Track and Trace Requirements Scoping

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This report provides an overview of the industrial requirements with regard to the optimization of track and trace processes across the aerospace supply chain. It also demonstrates how the application of ID-based solutions has improved track and trace practices in different industries. The aims of the report are to outline inefficiencies of current track and trace practices, describe the industrial requirements for improved track and trace and to demonstrate both the potential impact of RFID technology in this area and the business benefits that companies can gain from it. The report analyzes the key issues that result from the requirements analysis and the major research challenges that emerge from these.

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1. Introduction

1.1. Aims of the Report

This report provides a scoping of the current track and trace practices in the aerospace industry, highlighting their inefficiencies based on industrial sponsors feedback and other data. It describes the industrial requirements for improved track and trace practices across the aerospace supply chain and outlines the basic system requirements of the infrastructure that shall meet these industrial requirements. The report analyzes how RFID technology will improve track and trace processes and demonstrates the business benefits that the companies will be able to gain through improved track and trace performance. Furthermore, the report identifies key issues that require special research attention and proposes research activities through which these should be studied and analyzed.

1.2. Definitions

Engine and aircraft parts pass through numerous different states during their lifecycle. More specifically, they can change location, custodian, condition (i.e new/used, serviceable/unserviceable, scrap), function and form, they can be installed, removed, repaired, maintained, stored, shipped or they can be exposed to various conditions (i.e. temperature, humidity, vibration).

Tracking is the ability to determine the current state of a part at any time, while *tracing* is the ability to determine the past "states" and the origin (raw materials, subparts) of the part. Tracing is based *on traceability data*, which constitute the history of a part (previous locations and custodians, processing, maintenance and usage history). ATA defines traceability as the "ability to show where a part has been since it was manufactured or last certified". Relevant to tracking and tracing is the concept of *predicting*, which is the ability to determine the likely future "states" of an item (Figure 1.1).

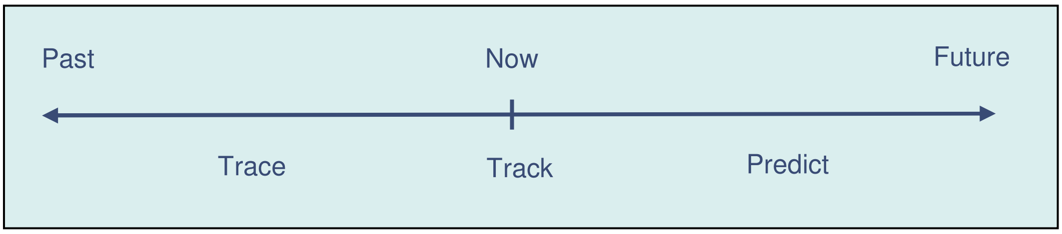

Figure 1.1 Track and Trace time dimension

A part can be tracked and traced either internally in a company (*internal* track and trace) or across the whole aerospace supply chain (*external* track and trace). Track and trace in the aerospace sector is a broader concept in comparison to other sectors, such as the food supply chain or the pharmaceutical sector. This is due to the fact that a part must be tracked and traced even after the plane has been manufactured and delivered to the airline company. In this stage part maintenance and usage information must also be recorded and possibly exchanged between maintenance centres, airlines and manufacturers.

1.3. Scope

Track and trace across the whole aerospace supply chain requires a standard for automated identification and data capture. More specifically, it is critical to assign a unique tracking identity to each item that needs to be tracked and traced (aircraft and engine parts, tools, shipping containers). Industry task force has defined a permanent bar code specification for that purpose. The proposition of an effective ID solution that will match aerospace tracking and traceability requirements is considered vital.

As far as traceability is concerned, according to Air Transport Association (ATA) the reconstruction of the physical history of a part requires a minimum amount of data, generated by every company that accomplishes a “transaction” on the part. A transaction is defined as any significant event which changes the state or ownership of the part (ATA spec 2000, chapter 9). It is very important to determine the ways in which information should be inserted into the track and trace system, in order to ensure accurate, complete and real-time data collection. Data insertion can be done either manually or using automated identification and sensor technologies.

Furthermore, traceability across the aerospace supply chain requires data sharing among business partners. Traceability data can be kept either in centralized databases hosted by authorized companies, in companies’ internal databases , in documents transmitted among partners or even on the part itself, for instance in a RFID tag. The overall system architecture (central and distributed databases, pedigree system), data access and security policies, the amount of information that can be stored on the tag are issues that should be addressed and solved.

1.4. Report Overview

This report has a scoping perspective and is structured so as to bring key issues in track and trace under a common framework. The structure of the report is outlined in Figure 1.2.

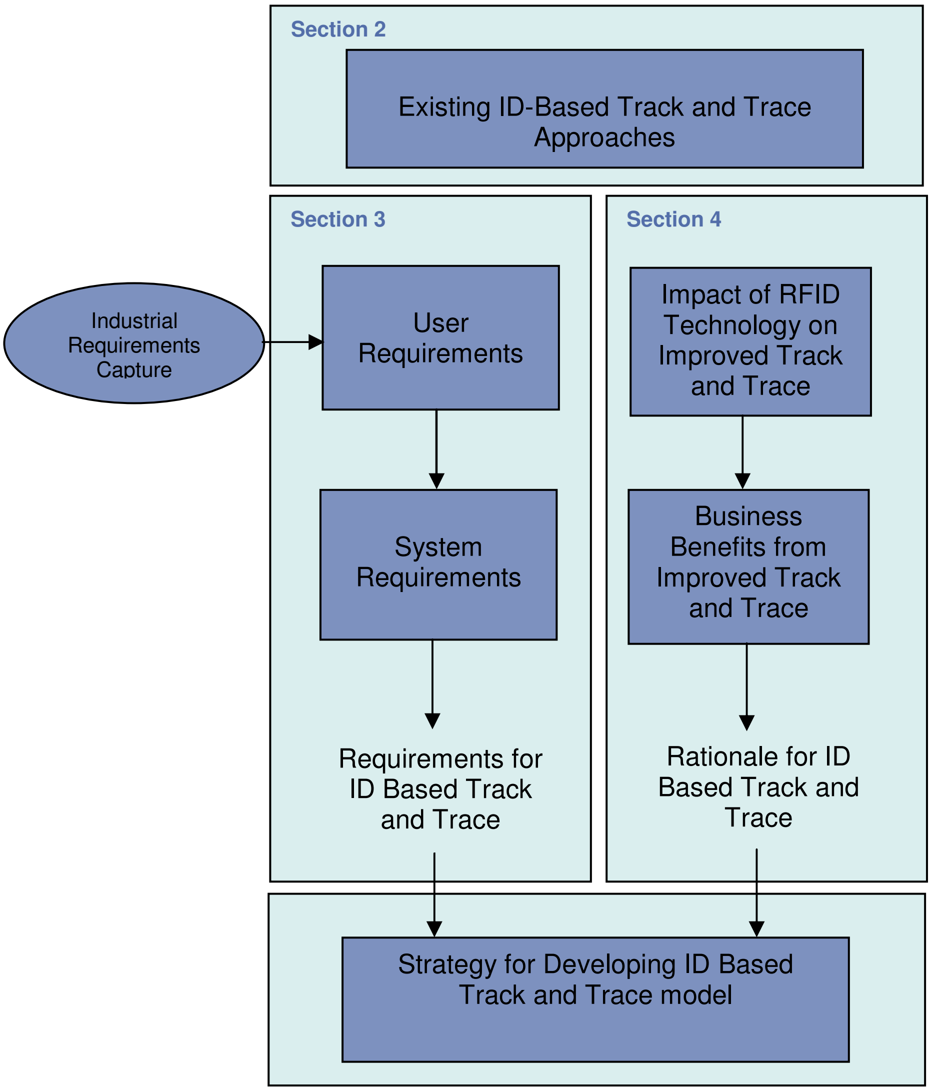

Figure 1.2 Report Structure

2. Existing Approaches to ID-Based Tracking and Tracing

2.1. Introduction

A great number of tracking and tracing systems linked to ID systems have been implemented or just trialled in order to track and trace items/products, reusable assets, as well as people, either in the internal environment of a company or throughout a supply chain. This section gives an overview of the existing approaches to ID-based tracking and tracing, by describing a number of tracking and tracing systems, which fall in different application categories. The systems described are automated, mostly RFID-based and refer both to aerospace and other supply chains. Examples of both internal (intra-company) and external (inter-company) track and trace systems are presented. The aim of this section is to demonstrate how ID based systems have been used to optimize track and trace processes.

2.2. Existing Industrial Track and Trace Applications

As stated in the introductory section, we summarize a number of existing approaches to ID-based tracking and tracing in terms of key application types.

2.2.1. Point-to- point reusable asset tracking

This application type refers to recording the position of a reusable asset, as it is transferred between critical points in either a maintenance or manufacturing process, or throughout a supply chain.

Savi 's Shared RFID-based Network: Savi Technologies, an RFID-supplier and a port developer have collaborated in building an RFID-based information network to track, trace and manage containerized ocean cargo at any point along the supply chain. More specifically, they have installed active RFID equipment and software in participating ports around the world to provide users with information on the identity,

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location and status of their ocean cargo containers and its contents, as they pass through such ports. In that way, shippers, logistics service providers and transportation companies are able to connect to the network by installing compatible equipment at their own locations. Moreover, the network is built on an interoperable architecture and is designed to work with other Automatic Identification Data Collection (AIDC) technologies as well, such as barcodes and Global Positioning Systems (GPS). The company is expected to establish relationships with additional port partners to further extend the network [1].

CHEP's Innovative Pallet Tracking System: CHEP, a company involved in pallet and container pooling services has developed an innovative pallet tracking system, in order to improve the administration of its customers' (manufacturers and retailers) supply chains through real-time sharing of RFID information with all the trading partners. Sharing of data is accomplished utilizing the EPCglobal Network through several Verisign services, such as Object Naming Service (ONS) and EPC Information Services (EPC-IS). EPC-IS enables the storage and retrieval of detailed product information on each pallet, including associated case information, as the former travels through the supply chain. At the same time, RFID data can also be integrated with the multiple backend systems of the trading partners. As a result, business processes, such as dispatch, receipt and picking have been fully automated, while the complete supply chain path of the pallet has become completely visible [6, 7].

Using Colour Codes (Visidot) for Reusable Asset Tracking: A supplier of reusable plastic containers, IFCO Systems GmbH, of Pullach, Germany, has implemented a colour-code system called Visidot, in order to track the rentals that flow every year through its network. Visidot is a kind of code that stores information in dots containing patterns of various hues of colour. Information is captured by the Visidot scanners, which can take a high-resolution picture of an entire stack of containers, as the assets pass in front of them. The system's accuracy was tested to be 99.74 percent over 1.5 million readings, assuring accurate inventory counts in real time, better records of shipments and improved cycle times [7].

2.2.2. Real time asset location

This application type refers to techniques which estimate the position of an asset in a great degree of accuracy within one area.

General Electric's Ultra Wideband (UWB) Engine Assembly Tracking System: The world's first, FCC-certified, ultra wideband (UWB) precision asset location system has been successfully installed in General Electric's (GE) new Flowline Building at the GE Aircraft Engine Peebles Test Operation, Ohio. The aforementioned system is used for

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real time precision tracking of engines, equipment and kits to better than one foot resolution in a severe multi-path environment. The UWB installed system automates processing operations and provides time critical information upon demand. Moreover, the infrastructure used is minimal, as the system employs only five receivers to cover an area of approximately 30,000 square feet [9].

U.S. Army's Real-Time Location System of Radar Systems: U.S. Army has conducted a pilot program to evaluate a real-time location system in a full-service repair, overhaul and fabrication facility of surveillance and radar systems. The system tracks individual parts and assemblies of radar systems as they are refurbished in order to prevent items from being lost and make refurbishment processes more time and cost efficient. More specifically, the system is configured to record when tagged items arrive in a monitored area, how long they remain there, and when they are removed from that area. The system can also be used to find specific items or send alerts when tagged items remain stationary for a designated amount of time. Active 2.4 GHz tags have been attached either directly to large antenna components or to containers used to transport assemblies or subassemblies of small items that are deconstructed for refurbishment. The pilot program was considered successful, as the system managed to locate assets to within 10 feet despite their high metallic context. As a result, the U.S. Army considers making the deployment permanent [10].

2.2.3. Full Traceability and Product Authenticity Assurance

This application type refers to tracking and tracing systems that support full traceability, providing a detailed product pedigree for each item and ensuring product authenticity.

Drug Security Network (DSN): In the pharmaceutical industry, pedigree legislation and mass-serialization have been introduced, in order to make the pharmaceutical supply chain safer and more secure. A pedigree is a record of every transaction for every transaction for every instance of a drug from the point of dispensing back to the original manufacturer, providing a complete, traceable chain of custody for the product. A number of major players in the pharmaceutical industry have formed a forum, called Drug Security Network (DSN) to consider the upcoming major changes and challenges to their business practices. More specifically, DSN activities are focusing in developing pro-active thought leadership and specific requirements not only on pedigree and serialization issues, but also on data sharing and security. RFID technology and EPC network are emerging as the key technologies to address the Drug Security Network requirements [5, 12, 13].

2.2.4. Tool tracking and tracing

Tools are reusable assets that are used on a shared basis among the engineers of the same or different companies. Tool tracking and tracing systems are among the few existing RFID-based tracking and tracing systems in the aerospace sector.

Airbus Tracking Tools: Airbus pioneered the use of the RFID technology in aircraft tool management in 1999. All its tools and toolboxes are now equipped with RFID tags, offering electronic support for loan and repair management of tools. RFID tags track the tools' movement and condition and apart from the manufacturer serial numbers, they contain data about the history of the tool, its manufacturing date, periodicals technical code, as well as shipping, routing and customs information. These data automatically updates the tools' status in multiple systems like SAP's ERP System, a MasterPack supply chain management system and even the EDI network that links those systems enterprise-wide. The manufacturer has also introduced the RFID technology to its supply of aircraft spare parts, in order to simplify their inventory and repair management [8].

2.2.5. Documentation Tracking

This type of application is also related to the aerospace sector and refers to the tracking of the documentation that accompanies aircraft and engine parts and contains part-related information (released document, aircraft readiness logs).

Boeing RFID Pilot: Boeing has launched an RFID pilot in its facility in Wichita, Kansas, testing a passive system for tracking work in process by attaching RFID tags to the documents that travel with the parts. The above-mentioned documents contain information, such as Boeing's certification of parts, Federal Aviation Administration requirements and quality assurance information. They follow the parts, as they are received and moved through shops that make up out production process until they are placed in the parts control area before being put on the plane. At that point the paperwork is sent on to closed records and the RFID tag is disassociated from the order. This RFID trial was completed in June 2003 and was considered very successful, for the implemented RFID system achieved 99 percent accuracy on the reads [2].

2.2.6. People Tracking and Tracing

People tracking systems have be used for ensuring that only authorised personnel with the correct training can access certain areas or use certain equipment.

BP Trial: BP has trialled a people tracking and tracing system, in order to test if the access to one of its enclosed pressure vessels could be controllable through RFID technology. More specifically, they RFID-tagged each of their maintenance workers as well as their safety equipment (boots, breathing apparatus, helmet).They managed to demonstrate that operations could only be carried out by authorized personnel with the correct training and correct equipment. In separate trials BP has also demonstrated how workers carrying RFID tags could be located and accounted for during emergency evacuation drills.

2.2.7. Baggage, Air Cargo and Reusable Asset Tracking

A number of airports and airlines have tested and in some cases are already using RFID technology for baggage-tracking purposes. RFID tags can be used to identify the baggage of high-risk passengers or offer one-stop baggage handling services, enabling hands-free travel. Moreover, a number of air cargo companies have trialled the use of active RFID tags on aircraft containers to track Unit Load Devices (ULDs) and thus reduce unit losses. Airlines have also adopted RFID systems for tracking the location of food trolleys at a great number of locations around the world [13].

eLSG. SkyChefs' trolley tracking solution: eLSG.SkyChefs is the first airline catering industry that has offered airlines an Internet-based solution to track catering trolleys throughout an airline's global catering network. More specifically, eLSG.SkyChefs employs Scanpak's Galley Equipment Tracking System (GETS), which is designed to track airline catering trolleys worldwide. The trolley tracking solution is comprised of an RFID transmitter tag secured on each trolley and a corresponding receiver capable of accurately accounting for each tagged trolley entering and exiting catering stations around the world. The installation is completed by a Web application that enables the airline to access its equipment status in real-time from anywhere in the world via the eLSG.SkyChefs Web site. The solution can significantly reduce trolley loss and maintenance costs, while optimising trolley equipment distribution throughout the airline's global network. Moreover, airlines will be able to reduce equipment-related flight delays and the need to purchase new trolleys. In addition, the system is able to track the performance and common defects of various trolley types/manufacturers, enabling airlines to objectively evaluate their suppliers. Trolley maintenance records are also tracked and as result, preventive maintenance can be easily scheduled to ensure equipment safety and extend the life of the equipment [14].

As far as baggage tracking is concerned, it is important to state that IATA has endorsed the use of ultra-high frequency tags and readers compliant with the ISO

18000-6C candidate protocol as a global standard. The above-mentioned protocol incorporates EPCglobal's Gen 2 standard. Furthermore, the Transportation Security Administration (TSA) has conducted an end-to-end trial, proving that UHF EPC tags can be read in different (Asian , U.S. and European) regulatory environments, and that airlines can share bag tag data through the EPCglobal data model [11].

2.3. Summary

This section has presented and classified a number of different examples of industrial tracking and tracing applications. The examples indicate the diversity of the solutions developed, the range of ID options available and a range of requirements. The above analysis demonstrates how tracking and tracing systems can provide increased visibility of the location and state of the item needed to be tracked and traced within a specific area/facility, the internal environment of a company or throughout a supply chain. It can be used as a directory for the aerospace companies, in order to examine in more detail the existing practices in the track and trace application type that they are mostly interested in. The track and trace theme aims to provides greater systematisation in this area.

3. Industrial Requirements

3.1. Approach

This section describes the requirements of the aerospace industry with respect to item tracking and tracing using RFID technology. We analyze industrial/user requirements and we propose the system requirements of the RFID infrastructure that can help meet user requirements and will enable item tracking and tracing using RFID technology.

The requirements analyzed in this section were captured using multiple information sources. Personal contacts with managers of the aerospace industry companies were the main source of information for the requirement analysis. Apart from this, feedback obtained from questionnaire circulated among the partners of the project was used to complete the picture of the needs that companies currently have. Moreover, documents from regulation authorities and trade associations (such as the US Department of Defence, the Air Transport Association of America, the International Transport Association etc) were taken into account for composing the requirements described in this report. In particular, the part marking and traceability requirements described in Chapter 9 of the ATA Spec2000 [15] e-business standard were adopted and regarded as a global standard (although the ATA does not mandate the use of Spec 2000 standard, most of the companies today use it). Finally, academic and industrial literature regarding traceability models and requirements were used as complementary to the above.

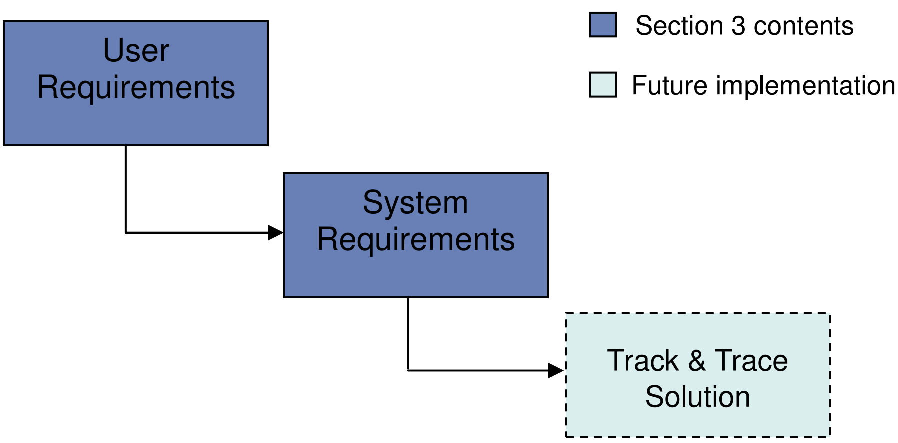

Figure 3.1 Section 3 structure

In the next sections the requirements are analyzed, as captured by the requirements analysis. Section 3.2 describes the requirements of the aerospace industry companies with respect to item traceability and operations optimization. Section 3.3 outlines the system requirements that an RFID infrastructure should meet in order to effectively and efficiently support the above. In section 3.3.7 additional traceability requirements from other industries are briefly described.

3.2. User Requirements

This subsection describes the user/functional requirements for the application of RFID technology for item traceability in the aerospace supply chain. We analyze how the companies expect RFID technology to optimize part traceability and operations across their supply chain. The user requirements for the key areas that the companies expect RFID technology to improve their efficiency, as captured by the requirements analysis, are described in the following subsections.

3.2.1. Item Identification

Currently, in most of the cases companies use human readable text or barcode for item identification. In some cases the use of barcode is below 50% of the company's product assortment. As a result, item identification requires human involvement which is both time consuming and error susceptible. There is a need for accurate and automatic item identification, which at the same time shall minimize labour costs related to item handling. RFID technology can solve these problems. RFID tags attached to parts and documentation can automatically provide companies with accurate and real time information about the location and identity of specific items.

3.2.2. Document and Asset Tracking

Documents regarding maintenance information or documents accompanying parts (e.g. certificates of conformance or certificates of release) are very often lost or misplaced when detached from the part. In those cases companies need to replace the document from the company that originally issued it, resulting in significant costs and loss of time. Moreover, when a part's paperwork is missing, the part is regarded to be "out of control", as the company that holds it has no information about its condition and reliability. For this reason, after a certain period of time being out of control, the part must be sent back to its original supplier to verify its condition. In order to avoid all this high cost and time consuming procedures, companies need to accurately track documentation on real time basis.

Apart from documentation, aerospace companies need to track and trace returnable assets, such as shipping containers, and tools throughout their supply chain. Returnable assets and tools are often misplaced or lost, leading in resource underutilization and cost increase. Effective track and trace through RFID technology can minimize the aforementioned problems.

3.2.3. Information System Update

Companies invest serious amount of time and labour work on manual data entry updating their ERP and other internal information systems with information regarding parts received and their attributes. Apart from the obvious cost, there is a high probability of error. There is a need for an automated way for updating their information systems with the required information and possibly compare it against expected information. For example, in the case of order receipt, the items could be crosschecked with those ordered and an invoice could be automatically issued. Information can be automatically captured and updated in the information systems through the use of RFID tags on parts and/or documents, which shall contain this information.

3.2.4. Part Maintenance History/ Configuration/ Failure Information

Companies in some cases need to have complete part maintenance history information, even if the part is no longer in their custody. Under current practices this information is held either on paper technical documentation or in repair station log cards. Companies' vision is to store all required information on an RFID tag which will be firmly attached to each part. In this way the data will be accurate, complete and could be retrieved in an automated way. Companies could then have access to real time accurate maintenance information even when the aircraft has no access to a network. The update of maintenance information can then take place directly on the part. In this way the part would always have up-to-date information.

Apart from maintenance information, companies of the aerospace industry require the RFID tag attached to parts to include configuration and manufacturing information, which will be useful during maintenance, as parts may require special treatment according to their configuration and manufacturing method. Moreover, information about part failure and the conditions that this happened under could be held on the tag as well so that when a part is sent to its supplier for repair, the required information can be found directly on the part rather than accompanying documentation. The information currently held on paper can be stored on RFID tags fostering the efficiency of information communication.

Respectively to item identification and attributes information, companies encounter problems on updating maintenance information in their internal information systems, as it is currently stored on paper. The information system update procedure is both costly and subject to errors. RFID tags will enable automatic system update, making the information available on internally information systems at minimum cost.

3.2.5. Operations Efficiency

There is an imperative need in the aerospace industry for improvement in operations efficiency. This would include manufacturing, distribution, maintenance and safety checks operations. Companies need to have accurate and real-time information about work in progress, parts in their depots and status of parts in transit. Moreover, they need to optimize maintenance operations with the use of accurate information about available spare parts and minimize decision making times about maintenance and repair. In addition, there is a need for minimizing the duration of routine safety checks before take off (e.g. check for availability of life vests). Accurate and real time information from RFID tags attached to parts will provide companies with needed information and give them the opportunity to optimize their operations.

3.2.6. Automatic Certificate Generation

Part and aircraft manufacturers currently store all needed information for part certificates in their information systems. However, information is communicated to their customers in paper. The transition from electronic format to paper (and possibly back to electronic through data entry) is not only costly but error susceptible. The aim of the companies is to provide the needed certificates to their customers along with the parts in electronic format (possibly in paper as well) so that the information is communicated more efficiently.

Table 3.1 summarizes the functional requirements that aerospace industry companies have with regard to optimizing item traceability information and operations across their supply chain and the way these can be met.

Improvement Through…	Track			Trace			Automated Information Capture and Processing
Requirement for…	Accuracy	Completeness	Timeliness	Accuracy	Completeness	Timeliness	
Documentation tracking	x*	x	x				
Efficient item identification	x		x				x
Automated information system update							x
Complete maintenance history information on the part				x	x	x	
Manufacturing and configuration information on the part				x	x	x	
Optimized manufacturing and distribution processes	x	x	x	x	x	x	x
Efficient and quick decision making on maintenance decisions	x	x	x	x	x	x	x
Automatic safety checks before take off	x	x	x				x
Returnable assets/tools tracking and management	x	x	x	x	x	x	
Automatic electronic certificate generation	x	x					x

* x: The requirement on the left can be met through improving the respective dimension of information quality or efficiency of information capture.

Table 3.1 Aerospace industry requirements and improvement opportunities

3.3. Towards System Requirements

In this section we provide an initial approach towards the system requirements of the RFID infrastructure that shall meet the industrial requirement presented in section 3.2. The system requirements are presented under a framework that defines different operational levels with regard to the use of RFID track and trace technologies in the aerospace industry (Figure 3.2). The levels of the framework are:

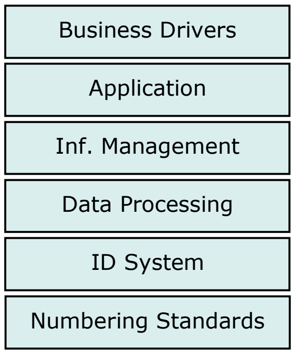

Fig. 3.2 Track and Trace Operational Framework

- *Business Drivers*. The drivers that force companies to seek for improved track and trace are analyzed from both legislative and operational perspective.
- *Application Characteristics.* In this level specific application characteristics that shall be improved/ redesigned in order to gain maximum benefits from improved track and trace are described.
- *Information Management.* This level includes the description of the way that information should be managed and communicated by information systems in order to fully utilize information flows from automatic identification technologies and improved information quality.
- *Data Processing.* The requirements for data capturing, storage on identification devices and editing are analyzed.
- *ID System.* The functional requirements of the identification devices to be used are described.
- *Numbering Standards.* The part unique identification numbering standards are analyzed and alternatives for additional part information encoding are outlined.

In the following subsections we follow a top down approach according to the above framework.

3.3.1. Business Drivers

The drivers for full item traceability in the aerospace supply chain lie in two dimensions. The regulations enforced by regulatory authorities and the need for optimization of business processes in the aerospace supply chain.

On one hand, the regulations issued by the regulatory authorities of the aerospace sector set a threshold for traceability practices and information that should be recorded across the aerospace supply chain. These regulations are issued by the Federal Aviation Administration [16], the Joint Aviation Authorities [17], state Civil Aviation Authorities, the U.S Department of Defense [18], the U.S Department of Transportation [19] and other regulatory authorities of the aerospace sector. The aims of these regulations, among others, are

- To ensure that all parts circulated in the aerospace supply chain are certified and accompanied by all required information.
- To ensure that any alteration or maintenance that takes place on a part is properly recorded and reported.
- To ensure that any significant event that happens regarding a part of aircraft is properly recorded and reported.
- To ensure that any part installed on an aircraft meets the minimum airworthiness criteria

The regulations and reports issued by the aforementioned regulatory authorities cover many additional issues, which are out of the scope of this report.

On the other hand, companies of the aerospace industry need traceability information in order to optimize their operations. Further above the threshold that the regulatory authorities set, companies aim at optimizing business processes and reducing costs across the aerospace supply chain, according to the requirements described in section 3.2.

The business drivers are included as a layer of the system requirements operational framework, as they define the requirements for the system design outlined in the following subsections.

3.3.2. Application Characteristics

A prerequisite for building applications based on RFID tagging in the aerospace supply chain is to have tags attached to parts and documentation that needs to be tracked and traced. Detailed requirements about the tags' requirements are included in subsections 3.3.5 and 3.3.6 of this report.

Automated Information System Update. An infrastructure should be developed so that information is updated in the companies' information systems automatically, with no human intervention at any point. In this way data entry errors will be reduced to the minimum and data quality will be significantly improved. Indicatively, automated system update could take place during item delivery, item shipment, maintenance information update and part configuration update. Automated system update will create a reliable master catalogue about parts or documents related to each company.

On-part information. The infrastructure that shall be developed along with the RFID tags themselves should support the storage of information on the tag attached to a part. This information shall include manufacturing and part configuration information, maintenance information as well as part certification. These different kinds of information will be used by the part's custodians during its lifetime for efficient decision making. The custodians could be the repair stations, original equipment manufacturers, the airlines or any other kind of company that could take advantage of the information stored on the tag. Ideally, the tag shall support authorization levels for the information stored in it, so that confidentiality of information is ensured. On-part information may gradually reduce the need for documentation presence for decisions to be made (e.g. in a case of part replacement) as this could take place according to the information that is stored on the tag.

Efficient Decision Making. In order to improve the accuracy and speed of decision making, companies will have to adapt their current practices on decision making so that these take advantage of the accuracy, completeness and accuracy of the information provided by RFID technology about documentation and part location and condition. These practices would include both manufacturing processes, where part availability and configuration information shall be used to optimize throughput, and maintenance processes so that the best and more effective decisions are made in a minimum amount of time in order to reduce aircraft down-time. The adaptation of these practices might include either the development of more sophisticated algorithms for decision making or reengineering of the processes in order to utilize the availability of accurate information.

Automated Safety Checks. Part identification and the information stored on the RFID tag attached on the parts shall be used to automate the safety checks before an aircraft takes off or routine maintenance checks. Using wireless data capture technologies the staff shall be able to check the existence of necessary items for take off (e.g. life vests) and ensure the reliability of critical parts based on the information that their tags contain. In addition, scheduled maintenance checks shall take place more efficiently, as the maintenance history information for a part shall be easily accessible through an RFID interrogator.

Returnable Asset Management. Returnable assets and tools shall be tagged in order to optimize their utilization and minimize phenomena of missing assets. For this reason, existing asset management systems must be upgraded to utilize real time information about asset tracking or new ones must be developed.

3.3.3. Information Management

Information Systems. In order to take full advantage of improved information quality provided by RFID technology companies shall integrate their existing information infrastructure with the RFID technology infrastructure which will be deployed. The information systems shall be able not only to read/receive the information stored on the RFID tags, which might be well beyond just identification information, but shall be also able to edit this information in an automated way, ensuring information quality on the tag itself.

After the deployment of RFID technology, information systems shall be able to handle information streams in a real-time basis and utilize it. If the systems keep on operating on information batch basis, then information will be underutilized and companies will not gain the benefits that could potentially gain. The information systems shall support real time decision making and communicate the information regarding decisions to the respective users. Moreover, information flow shall be used for triggering alerts warning for possible problems in the supply chain, minimizing in this way risks and costs for companies (e.g. low product stocks, required maintenance).

Information communication. An important perspective for achieving operations efficiency in the aerospace supply chain is information visibility. In order to maximize benefits gained from improved information quality provided by RFID technology, effective and seamless information communication shall be ensured. Information exchange in paper creates a serious bottleneck in the speed and quality of information exchange. Having information in electronic format, it should also be communicated in electronic format. Only then will real-time information availability be ensured. Standards for information exchange should be adopted so that this takes place in a uniform and efficient way across the aerospace supply chain.

The aerospace companies may consider the use of the Electronic Product Code [20] network for supporting lookup and indexing services for information exchange across the aerospace supply chain. The EPC network is designed for supporting effective information exchange between partners regarding Electronic Product Code observations and additional information related to them, providing at the same time network scalability and timeliness of information. The EPC network should be considered for future adoption by the aerospace industry.

3.3.4. Data Processing

Data Storage. An important issue to be decided is the amount and kind of data that will be stored on the RFID tags compared to the data that will be stored on the information systems. This is subject to the capacity of the tag and the needs of the aerospace sector companies. For further analysis of this issue please refer to section

3.3.6. Having information stored in two separate locations, the issue of data synchronization becomes critical. Methods that will ensure that data is synchronized in the best possible way should be developed. The first priority should be to ensure up-to-date information on the tag, as this will be the reference point to update information to the rest of the network. Decisions on maintenance and operations shall be made according to the information on the tag. Data synchronization shall take place with a tag-to-information-system direction on a regular basis. Data on the information systems shall be accompanied by a date indicating when the last update took place. Apart from the approach described above, alternative solutions for data synchronization shall be considered by the partners.

Data Capture and Update. Once data is stored on the RFID tag attached to parts or documents, it must be captured from and updated on that. The RFID infrastructure deployed to support the initiative of this project shall include a sufficient network of RFID readers (interrogators) that will be able to capture the required information at any time and will be able update it as needed. Special attention shall be put in the infrastructure use by the maintenance personnel. There may be a need for use of mobile interrogators that will be able to read and update the information on the tag, but will be able to store it as well, in order to update the back end information system at some later time. The effectiveness of this procedure will be the cornerstone of the success of this initiative. Respective mobile interrogators shall be used for safety checks before take off or scheduled maintenance checks.

3.3.5. ID System

This subsection outlines basic the requirements that the RFID tags used by the aerospace industry should meet, according to published regulations and reports by the FAA [16] and the U.S. Department of Defence [21].

RFID tags specifications. In order to avoid any possible interference with equipment on the airplanes necessary for safe flight and landing, only passive RFID tags shall be used for part marking and traceability data storage. These are tags that employ no on-chip power source and provide information only when interrogated.

The use of passive tags should be limited to ground operations only, i.e. aircraft not in motion, where the intended interrogation of any passive RFID device is not conducted while the aircraft is positioned on an active taxiway of runway.

The RFID tags should be destroyed if removed from the parts attached to in order to prevent any forging phenomena.

Memory size. Taking into account the amount of data that needs to be stored on the tags (in the case of parts), it seems that the new 64KByte should be used for this purpose. A part of this memory capacity shall be used for the identification information (write once) and the rest of it for rewritable part life history information.

However, the management of this memory is a critical issue which shall be discussed in depth in future.

Frequency. The RFID devices must not radiate (back-scatter) characteristics with harmonics below a level of 35bBuv/m. This limited is established to prevent any unwanted signals from becoming a possible source for interference to, or intermodulation with, required critical or essential aircraft equipment or systems. Moreover, the frequency assignment of RFID devices must remain outside of the published aviation frequency bands in order to prevent their radiation from affecting critical or essential aircraft systems. More specifically, the generation of harmonic frequencies from the RFID tags will be maintained such that the fundamental through the 4th harmonic frequencies do not impinge upon any assigned aviation communication or navigation frequency. [21]

Standards and Regulation Compliance. The RFID tags attached to any aircraft part must meet the requirements of the Federal Aviation Regulations 23, 25, 27 and 29.1301 i.e. each item of installed equipment must function properly when installed [21].

All tags attached to aircraft parts should meet the RTCA DO 160 airworthiness criteria about environmental conditions and test procedures for airborne equipment [22]. Among others, the RTCA criteria describe the required resistance of any equipment installed on aircrafts to vibration, power input, radio frequency susceptibility, lightning, and electrostatic discharge. Apart from the above the RFID tags should be able to sustain high temperatures, contact with chemical liquids and increased humidity

3.3.6. Numbering Standards

This section analyzes the industrial requirements on permanent aerospace part marking, coding rules according to Spec2000 e-business standard and the way these may be supported by RFID tags. Furthermore, alternative schemas of coding part lifecycle information are outlined.

Part Identification. The ATA spec2000 standard defines the data format of a “social security number” that will uniquely identify each part throughout its life. This “social security number” consists of an Enterprise Identifier and a unique serial number within the Enterprise. These two codes do not change during part’s lifetime, contrast to Part Number (PNR) which may change when the part is modified in any way. The Enterprise Identifier of the tag should be either the Manufacturer’s Code (MFR) for new parts or the owner’s/ user’s code (SPL) for the parts that were in service when the marking took place. Both these codes are five character CAGE codes (or NCAGE for outside North America). A Part Serial Number (SER) or a Unique Component Identification Number (UCN) should be assigned to the part by the manufacturers or owners/ users of the part respectively, who should make sure that this is unique within their enterprise identifier. Alternative identifiers, for companies that do not have

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a CAGE/NCAGE code are (1) Commercial and Government Entity Code (CAG) (2) Dun & Bradstreet D-U-N-S Number (DUN) (3) EAN.UCC Company Identifier (EUC). For details please refer to Chapter 9 of ATA Spec2000 e-business Standards [15].

Consequently, a part shall be uniquely identified using either the MFR [or CAG/DUN/EUC] + SER combination for new parts of the SPL [or CAG/DUN/EUC] + UCN for parts in-service when marked. This information should be static and marked on the part once, at the beginning of its lifecycle, and not change ever after, so that the part can be traced effectively throughout its lifecycle.

Traceability Data Encoding Alternatives. Apart from the permanent part identification, Chapter 9 of the ATA Spec2000 standard suggests a traceability data standard which defines the minimum number of data elements necessary to reconstruct the physical history of a part. Each company that accomplishes a "transaction" on a part should retain, at a minimum, at least this amount of data in their database. A transaction is defined as any significant event which changes the state or ownership of the particular part. The focus of this standard is to allow the companies track the physical state of any part using the recorded transactions.

A record describing a specific transaction on a part should include the following fields:

1. CAGE Code of the manufacturer (MFR) or supplier (SPL)
2. Part Serial Number (SER) or Unique Component Number (UCN)
3. Current Part Number (PNR)
4. Action company's CAGE Code (ACO)
5. Action Date (ACD)
6. Action Code (ACT)

The data definitions for the above are described in the ATA Common Support Data Dictionary.

Chapter 11 of the ATA Spec 2000 defines a set of information that companies are advised to record and share. This set includes information about

1. Aircraft status change.
2. Aircraft general statistics
3. Aircraft event.
4. *Component removal and installation.*
5. Aircraft logbook.
6. *Scheduled maintenance.*
7. *Component shop repair.*
8. Service Bulletin/Modification incorporation.

From the above, points 4, 6 and 7 refer to information that shall be considered for inclusion to be encoded on an RFID tag attached to parts. The availability of this kind of information on the part it self could significantly help to improve the efficiency of maintenance operations and information quality available to maintenance personnel.

Apart from what the ATA Spec2000 defines, some other information might be worth considering being included for encoding on the RFID tags. This could include:

- Product attributes, critical for part maintenance and handling
- Safety information
- Operational history
- Transportation and storage.

It is obvious that not all of the aforementioned information can be included on an RFID tag. The exact set of traceability information encoded on an RFID tag that shall be attached to a part should be discussed and agreed upon by the industrial partners.

3.3.7. System Requirements for Other Industries

The aerospace industry can extract lessons from other industries that currently use RFID technology for traceability applications.

The pharmaceutical industry is a good example where RFID and other technologies are used not only to support full traceability, providing a detailed product pedigree for each item, but also used to ensure product authenticity as well. Each product instance is uniquely identified by an RFID tag. Information exchange among supply chain partners is supported by the ONS infrastructure. Each company can make a query about the previous custodians of each product and view its history. The above combined with internal traceability information result in full supply chain traceability. Consequently, any potential problems and product recalls can be effectively and efficiently managed. Moreover, the authenticity of products is ensured through digitally signed electronic documents that accompany each product, verifying the custody of each product at a specific period of time. These documents are either propagated across the custodians of the product or kept fragmented in the system of each of the custodians under the supervision of a trusted third party that ensures the validity of digital signatures. In this way, companies in the pharmaceutical industry achieve full traceability of products across the chain and prevent the circulation of unapproved products in it.

The food industry is probably the most obvious example of a traceability application. There are quite some traceability application providers that support traceability either based on RFID technology or on legacy encoding schemas. In either case, product batch dispersion among companies is usually recorded in a centralized information system, hosted usually by a third party. Each company is forced by law (EU regulations and State laws, [23]) to keep records of internal traceability. Once a problem occurs, the cause of the problem can be traced back recursively and the products to be recalled can be identified by tracking them forward, combining each time internal and centralized traceability information.

The concepts of centralized traceability information and that of the electronic custody certificate may need to be considered for adoption by the aerospace industry as well for ensuring traceability of parts and components among companies and for preventing the circulation of unapproved parts in the aerospace market.

3.4. Summary of Requirements

The requirements for using RFID technology for part and documentation traceability are driven by both the legislation and the need for improved efficiency in the aerospace supply chain. Companies need the deployment of an automatic identification technology that will enable improved tracking and tracing in order to

- Have access to accurate, complete and timely information about location, state and history of parts and documents across their chain
- Improve supply chain operations efficiency
- Be able to efficiently update their enterprise information systems will timely information
- Be able to have critical part information on the part itself

In order to achieve the above using RFID technology, the RFID infrastructure deployed should meet the following key functional requirements:

- It should be effectively integrated with existing information systems
- New system features shall be developed where needed, in order to utilize the improved information quality.
- RFID tags that will effectively hold the needed identification information and satisfactory amount of additional information shall be deployed.
- New methods for capturing, updating and communicating information across the supply chain shall be developed in order to ensure high information quality both on the tag it self and in the information systems throughout the supply chain.
- A comprehensive set of information that will cover the needs of all kinds of partner companies shall be agreed upon to be encoded on the identification device, following a common encoding standard that will enable seamless and uniform communication of information across the aerospace supply chain.

4. Impact

The aim of this section is to describe how the deployment of RFID technology will improve tracking and tracing quality in the aerospace supply chain and to demonstrate the business benefits that stem from this improvement.

4.1. Impact of RFID on Track and Trace

Apart from the well established and broadly analyzed benefits of RFID technology, relating mainly to labor cost reduction, ease of item identification and information capacity, RFID technology with significantly improve track and trace performance across the aerospace supply chain.

Track and trace performance relies in data quality. Data quality has three main components: **Timeliness**, **Accuracy** and **Completeness** [24, 25]. Figure 4.1 illustrates the instances of each of the dimensions that affects track and trace performance.

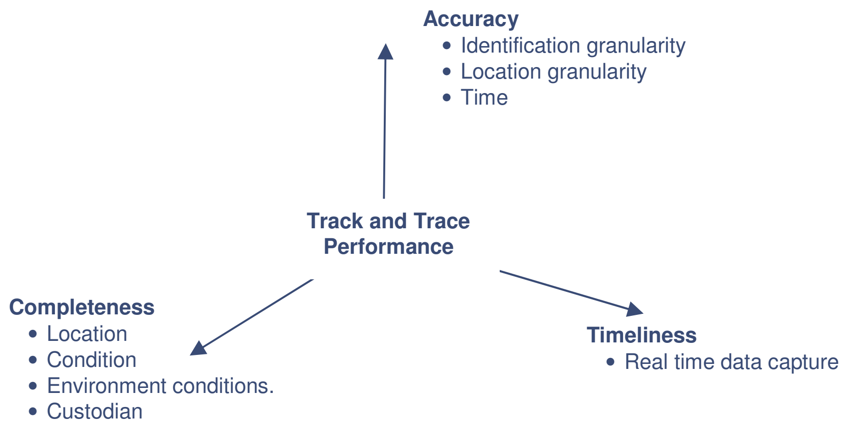

Fig. 4.1 Track and Trace Performance Components

We briefly analyze the contribution of RFID technology towards the improvement of each of the data quality dimensions and track and trace performance in general.

Timeliness. Traditional identification technologies (such as barcode) cannot support high speed data capture because of the required manual effort and lack of automated data capturing techniques. As a consequence, data are provided to information systems in batches, subject to significant time delays. RFID technology can enable the configuration of true high-speed, fully automatic data collection points that will provide the companies with near-real-time data about part and documentation location and state. Moreover, the deployment of RFID technology will allow the storage of maintenance data on the tag itself, providing real-time information to the engineers. Potentially, the EPC network can further contribute towards communicating these data in near-real-time to supply chain partners, enabling the “Internet of things” in which near-real-time communication with objects located anywhere is feasible.

Accuracy. Information accuracy can be improved through the use of RFID technology in many aspects. Above all, RFID will enable the identification of specific item instances rather than item types (although this is already implemented in some cases using barcode as well). RFID tags attached to items will provide accurate information for the location and state of each item for both inventory management and safety check purposes. In addition, RFID tags will be able to store maintenance and part life history information that can be accurately read and edited using wireless media, avoiding misreads and errors under demanding conditions (dirt on parts or access difficulty). Automatic data capture will also increase the accuracy of information on information systems, eliminating errors resulting from manual data handling. Finally, a network infrastructure (e.g. EPC network) can provide accurate location information about time and location of item observations across the supply chain, which can potentially be very detailed, locating items in specific facility sections or even specific shelves depending on the granularity of the data capturing network.

Completeness. RFID technology will greatly increase the completeness of traceability information that the supply chain partners have access to. RFID infrastructure can provide a complete set of information about an item, including a) the exact location and custody of each item at present and during its life history b) the condition of the item with regard to its quality, reliability and its maintenance history c) the environmental and operational conditions that the item has been subject to throughout its lifetime using embedded sensors on the tag (these might include temperature, humidity, vibrations and shocks) and d) potential tampering attempts information using tamper-evident seal sensors. In conclusion, RFID technology can provide companies with a complete set of track and trace information that can be utilized in many applications and processes of the aerospace industry.

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4.2. Business Benefits from Improved Track and Trace

Improved track and trace information quality through the use of RFID technology will enable the companies of the aerospace industry to optimize their supply chain operations and decision making. Figure 4.2 provides an overview of the business benefits that stem from improved track and trace.

Figure 4.2 Business Benefits from Improved Track and Trace

4.2.1. Operational Performance Improvement

Inventory Management. Improved track and trace of parts will provide suppliers and manufacturers with complete and accurate knowledge of inventory levels throughout the entire aerospace supply chain. Based on real time inventory visibility, manufacturers will manage to reduce their inventory holding costs by reducing their WIP stock levels. Moreover, information visibility will give suppliers the opportunity to adjust their production levels according to both their inventory levels and their customer's as well. In that way the JIT principles of lean manufacturing will be realized and order turn around times will be reduced. Knowing the exact stock life of life limited parts can also ensure the usage of the oldest parts first, resulting in the optimization of life limited inventory circulation. Improved track and trace can also help in the development of processes for dealing with misplaced parts, by easily detecting the parts that have stayed stationary in the warehouse for a very long period of time. The impact of improved track and trace on inventory management can be assessed by monitoring the inventory levels and comparing them to the present ones.

Order and Delivery Processes. Tracking the status of parts will enable manufacturers and airline companies to know exactly when they should order a replacement part. Furthermore, accurate information regarding part numbers and pricing data can help them generate accurate replacement orders. Based on the inventory accuracy that can be obtained through improved part tracking, replenishment processes will be optimized, as manufacturers will be able to order parts and spares only when they actually need them (JIT ordering process). The implementation of a comprehensive track and trace system can prove extremely beneficial for the logistics sector. Real-time monitoring of shipments' location and status, combined with complete and accurate information about inventory levels at warehouses and other key logistic nodes can ensure delivering the right material (parts), to the right customer, at the right time and in the right condition. Apart from the above, timely tracking of parts will enable automatic proof of delivery and therefore speed up financial procedures between companies. The business benefits from improved track and trace on ordering and delivery processes can be assessed by measuring and comparing the number of correct replacement orders and lead times with and without the deployment of automatic identification technology.

Optimized Maintenance and Repair Processes. Having available a complete and unambiguous maintenance and usage history for a part in near real-time, engineers will be able to measure all the variables that might cause a part to malfunction or fail, resulting in the reduction of mean-time-to-repair (MTTR). Moreover, by referencing a part's history and by tracking its current state, possibly by health monitoring systems (on board each aircraft), experts can predict, at a certain degree of accuracy, the part's future state and hence determine the time this should be serviced. In that way, the character of maintenance activities can be partly transformed from preventative to predictive, resulting in the increase of the mean time between process maintenance events and in more efficient use of replacement parts. Moreover, optimized maintenance and repair processes will have as a consequence reduced aircraft down time, boosting airline companies' earnings. The impact of improved track and trace on optimizing repair and maintenance processes can be measured by using metrics such as MTTR, average cost and time for unnecessary part replacement and mean time between process maintenance events.

Document Management. Improved track and trace will result in the efficient tracking of the documents that accompany parts, in case a document is detached from the respective part and misplaced. In that way, the number of "out of control" parts will be reduced, saving companies from shipping parts back to their suppliers and reducing the associated costs and time loss. Moreover, RFID tags may gradually replace or just reduce documentation, by storing most of the part-related traceability information on the tag itself. The impact of improved track and trace on document management can be assessed by measuring the percentage of lost or misplaced documents.

Reusable Asset Management. Aircraft tools and toolboxes are assets that are often used on a shared basis, either among a number of mechanics in the same repair centre (or MRO) or among different repair centres (or MROs). Their accurate and real-time tracking is considered critical, as it can help mechanical engineers save valuable time searching for tools and it can also minimize the possibility of tools' loss or theft. As far as tools' loss is concerned, tracking can ensure for instance that no tools are concealed during assembly and left on the plane. In that way, tool capacity utilization will be increased and tools' turn around times will be decreased. As in the case of parts, predictive tool maintenance is also feasible. Moreover, tool usage history allows optimizing the content of toolboxes, by removing tools that are used infrequently from the toolbox and placing them in the tool inventory. Apart from tools, efficient and real-time tracking of shipping containers will be enabled, resulting in their increased utilization as well. Business benefits from improved track and trace on reusable asset management can be assessed by measuring assets' turn around times as well as the percentage of lost or misplaced assets.

Optimized Manufacturing Processes. Improved part and WIP tracking in an internal manufacturing environment can help minimize the time spent searching for parts and WIP, having as a result the reduction of cycle times and the increase of productivity. Efficient and timely part tracking can also ensure that all parts are available for an assembly process, before locking constraining resources, such as fixtures and tools to an assembly process. Moreover, real-time monitoring of the dynamics of actual operations can enable effective configuration control and exception management, ensuring that the right part is installed in the right place and enabling automated check procedures. As a result, scrap production and costly rework will be greatly reduced, achieving increased quality assurance and accurate part configuration. Apart from part tracking, improved track and trace methods in an internal manufacturing environment can also automate tracking of workforce, tools and machines that have been used in the production and assembly processes. The business benefits from improved track and trace on manufacturing processes can be estimated by measuring exceptions and production cycle time with and without the deployment of RFID tags.

Part Recall and Warranty. Improved track and trace can give quick and efficient solutions to intractable problems, such as recalls of parts, jet engines, etc. For instance, in case of part failure, the genealogy analysis of a jet engine and its parts can help manufacturers quickly and accurately determine the batch that the parts belong to and recall faulty parts if necessary. Faulty parts should be tracked and removed, in order to avoid future failure problems. Having recorded the complete usage history of a part, including the conditions the part was subject to through its life cycle, warranty claim processing will be optimized, as the validity of a warranty claim will be easily confirmed by both sides. The business benefits from improved track and trace on part recall processes can be assessed by measuring the reduction in invested time and costs associated with part recalls. As far as warranties are concerned, the respective impact can be assessed by the average time required for processing a warranty claim.

Part Life Cycle Management. End of Life (EOL) decision-making can be greatly optimized through improved tracing using accurate and complete information about the usage, maintenance and repair history of the part. Moreover, the information recorded through a part's lifetime, such as failure information, can be used by engineers and designers to assess the performance of the part and possibly improve its design. The result is the creation of better parts with greater utility and extended life. The business benefits from improved tracing on EOL decisions can be estimated by measuring the average time needed to make correct EOL decisions.

4.2.2. Legislation Compliance

Regulation Compliance and litigation. Complete and accurate information on part manufacturing processes, state and maintenance history will enable aerospace companies to ensure that their parts and aircrafts comply with the Federal Aviation Administration (FAA) and Joint Aviation Authorities regulations (Suspected Unapproved Parts program etc.). More specifically, companies will be able at anytime to prove the genuineness of a part and its compliance with the airworthiness criteria set by the aforementioned regulatory authorities, as well as to ensure the availability of safety-critical items (e.g. life vests) required by the regulations. In that way, improved track and trace will save aerospace companies from fine-related costs, which may reach $100milion per year for the customers of aircraft manufacturers [26]). Moreover, manufacturers and airlines will be able to prove the aircraft airworthiness in case of accidents, minimizing litigation and compensation costs. The effectiveness of improved track and trace in minimizing the aforementioned costs can be assessed by measuring the reduction in fines and litigation costs resulting from the deployment of RFID technology.

4.2.3. Risks and Safety

Flight Safety. Accurate and complete information provided by RFID tags about the maintenance history and the current state of each part can help airlines and maintenance centres to accurately assess the reliability of the part and the probability of its future failure. In this way, part failures and the related flight delays will be reduced, resulting in increased flight safety and increased airlines' reputation. Moreover, reduced part failures will save companies from significant exception handling costs such as back up aircraft hiring in case of failure and compensations. The business benefits resulting from increased flight safety based on improved track

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and trace can be measured by recording part failures frequency as well as exception handling costs and comparing them to present figures.

Unapproved Parts. Unique part identification as well as accurate information on the complete history of custodians of a part can eliminate counterfeit parts in the aerospace supply chain. Part manufacturers (for new parts) and suppliers (for parts under service) typically keep records of the unique identifiers which have been "commissioned" for the genuine products they have released or serviced. The unique part identifier is also associated with the original hard-coded ID of the RFID tag. Typically, the hard-coded ID of each tag cannot be duplicated into another tag. As a result, all downstream supply chain partners will be able to authenticate each part by crosschecking its unique identifier and the corresponding hard-coded tag ID and by checking the part's exact route in the supply chain. A prerequisite for the above is the access capability of the supply chain partners to the manufacturers/ suppliers' aforementioned records. The impact of improved track and trace on eliminating the circulation of unapproved parts can be assessed by recording the number of events of early detected unapproved parts (before aircraft installation) and comparing it to current successful unapproved parts detection figures, as well as measuring decrease of unapproved parts circulation.

Shrinkage / Theft. Unique part identification in combination with the automatic monitoring of a part's exact location at a specific timestamp can significantly help towards eliminating shrinkage and theft phenomena. For example, as far as items in stock are concerned, if a part is removed from the warehouse, the information system will be updated automatically and possibly the personnel will be notified for a suspicious event. Moreover, even if theft is not prevented, the exact time that the part stopped being observed by the automatic observation system will be recorded and the cause of the part missing can more easily be detected. As a result, accurate information on the complete route of a part through its lifecycle can prove to be very useful. The impact of improved track and trace on reducing shrinkage phenomena can be estimated by recording the frequency of these phenomena and the percentage of the cases that theft was prevented or detected/solved/penetrated/unravel.

4.3. Summary

RFID technology will enhance traceability data quality by increasing information accuracy, timeliness and completeness. This will enable aerospace companies to optimize internal operations, increase flight safety, reduce risks across the chain and minimize costs regarding legislation compliance. Table 4.1 summarizes how the different types of aerospace companies will be benefited from the three dimensions of improved track and trace analysed in section 4.1.

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Category	Benefit	Track Completeness	Track Timeliness	Track Accuracy	Trace Completeness	Trace Timeliness	Trace Accuracy	Companies Benefited*
Operational Performance Improvement	Increased inventory accuracy	x	x	x			x	All
	Optimized order and delivery processes		x	x				All
	Reduced MTTR	x		x				A, RA, MRO
	Reduced costs and time for unnecessary part replacement						x	MRO, RA, A
	Predictive maintenance (maintenance according to use)					x	x	A
	Optimized manufacturing processes		x	x				AM, EM
	Reduced scrap and rework		x	x				AM, EM
	Product recall cost reduction	x	x	x	x		x	All
	Increased tool capacity utilization	x	x	x				RA. MRO
	Reduced costs from wrong part numbers on customer orders	x		x				AM, EM
	Automated warranty claim processing				x		x	All
	EOL decisions				x		x	AM, EM
	Document Tracking	x	x	x				All
Legislation Compliance	Safety regulation compliance				x		x	A, AM, EM
	Reduced costs from fines				x		x	A, RA, MRO
	Reduced litigation costs				x		x	A, AM, EM
Safety and Risk	Increased flight safety	x		x	x		x	A
	Reduced counterfeit products			x	x		x	All
	Improved company reputation	x			x			A, AM
	Reduced theft	x		x	x		x	AM, EM, OEM

x the dimension/component of improved track and trace information quality that can contribute to the respective business benefits

*: A: Airlines; MRO: Maintain Repair Overhaul; RA: Repair Agencies; AM: Airframe Manufacturers; EM: Engine Manufacturers; OEM: Original Equipment Manufacturers

Table 4.1 Business benefits resulting from improved track and trace information quality

5. Conclusions

5.1. Key Issues – Research Challenges

On-chip information. The attachment of RFID tags to items that need to be tracked and traced along with the information that these will carry is the cornerstone of the successful improvement of current track and trace practices. In particular, special attention should be paid to the information stored in the tags, so that it covers the different needs of companies across the aerospace supply chain. This information could vary from simple part attributes to maintenance and operation information for a long period of time, as analyzed in section 3.3.6 of this report. The definition of a comprehensive set of information to be stored on the tag is vital, as it will provide the basis for the optimization of many business processes, for example eliminating manual data entry and providing access to timely and accurate maintenance and operation information even when the aircraft is offline.

The definition of this comprehensive set of information requires capturing the information needs of all industrial partners and defining the information that each of them would expect the part to provide them with in the future. This would be the result of a detailed requirements analysis. Furthermore, a major research challenge for the next step of this study is the way that the information defined above will be stored effectively in an RFID tag, as special attention should be paid to efficient memory space utilization and data management.

Information synchronisation. Once information has been stored on the tag that the parts/ assets will carry, it shall be effectively and efficiently communicated to enterprise information systems and vice versa. Only if synchronized information between the tag and the information systems is ensured, will the use of RFID tags be of some value for the aerospace industry. In order for the companies to have access to timely information, information synchronisation should take place in a way that the timeliness of information provided by both the tag and the information system is satisfactory.

Information synchronisation when the part/asset is within a company's facilities and not yet mounted onto an aircraft should not be a major problem, as RFID interrogators should be available throughout its manufacturing and delivery process updating the information on the tag and updating the information systems at the same time. The real challenge emerges in the case where the part is installed in an aircraft and maintenance information should be updated both on the tag and the company's information system, while no network access is available during maintenance. The research group should study different approaches that will ensure maximum efficiency and effectiveness for this kind of data synchronization.

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Documentation Tracking. One of the most important aspects of the track and trace issue in the aerospace industry is documentation tracking. RFID technology should be used to effectively track documents across the aerospace supply chain, once these have been detached from their respective parts. The research group will have to study both the type of information that the tags attached to documents should carry and the type of RFID tags that should be deployed for documentation tracking. Moreover, special attention should be put in the design of the automatic reading points (interrogators) network that shall be installed in each company so that it covers all possible locations that a document might be placed, providing at the same time support for automating business processes such as part delivery and shipping.

Security/ Data Access Rules. Information security on the tag is vital for the success of track and trace processes based on RFID technology. Above all, the identification information stored on the tag must no be subject to any alteration/deletion. It should be written once at the beginning of parts life and not changed ever after. Other information (item attributes, maintenance information) shall be stored in a different data bank on the tag and shall be editable. However, different security access levels might need to be supported as not all companies across the supply chain will have the same read and edit rights on the data stored on the tag. The research group shall study different approaches in order to provide effective security for the data stored on the tag.

Information Sharing and Data Access Security Issues: Information sharing among the aerospace supply chain partners is one of the most important issues that need to be addressed and solved, in order to achieve enhanced information visibility across the whole supply chain. This is considered vital, as it will enable the aerospace companies to optimise their decision-making processes.

One of the key research challenges regarding this issue is the design of an overall system architecture that will enable efficient and secure information sharing between partners. Special attention shall be put on the scalability of the architecture, given the volume of the data that will be exchanged over it. Some issues that need to be considered in this context include security policies, data standards and general architecture (for example centralized information systems or distributed and propagating information). The research group shall study and evaluate the adoption of EPC network for this purpose.

5.2. Summary

The optimization of track and trace practices in the aerospace supply chain requires optimum solutions in some key issues that will enable the exchange of high quality information across the supply chain. These issues mainly refer to the information that the tags shall store, the way this will be done and the overall infrastructure through which this information will be communicated across the supply chain. When information is exchanged between partners then security becomes a critical issue that needs to be ensured. Once these key issues have been studied and agreed upon, they will provide the basis for optimized track and trace practices in the aerospace supply chain.

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