RFID Components, Tool Types, Approach for Line Maintenance Tool Tagging, Business Scenarios and Challenges

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Abstract—The paper presents Radio Frequency Identification (RFID) based Tool Crib Management Solution for inventory management for aircraft's line maintenance. This enables RFID based issue and return counter. The solution will adopt RFID middleware as the support platform, cover tools entry, checking, issue and many other operation flows to decrease the labor intensity, miss scanning and other human errors, and improve the efficiency and accuracy. The tool issue and return counter based on RFID would help to improve the efficiency of tracking of lost tools. The presented architecture helps to manage inventory of tool crib's in an efficient and accurate manner. It automates the asset management application by making it capable of real time monitoring of tools. The paper also critically presents a different type of RFID readers needed to enable solution.

Index Terms— RFID, Inventory Management, Fixed Reader, Tags, RFD Antenna, UHF Passive Tags , RFID Use cases.

1 Introduction

RADIO frequency identification (RFID) is an technology which supports accurate, timely and reliable information to manage operations and co-ordinate material flows. Powerful actors such as the US Department of Defense, the US Food and Drug Administration, large international retail firms, pharmaceutical firms [1] IT firms [2] and automotive firms [3] have taken offensive actions in adopting RFID technology. This has made researchers and practitioners speculate about the widespread adoption of RFID, and Research has reported that adopting RFID technology provides an opportunity to improve inventory management, assembly automation, returns management, tracking and tracing systems, process control, product availability, security and can enhance consumer experiences. Over the last few years, a number of airlines/defense organisations have started seriously exploring RFID Technology [4] in their technical operation and aircraft maintenance. It is appears that RFID technology will soon be widely available in commercial aviation/defense for line maintenance. In line maintenance everyday hundreds of aircraft get repaired and tool crib plays vital role in issue, return and lost/found of tools needed for aircraft maintenance hence tool inventory inaccuracy is a major challenge.
The Purpose of this is to provide a realistic overview of where RFID technology can be used and is being used, in the line maintenance. Many RFID pilot projects have started and completed, and few companies are using this technology in production. 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 remainder of the paper is organized as follows. The next section presents the RFID Overview. In the subsequent section described Architecture used for tool crib management solution. In the next section, tool issue and receive counter design explained followed with tagging feasibility with different type of tags.

2 RFID Overview

This section explains overview and components of RFID system. RFID refers to a technology whereby digital data encoded in RFID tags [5] (defined below) are captured by a reader via radio waves. RFID is similar to barcoding in that data from a tag captured by a device that stores the data in a database. Figure 1 shows these essential components in order.

2.1 RFID Tags

The heart of an RFID system is a data carrier, referred to as the Tag. The designs and modes of function of the tags also differ depending on the frequency range, just as with the antennas.
In the LF and HF range, a unique, worldwide ID number is stored on the chip. This can be connected to information in a database. There are coil designs for these two frequencies in the tags that are used in the magnetic near field of the antennas (inductive coupling).

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In the UHF range, the tag has an EPC (Electronic Product Code) [6] storage area that can be programmed by the customer. Dipoles are used here within the antenna design.
Communication is by means of a backscatter method [7]. Here, data transfer is not by means of inductance, but by changes to the impedance at the tag antenna, resulting in backscatter. If you now switch this on and off in time with the data flow to be transferred then this results in an amplitude-modulated signal which the scanner or antenna can then receive and process.

Passive tags are available with a storage capacity of up to 10kbit, thereby allowing additional information to be stored.

Distinguishing features

The most common distinguishing feature among tags is their power supply. Both active and passive models are available.

Passive tags do not have their own power supply and gain their energy from establishing an inductive field from the radio signals of the scanner. The missing source of energy does result in lower ranges, but allows smaller and lighter designs. Additionally, passive tags are maintenance-free and can be obtained much more cheaply. They are mainly used for product authentication and tracking, but also as data storage media for access control systems.

Active tags draw their energy from a built-in battery and can therefore transmit signals themselves for data transfer. Due to their integrated power supply, they are more expensive than their passive counterparts but have a wider scanning range of up to 100 meters. They are mainly used to identify objects with a long lifetime and that can be used repeatedly.

Designs

Depending on their purpose, tags are available in various sizes, designs and protection classes. The most common types are self-adhesive labels or chip cards. They are available as "read only" versions, which can only be read-out, and "read/write" versions that can both read and write the tag.

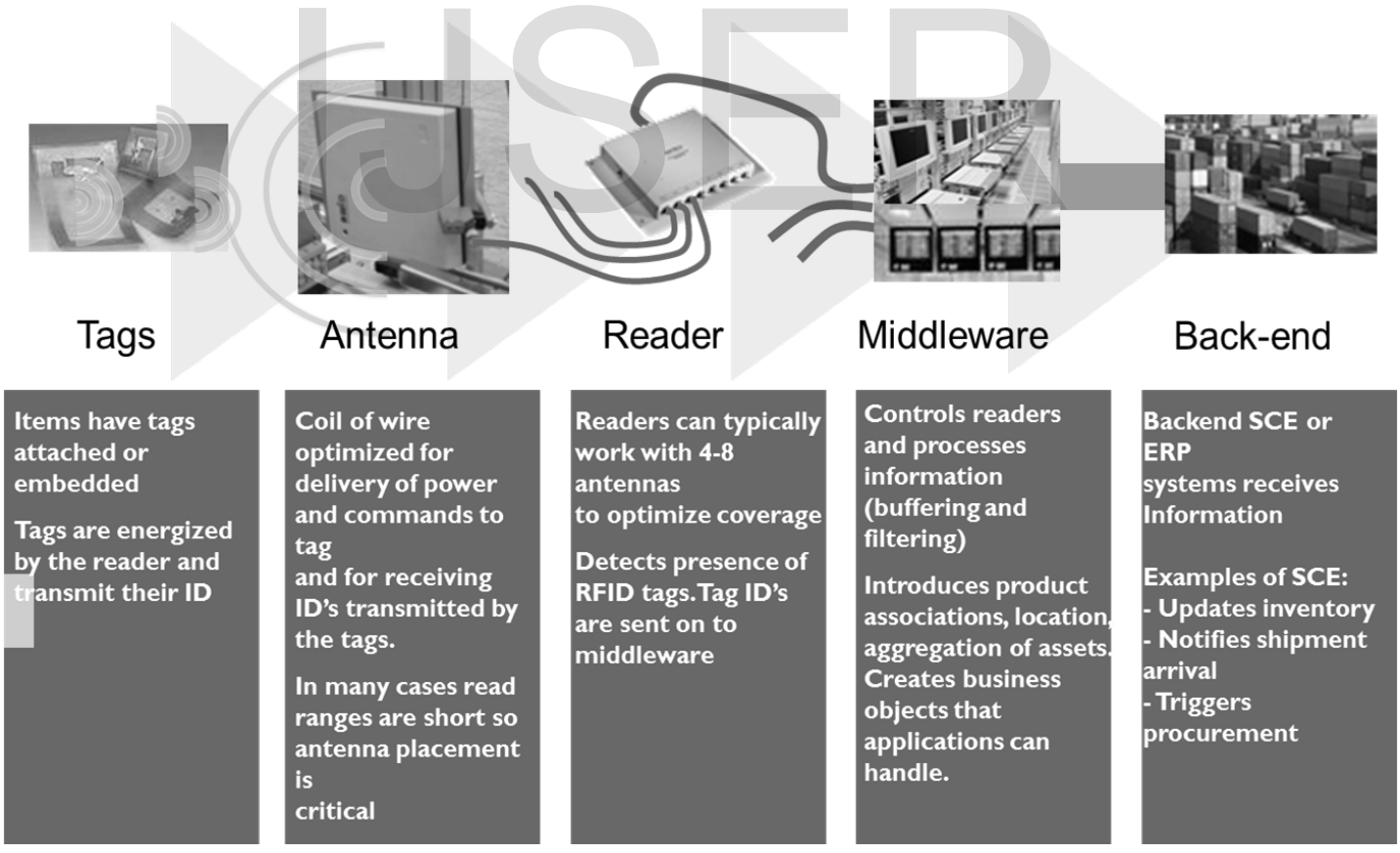

Fig.1 RFID solution component

2.2 RFID Antenna

An RFID antenna consists of a coil with one or more windings and a matching network. It radiates the electromagnetic waves generated by the reader, and receives the RF signals from the tag. An RFID system can be designed so that the electromagnetic field is constantly generated, or activated by a sensor. Antennas also come in different sizes and designs, this depending very much on the environment into which a system is integrated. The required read and write range also play a role. Common forms are rod or loop antennas. For greater reading range or different orientations of a tag, a number of antennas can be arranged in one reader unit.

In this technology, the antennas are different with regard to configuration and mode of function depending on the frequency used.

LF (Low Frequency) – 125 / 134.2 kHz

The antenna is comprised here of a defined number of wire winds which thereby result in a defined inductance in the antenna. A difference is made here between frame antennas (air coils) and rod antennas (coil with ferrite core). Within the complete system, the magnetic near field is used, i.e. inductive coupling.

HF (High Frequency) – 13.56 MHz

Within the HF range, the antenna is comprised of one or more windings and is frequency tuned by a connected tuning board. The antenna winding material should have a large area when possible because in the HF range the waves spread out on the surface of the condustor and more current can flow through a larger area, thereby influencing the performance of the antenna. Within the complete system, the magnetic near field is used, i.e. inductive coupling.

UHF (Ultra High Frequency) – 865 to 950 MHz

Here a distrinction is made between two types of antenna – dipole and patch antenna. As already suggested by its name, the dipole antenna is a design that comprises two poles. The chip is arranged in the middle and the two antenna poles are to the side. The patch antenna is a metal surface which must have defined edge lengths. The surface thereby functions as a resonator. Within the complete system, the magnetic distant field is used in these antennas, i.e. electromagnetic coupling.

2.3 RFID Reader

Depending on the frequency that is used and its performance, an RFID reader sends radio waves of between one centimeter and 30 meters or more. If a tag enters this electromagnetic region, it detects the activating signal from the reader. The RFID reader decodes the data stored in the integrated circuit of the tag (silicon chip), and communicates them, depending on the application, to a host system.

Bidirectional Communication

The majority of these devices can both read and write, so data transfer will also work in the reverse direction from the system to the data medium or tag. The reader is consequently the major component of the system, responsible for activating the transponder and thus for initiating data communication.

Categorization

RFID readers are differentiated by their features, the main ones being stationary or mobile. Stationary devices are intended for firm incorporation in existing systems, and are the commonest type found. The necessary antenna is attached through an interface. Detected data can be conducted to a host on standard interfaces like RS232, Ethernet or USB.

Mobile readers serve for detecting data on various objects and are notable for their compactness. The antenna is integrated in the device or directly attached to it. Data transfer to a host uses wireless standards like WLAN or DECT.

2.4 RFID Middleware

Middleware is the command center of your RFID solution – the bridge that connects all of the components of your RFID system. Without it, all of the data captured by an RFID reader would simply stay on that individual device. RFID middleware collects data from all of your hardware, filters out duplicate or junk data, and then translates the data into a format that other business software can understand. This gives you single-pane-of-glass access to your data so that you can interpret the information and take appropriate action.

RFID middleware typically performs the following functions:

Data management and filtering – automatically eliminating duplicate reads and redundant information
Application integration – enabling you to access your RFID data from an existing business application

2.5 RFID BACKEND

RFID backend system plays crital role in terms of recording transaction. Valid data received from RFID tags is passed by the middleware to the backend system. The backend system is where data is manipulated and stored, and forms the data resource for the system users. Typically the backend system incorporates some sort of database which allows the linking of the RFID data to other stored information or storing of the tag details themselves. For example, a given bit string RFID tag code is essentially useless as a piece of data in isolation, but if this unique code is associated with a given product or person, then the backend system can be used to cross reference the code and thus reveal the identity of the tagged item. Equally, a backend system may simply record the occurrences of RFID tags in specific locations, and thus tracking of tags becomes possible even if the identity of the tagged item is unknown.

The construction of the backend system is very application specific and can range from one computer which simply logs data, to banks of machines which perform complex analysis on data from thousands of distributed readers. Notably the backend system need not be geographically near to the RFID readers.

3 CASE DESCRIPTION

In the field of line maintenance, productivity and timely completion of aircraft maintenance depends on how quickly tools can be issued, procured, loaned and returned.RFID based tool crib (issue/return) solution can completely remove the paper or register based issue/return accounting system. The tradesman at tool crib would be able to view requirement of tools per aircraft/equipment/trade on his terminal as per the tasking for the day and would be able to prepare tool bags in advance.

Solution can facilitate- Issue and return of tools to tradesmen assigned with a task as per task detail for the shift/ day, the solution would have provision for traceability and identification of tools based on electronic identification. The accounting for issue/return of tools would be done based on electronic identification only. To ensure quick delivery of tools/spares the tool crib can maintain three/ four counters for issue/ return. In case a tool is reported missing or has not been returned after at ask within defined period, an alert will be raised for counters and autorities.If the tool was drawn for work on an aircraft, it shall not be cleared for flying until the tool is traced and returned.

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4 ARCHITECTURE OVERVIEW

Below architecture describes the interactions of various components. All type of tools which are required for line maintenance would have RFID tag attached. There are different types of tags identified as part of tagging feasibility exercise (described in detail in subsequent section). Overall solution perspective, RFID fixed reader and handheld readers were used to read RFID tags attached with tools. RFID resident application deployed on RFID reader would interact with middleware using Web Service/XML/MBO technologies and middleware would enable persistence in database.

4.2 Solution for Handheld RFID Reader device

1) Development of thick client in Java running in J9 JVM
2) Build a lightweight middleware web service which can be hosted on application server i.e WebLogic or WebSphere. This lightweight middleware web service will map request from thick client to Asset maintenance system's web service request and asset maintenance system's web service response into lightweight middleware web service response.
3) Rationale - Java ME platform has limited SDK features when it comes to using Web services.

4.3 Solution for Fixed RFID Reader device

1) RFID device will be connected to LAN port and will have static IP. IP addresses to be mapped with user profile of maintenance system's user to identify from which device tags are to be read.
2) Develop a lightweight middleware web service on .NET platform hosted on any of windows servers (IIS).
3) Sole purpose of .NET Web service will be to provide interfacing with IP based RFID device. Web service will return the tags read.
4) Asset Maintenance system's (COTS) to customize and invoke .NET Web service to read RFID tags.
5) Rationale - Fixed reader provides SDK only on Microsoft platform (.NET & C).

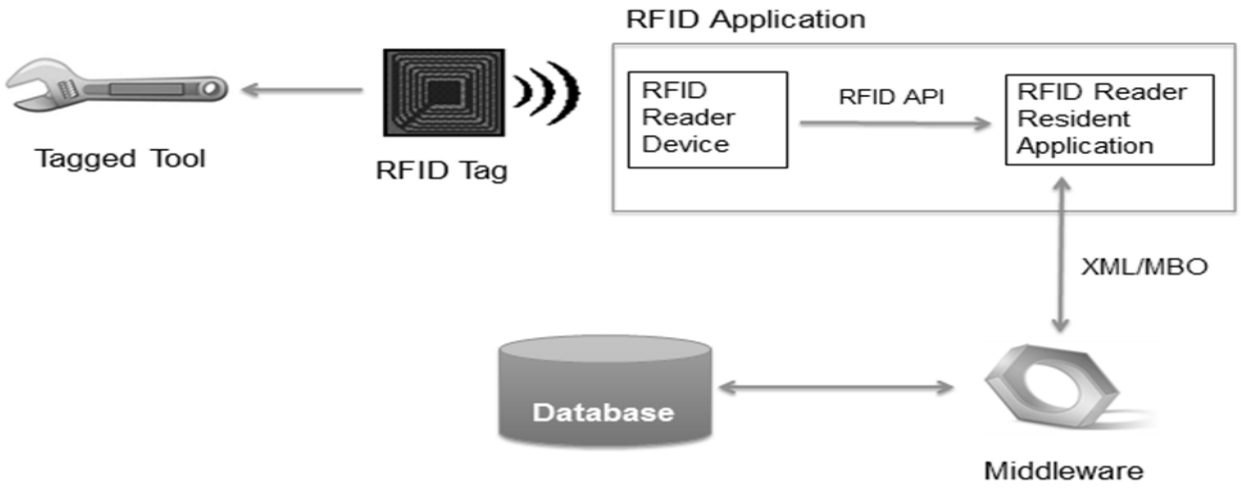

Fig. 2 RFID Architecture diagram depicts integration of various components

5 TOOL COUNTER SETUP APPROACH

RFID reader & RFID antenna installed under the computer table as shown in fig. 3 where Antenna face towards the table top. RFID reader connected to work station with Ethernet cable. RFID reader & RFID antenna connected to each other with RF cable Assumption taken while setting up tool counter is that within 1 meter radius area (Horizontally) no RFID tagged tools should be placed in the Tool Crib (Issue/Return Counter) and also there should be no Storage for RFID Tagged Tools planned vertically in the Tool Crib (Issue/Return Counter).

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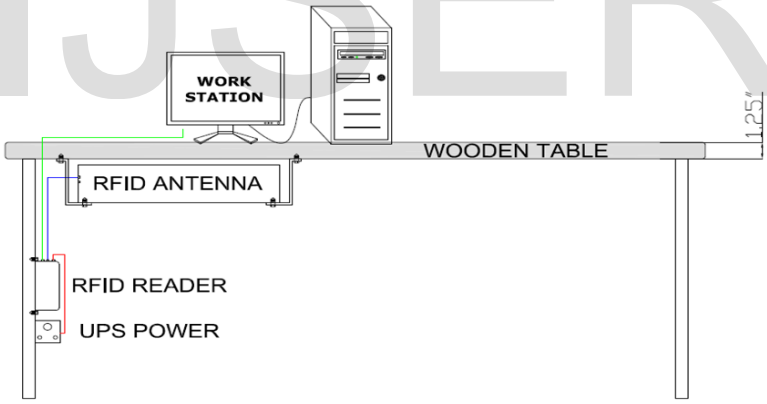

Fig. 3 Tool counter component and setup approach

6 IDENTIFICATION OF TOOLS/TAGGING FEASIBILITY

In RFID based solution, very first activity is to identify and categorize the tools which are to be RFID tagged. In aircraft line maintainace primarily, tools can be categorized in three ways- General hand-held tools, specialized tools and Trade specific tools. Once all tools are categorized then these can be segregated based on tagging feasibility.

There will be three types of inventory in tool crib-

Type A: Tools which can be tagged with RFID tag
Type B: Tools which can't be tagged with RFID Tag hence, Tool Box/Bag will be tagged
Type C: Consumables hence, No RFID Tagging will be done

6.1 Type A tool tagging feasibility

For type A tools, to fix RFID tags, three approaches were explored which has their own pros and cons.

As option 1) it is proposed to hang tags on tools for tagging purpose. Hang-tags are nice if they're small and don't pose a problem inside the store's display case but in case of rough use of tools in maintenance, higher chances of losing tags hence this option was not viable at all.

Option 2) paste tags on tools instead of following hanged tag method of tagging tools as mentioned in option 1. However fixing tag on tool has its own issues of detachment of tag from some of the tool which are being used very rough.

Option 3) last option was proposed to tag tools with epoxy adhesive and protecting these tags from detachment by covering area of tagging with heat shrink sleeves.

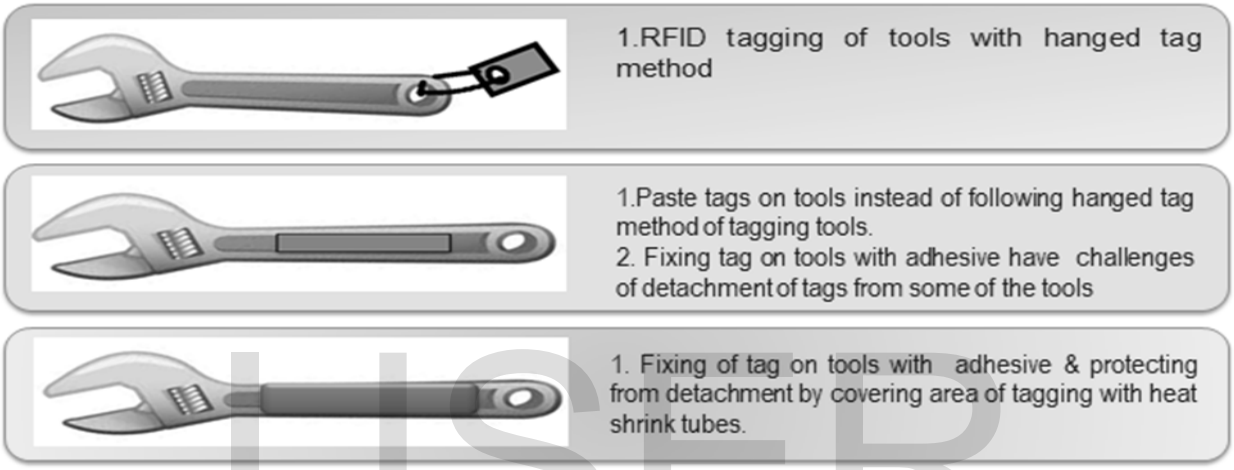

Fig. 4 Tagging feasibility – Tool Type A

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6.2 Type B tool tagging feasibility

For type B tools which can't be tagged with RFID tags, tagging can be done on Box/bag level for that type of tools. Type B tools cannot be tagged individually with RFID tag for following reasons:

1) Due to rough use
2) Insufficient surface area

For tools that are kept as set in boxes, the boxes will be tagged with RFID tag and the tool transaction will be done at box level. Items which are not issued/returned at individual level or at box level would be captured through asset management application rather scanning and updating records using RFID readers. It not that line maitainace performed at one place, it is performed across different maintenance centers hence tool movement, issue and return process should be harmonize across all locations. All tools need to be tagged with RFID tag at Flight store or site store.

Fig. 5 Tagging feasibility – Tool Type B

After tools tagging; tool registration activity needs to be conducted at site store level and accounting to be taken care at individual tool crib. All tools kept on RFID enabled issue counter or tool crib, will be ready for RFID reader. Once it's scanned by RFID reader, tool details will be populated to computer terminal screen and tool will be issues to technician.

Fig. 6 Tool Type B- Registration

6.3 Type C tool tagging feasibility

Consumable tools are the tools that are intended to be consumed. These tools used one time as part of aircraft maintenance hence no RFID tagging required.

7 TOOL TAGGING APPROACH

Once types of tools are identified for entire inventory and feasibility exercise completed (that how tools would be tagged with RFID) then next milestone is to plan tagging RFID on actual tools.

7.1 Existing tool tagging

The operation flow of existing tool tagging is shown in fig. 7.

1) Tool details should be collected from all tool crib locations, bulk stores and site store. This process would ensure that no tool is left behind without RFID tagging. This process also helps in tool consolidation across different maintenance sites.

2) Once tool details are collected from all locations, they have to be serialized in sequential number to have unique identifier.

3) As next step - serialized data for all tools should be consolidated as single repository of all locations tool cribs, bulk store and site stores. This can be consolidated excel sheet.

4) Now all tools have to be tagged with RFID as described in section 6 based on their type.

5) Every tool in inventory has part no. and serial no. RFID tag has to be mapped with part no. and serial no as part of unique tool registration.

6) As last step, data migration should be performed for serialized tool information from excels into asset management application.

Fig. 7 Step by step tagging approach – existing tools

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7.2 New tool Induction and tagging

New tool is inducted everyday based on current and future demand. First place to introduce new tool is bulk store.

1) Once tools are available in bulk store, they should be serialized first.

2) Before tools can be issued for scheduled aircraft maintenance, all new serialized tools should be moved to bulk store of asset management application for updation of tool/asset inventory.

3) In asset management application, asset ID would be generated and RFID tag would be fixed in bulk store.

4) As final step, RFID will be registered (Scanning of RFID tag and assigning the ID against a serialized tool item) against tool's part no. and serial no,

5) Tools would be issued on as-required basis to 'Tool Crib Store' through asset management application's initiated demand transaction

Fig. 8 Step by step tagging approach – new tool induction

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8 BUSINESS SCENARIOS

In line maintenance, there are primarily two kind of task –'Scheduled tasks and unscheduled tasks'. Scheduled tasks are usually organized into a check (e.g., transit, daily, weekly). Unscheduled tasks, such as troubleshooting and defect rectification, may be performed outside of a scheduled check. Irrespective of the type, all maintenance tasks follow three stages as per the manufacturers' publications: setup, procedure, and close-up [8]. Setup stage includes any tasks conducted in preparation for the check and usually takes place in the line office before attending to the aircraft. This stage may involve reviewing and printing documentation, preparing tools and spares, and communicating with other members of the team. During this stage, the maintainer carries out the tasks required by specific checklist and defect rectification according to the technical log or any other tasks communicated from maintenance control. This stage finishes with the maintainer having completed all required tasks and returning back to the line office

For all line maintenance, preparing tools and spares is necessary step and can involve different business scenarios which are described as below and can vary based on individual organizational line maintenance process.

8.1 Tools from Bulk Store to Tool Crib

In order to maintain tools inventory, tool crib demands tool from Bulk store; as described in above section Bulk store is a place where tools gets inducted after procurement process and moved to Bulk store based on demand from tool crib. RFID assigned tools are to be moved physically from bulk store to tool crib for assigned or upcoming maintenance. All tools received by tool crib have to account against the issued tools from Flight store using RFID fixed reader. Tools inventory quantity for Bulk store and Tool crib should be updated in asset management applications, which keep tracks of tools.

Fig. 8 Flow for tools from bulk store to tool crib

8.2 Daily issue of Tool Crib for Line Maintenance Work order

Tradesman is the one who has to perform maintenance on aircraft and they need required tools to do the same. Tools are issued to tradesman as per work order generated through asset management application. Issue Counter (IC) shift has access to asset management tool and gets the information of the tools required for work order. Once IC has the information of tools, IC shift prepares tool bags for tradesman as per work order requirement and IC shift uses RFID fixed reader to scans tool (as mentioned in Issue counter setup approach). Issued tools detail gets updated back in asset management application with status 'Issued'.

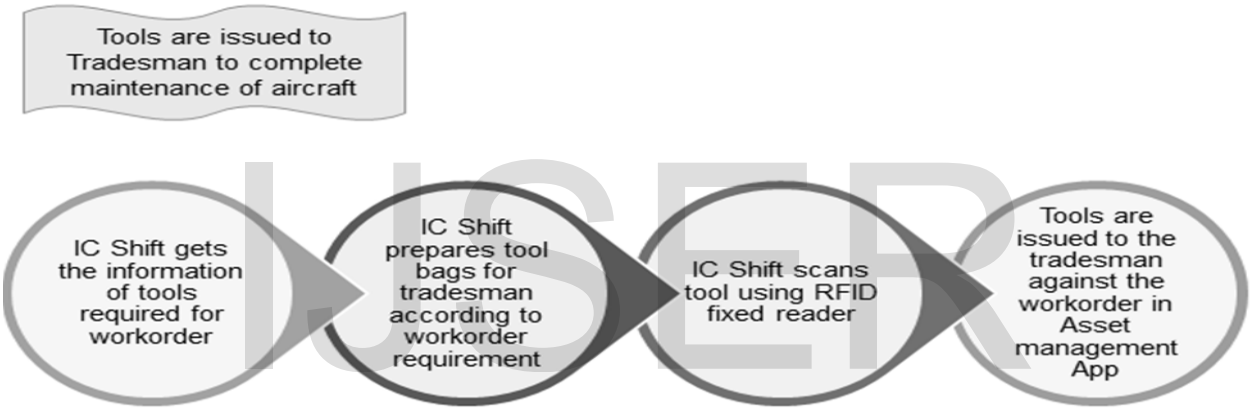

Fig. 9 Flow for daily issue of tool crib for line maintenance work order

8.3 Return of Tools at End of Shift

Once maintenance is completed as per work order, tools have to be returned back to IC shift at the end of the day which triggers reconciliation process. Tradesman returns bag of the tools to the IC shift at Issue/return counter. IC shift scans the tools using RFID fixed reader and accounts for the tools being returned with the tools issued to tradesmen. IC shift is also responsible to verify the condition of tools and update condition back in asset management application. Condition could be serviceable, unserviceable or lost.

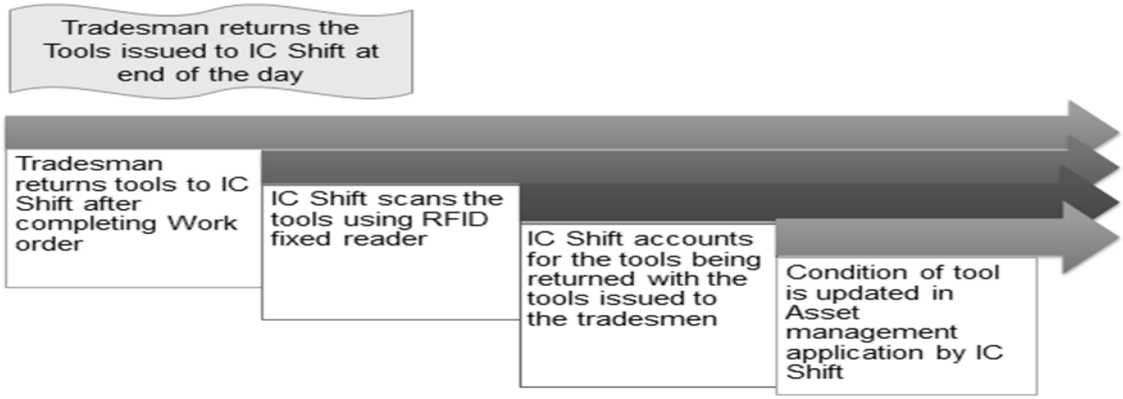

Fig. 10 Flow for returns of the tools at the end of shift

8.4 Accounting of Tools by Gang IC during Work Execution

It is possible that more than one work order be assigned to tradesman and for different aircraft. In that case, tradesman moves from one aircraft to another to perform their assigned task. It is easy for tradesman to move to another aircraft once tradesman completes his work order on currently assigned aircraft but tools cannot be moved for aircraft maintenance. These have to be reissued. Gang IC scans the tools of tradesman using RFID hand-held reader rather returning back to IC shift. Gang IC accounts for the tools issued to tradesman and updates the system and matches with issued tools to ensure that no tools are left in aircraft. Gang IC scan tools for all tradesmen working for existing work order. Once tools are reassigned using RFID hand-held reader, tradesmen can move to another aircraft for different work order. If Gang IC found gaps in scan count against issued tool count, then lost tool process will be triggered and tradesmen would not be allowed to move to next work order maintenance.

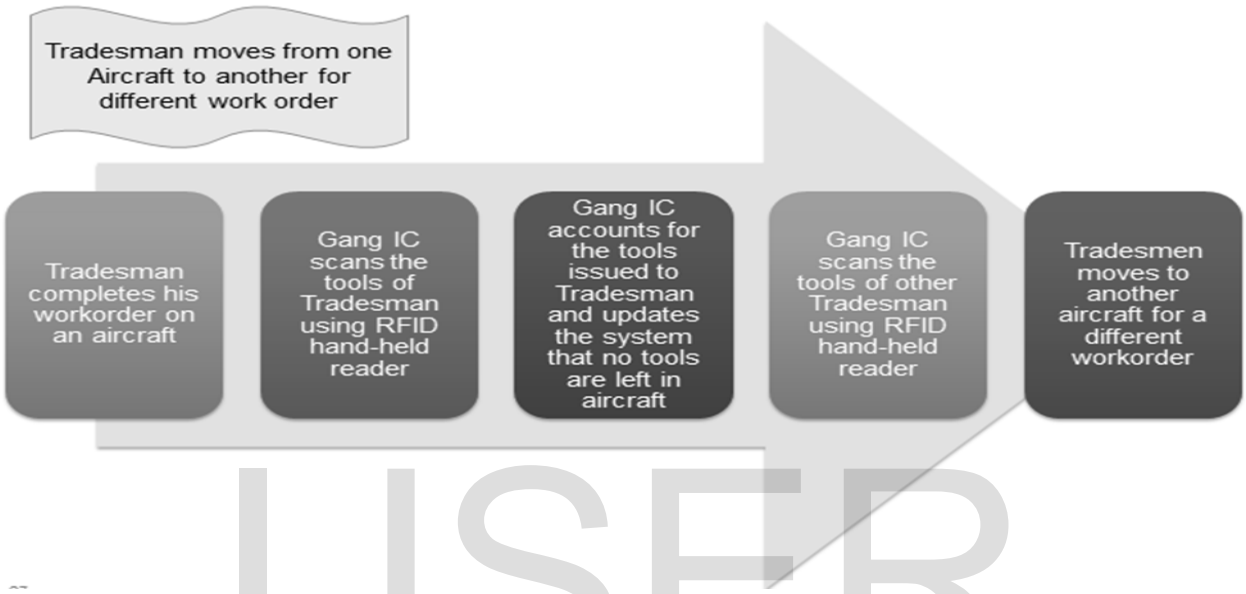

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Fig. 11 Flow for accounting of tools bt Gang IC during work execution

8.5 Lost Tool: Identification of Lost Tool

As mentioned in sub section 8.4, tradesman can loose tool during maintenance. In that case, 'lost tool' process would be triggered. Gang IC will scan the aircraft and tarmac area using hand-held RFID reader. Hand-held reader prompts for RFID tagged tool found in vicinity. Hand-held reader displays the tag of the found tool along with part no. and serial no.

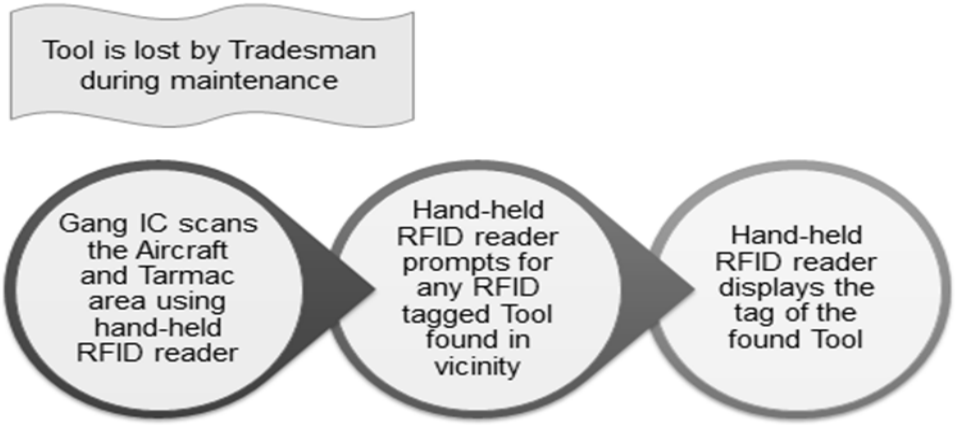

Fig. 12 Flow for lost tool- Identification of lost tool

8.6 Lost Tool: Retrieval & Return of Tool

After completing assigned work order, tradesman have to return tools bag back to IC Shift, and IC shift scans the tools to match with issued tools marked in asset management application. Now while scanning, IC shift may report missing tool. For retrieval

and return of tool, mobile hand-held RFID reader would be issued to designated person from tool crib. Person would scan the work area with hand-held reader to trace the presence of any tool. If tool tracked within the range of hand-held reader then hand-held reader would display tool details. RFID hand-held reader may display more than one tool however RFID hand-held reader would have provision to search only lost tool by providing serial no. on hand-help reader's search screen. Each serial no. has unique RFID no. stored in device for exact match. Found tool would be returned back to tool crib and IC shift receives the tool with fixed RFID reader after matching with lost tool data.

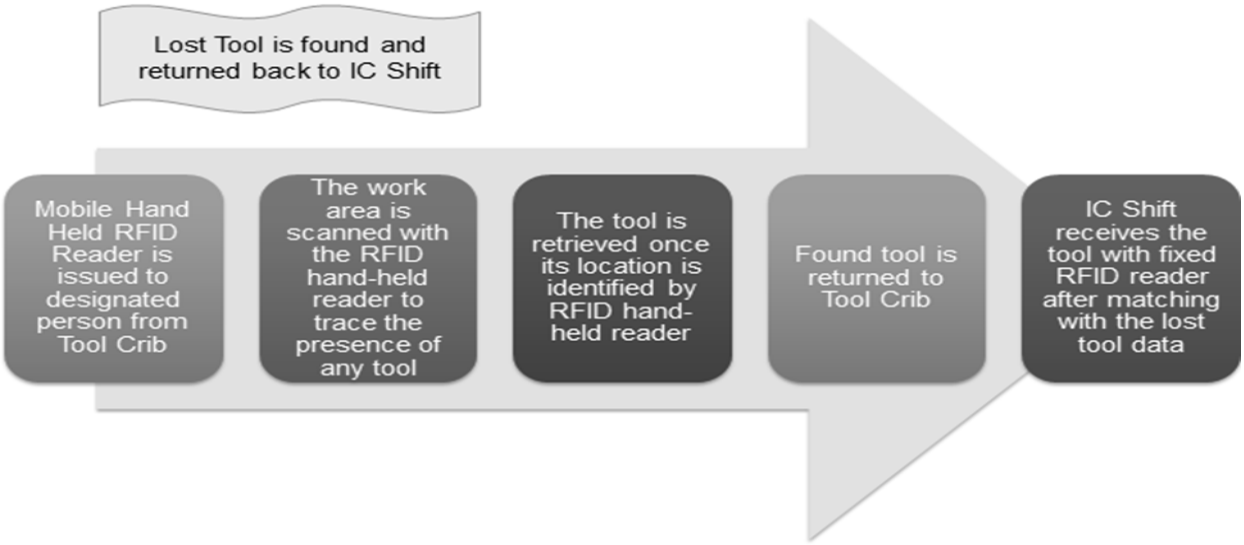

Fig. 13 Flow for lost tool- Retrieval and return of tool

8.7 Tradesman Demands Tools from Bulk Store on Loan

During work order execution tradesman may demand tools which are not available in tool crib or Flight store inventory then tradesman may reach out to Bulk store to get tools on loan and return back after stipulated time.

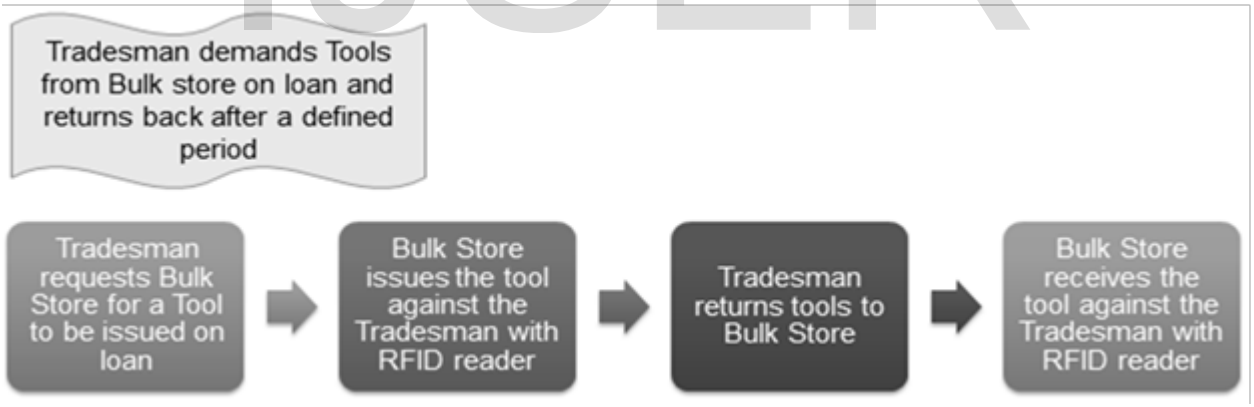

Fig. 14 Flow for tradesman demands tools from bulk store on loan

9 BENEFITS

Though RFID is not likely to entirely replace manual process of tool issue/return process, the following advantages suggest to Additionally apply RFID for added value of identification-

1) Tag detection not requiring human intervention reduces employment costs and eliminates human errors from data collection.

2) RFID tags have a longer read range than, e. g. Barcodes.

3) Tags can have read/write memory capability.

4) An RFID tag can store large amounts of data additionally to a unique identifier.

5) Tags are less sensitive to adverse conditions (dust, chemicals, physical damage etc.),

6) Many tags can be read simultaneously.

7) Automatic reading at several places reduces time lags and inaccuracies in a tools inventory.

10 CHALLENGES

1) 100 % Tools tagging can't be done with RFID tags due to reasons explained in tagging feasibility section.

2) Methodology for RFID tagging implementation cannot be repeated in all locations due to tools inventory is not similar in different Tool Crib locations.

3) RFID tag longevity on tool is dependent upon usage of tool.

4) If RFID fails due to unforeseen reason, transaction of tool will be done using unique serial number of tool.

5) Tools issued/returned as set in boxes will be issued/returned with RFID tags on boxes only.

6) Issue/Return for individual tool of a box will not be done using RFID tag.

7) If any individual item in a box is lost, lost tool process for that individual tool will not be initiated as there would be no mapping available with serial no., part no.

8) The availability of tools in the box while issue/return has to be accounted manually by issuing authority or IC Shift/tool crib.

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11 CONCLUSION

The paper gave an overview of the current state and uses of RFID technology to setup tool issue/return counter. Despite these challenges, RFID continues to make viable solution for tool issue/return system for aircraft line maintenance. RFID's potential benefits are large, and we're sure to see many novel applications in the future - some of which we can't even imagine. Moreover, above solution for setting up tool's issue/return counter and tagging approach using RFID to enable automated tool management, enhance accuracy which can be used by practitioners in their quest for eliminating manual process and improving time for line maintenance.

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