers. The FAA, SAE, ARINC and other standards bodies expect RFID tags to be applied to various items, so the few patents that pertain to RFID tags applied to a certain aviation related items are easily shown to not be unique, but rather a joint collaboration across the entire industry for using RFID technology. This frees each company to move ahead confidently with their own industry standard RFID solutions to their business problem and gain the advantages promised by this technology.

Intellectual Property Highlights:

- *All standards are open to the aviation community with nothing significant being proprietary*
- *GS1/EPC Class 1 gen2 standards available online. Some hardware OEMs may have ‘extensions’ beyond the basic standard - use at your own risk.*
- *ATA Spec 2000 Chapter 9-5 and CSDD documents available with industry use described in the specification.*
- *Your business solution will be built with all these standard components available from various vendors.*

10. Future Developments

The ATA RFID Taskforce setting the standards on what kind of data goes on the tag continues to work and add clarifications and enhancements. A new release of the Chapter 9 specification will offer clarity and more flexibility for companies to include their own desired data in a structured format. The hope is this will bring a quicker ROI to the companies using the highmem RFID tags.

With the significant memory the highmem tags offer, there have been creative uses imagined, such as putting component installation video clips right on the part to instruct the mechanic. Although this is technically feasible, this is not yet a practical thing to do because of the communications speed between the tag and the reader. There likely will be business process issues that the airline/regulatory agency may have some issue with "training" in this way The ATA RFID on Parts Taskforce is open to any and all ideas the industry may have for new uses for the RFID data. Contact admin@ataebiz.org for more information.

Broad usage is just beginning to be tapped for the lowmem tags that would include industry standard data. A list of some of the ideas follows:

1) Employee badges
2) Ground Service Equipment (GSE)
3) Cargo ULDs
4) Tools
5) Wheels
6) Placards
7) Seat Covers
8) Sensors
9) Structural Repair
10) Delivery Tracking, both internal and PO/Repair order shipments

Another possibility for the RFID tags is to include the electronic version of the 8130/Form1 data. There seems to be broad interest in this option and the Taskforce will need to discuss the various options more fully after the current version is released for publication.

11. Aircraft Environment Engineering Assessments

Employing an RFID system on an airplane requires significant pre-deployment preparation and consideration of many factors. As mentioned previously in this article, metal surfaces, orientation, tag design and other barriers can significantly impact system performance.

Before the RFID system is deployed, it must be designed to overcome the technical and mechanical constraints of each individual airplane platform. Be aware that even submodels of the same platform (i.e. B777-200 and B777-300) can present unique challenges.

As an example, interior applications related to the management of emergency equipment can be discussed. Life vest management is a common airplane cabin application of RFID. The goal of the Life vest management application is to provide a non-line-of-sight inspection method which can reduce inspection lead times by 80%.

Overall, there is no existing solution (from off-shelf product) which can be directly used.

On site test and product modification will be necessary due to the important impact of the environment on the RFID efficiency.

12. RFID tag lifecycle management

All RFID tags expire. From the moment the tag's integrated circuit (IC) is manufactured, the IC begins to degrade, especially once it's commissioned. Depending on the quality of the IC and its protection from exposure by the encapsulation (tag), some tags will last 10 to 20 years and others only a few years.

Based on the manufacturer's specification, it is necessary to keep track of every RFID tag's expiration date and plan its replacement as part of the current aircraft / component maintenance program. Otherwise, at the most critical moment, the tag will fail, and fail in such a way that the end user may not even be aware of it.

One very simple method of keeping track of tag expirations is to print / etch the date of data commissioning on the tag so it's visible to the end user. Another is to encode the expiration date in the tag data, however this provision does not exist under the current standards.

Low memory tags used in benign environments can be especially susceptible to early expiration because the encapsulation often offers very little protection from exposures to cabin thermal cycles. Ensure that the tag that you select for cabin management has been appropriately designed to maximize the lifecycle of the IC.

Used as alternative means of compliance and for maintenance inspection activities, RFID tags must satisfy the requirements of the Safety assessment pointed out in FAA AC 20-162 "Airworthiness approval and operational allowance of RFID systems" as follows.

"…8. Specific Requirements Table.

c. Configuration control. To ensure RFID device and system interoperability or compatibility between those components, it may be necessary to enter the RFID device(s) make, model, part number, and perhaps serial number into the product or equipment ICA or FAA accepted documentation. In addition, if there are particular details and requirements about how the device is mounted, located, oriented and used where configuration control are significant, ensure that you enter those details in the ICA or FAA accepted documentation.

j. ICA. If the RFID device has a service life limit, state it in the ICA. State if and when the RFID device requires battery replacement, recharging, or other periodic maintenance. State whether the RFID device, if malfunctioning, must be removed from the aircraft and replaced with one of the same type and configuration. Your responsible aircraft certification office (ACO) will use FAA Order 8110.54, Instructions for Continued Airworthiness Responsibilities, Requirements, and Contents, to give you further requirements or details for preparing ICA…"

RFID Tag Lifecycle Management Highlights:

- *All RFID tags have an expiration date*
- *Tags used in a benign environment are most susceptible*
- *Once used as alternative means of compliance, the RFID tag life limits should be stated and other safety assessment requirements satisfied in ICA documentation*

Appendices

These appendices provide a reference to various documents referred to in the paper. The first two references are free and available online. The Spec 2000 standard is freely available to ATA e-Business Program members online, and available for purchase by non-members the AS5678 standard is available for purchase at the link below:

Appendix 1. FAA Advisory Circular 20-162

www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/74349/

Appendix 2. GS1/EPCglobal Tag Data Standard (TDS)

http://www.gs1.org/gsmp/kc/epcglobal/tds/

Appendix 3. ATA e-Business Program

SPEC 2000 Chapter 9
http://www.ataebiz.org/specifications/

Common Support Data Dictionary
http://www.ataebiz.org/specifications/

Appendix 4. SAE AS 5678 Specification

http://standards.sae.org/as5678

Appendix 5. Boeing considerations on tag survivability in the Maintenance Environment

Appendix 5. Boeing considerations on RFID tag survivability in the Maintenance Environment

While SAE AS 5678 has outlined requirements for tag survivability in an operational environment, it does not account for the component maintenance and overhaul environment which is by far more intense than normal operating conditions.

Few suppliers offer harsh environment tags designed to withstand the extreme conditions of component maintenance and overhaul. It is recommended that all suppliers of RFID tags intended for use in harsh conditions do the following;

a. Conduct visibility testing to determine the effectiveness of various AIT device colors when attempting to locate the device on an aircraft component.

b. Ensure that the tags will withstand the effects of extreme vibration such as that caused by close proximity operation of various pneumatic and hand tools, including rivet guns or other reciprocating air tools.

c. Ensure that the tags will withstand exposure to various corrosion inhibitors applied directly on the various Auto-ID devices. Verify readability characteristics and define the point at which a device no longer functions due to the buildup of the inhibiting compounds in order to document operational parameters.

d. Determine the effects of various hydraulic fluids on the various device encapsulations and on device readability. Verify readability characteristics and define the point at which a device no longer functions due to the buildup of the various hydraulic fluids. Establish and document operational parameters.

e. Determine the effects of various aircraft finishes on the various AIT device encapsulations and device readability. Verify readability characteristics and define the point at which a device no longer functions due to the buildup of layers of paint. Establish and document operational parameters.

f. Determine the effects of electromagnetic dent removal in close proximity to the various AIT devices. Establish and document operational parameters.

g. Determine the effects of ultrasonic inspection in close proximity to the various AIT devices. Establish and document operational parameters.

h. Determine the effects of various cleaners and solvents on the various AIT encapsulations. Specifically determine the effects of Trichloroethylene, Methyl Propyl Ketone (MPK), Toluene, Acetone, and other highly volatile solvents. Establish and document operational parameters.

i. Determine the effects of various acids and chemical bases such as Alodine I through III, Potassium Hydroxide, and other surface etching and metal treatment fluids on the various AIT device encapsulations. Establish and document operational parameters.

j. Determine the effects of deicing chemicals such as glycol on the various AIT encapsulations. Establish and document operational parameters.

k. Determine the effects of AIT device direct exposure to radioactive isotope x-ray inspection. Determine the effects, if any, on the device integrated circuitry. Establish and document operational parameters.

l. Determine the performance characteristics of the various AIT devices in extremely warm operational conditions. Establish and document operational parameters.

m. Determine the performance characteristics of the various AIT devices in extremely cold operational conditions. Establish and document operational parameters

n. Determine the effects of local and wide area degaussing operations in close proximity to various AIT devices. Establish and document operational parameters.

o. Determine the various AIT-operational effects of scratches, nicks, chips, erosion and other forms of normal and extreme wear and damage to the device encapsulation. Determine a device’s tolerance to normal wear and point of failure due to excessive deterioration. Establish and document operational parameters.

p. Determine the amount of force and specific point at which a direct impact renders various AIT devices inoperable. Establish and document operational parameters.

q. Determine the effects of snow and ice build up on the performance of various AIT devices. Establish and document operational parameters.

r. Determine the effects of petroleum based fuel, biofuels, and various oils and grease on the performance of the various AIT devices. Determine the effects of the various petroleum based products on the AIT device encapsulations. Establish and document operational parameters.

s. Determine the various AIT device installation performances against high pressure cleaning devices. Establish and document operational parameters.

t. Determine the performance characteristics of the various AIT devices when being interrogated in close proximity to operating systems such as engines, APU, pumps and motors. Establish and document operational parameters.

u. Determine the effects of various forms of aggressive media (walnut, glass bead, aluminum oxide, etc) blasting on the various AIT device encapsulations. Establish and document operational parameters.

v. Determine the effects of lightning strike and static discharge in close proximity to the various AIT devices. Establish and document operational parameters.

w. Determine the ultimate durability of the various AIT reading devices by performing impact, vibration and other forms of extreme operational considerations. Establish and document operational parameters.

x. Determine the performance of AIT reading devices in various levels of illumination, including direct sunlight and total darkness. Establish and document operational parameters.

y. Determine the various AIT reader resistance to various chemicals typically encountered in aircraft operations. Establish and document operational parameters.

z. Determine the various AIT reader performances in extreme heat and cold environments. Establish and document operational parameters.

aa. Determine the effects of various forms of intense noise such as engine, APU and other aircraft systems on the performance of the AIT reading devices. Establish and document operational parameters.

bb. Determine the effects of EMI produced by engine / APU generators and other power generation components. Establish and document operational parameters.

Tag Survivability Highlights:

- *Ensure your RFID system has been designed to survive in the environment in which you intend to use it*
- *SAE AS 5678 does not currently cover many conditions related to component overhaul*
- *RFID readers must also be designed for the harsh aircraft maintenance environment*

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