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SURVEY OF EXISTING AND EMERGING AUTOMATIC IDENTIFICATION AND TRACKING TECHNOLOGIES

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PREPARED

FOR

OO-ALC/LILE

BY

AGING LANDING GEAR LIFE

EXTENSION PROGRAM

PREPARED UNDER

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FOR OGDEN AIR LOGISTICS CENTER

HILL AFB, UTAH

PROJECT 39035

GENERAL ATOMICS

SIGNATURE PAGE

SURVEY OF EXISTING AND EMERGING AUTOMATIC IDENTIFICATION AND TRACKING TECHNOLOGIES

PREPARED FOR OO-ALC/LILE

BY

AGING LANDING GEAR LIFE EXTENSION PROGRAM

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INTRODUCTION

ıder the Aging Landing Gear Life Extension (ALGLE) Program, a survey of existing and emerging automatic entification and tracking (AIT) technologies was performed. OO-ALC/LILE requested a survey of existing and merging AIT technologies to assist with identifying and tracking landing gear parts.

OO-ALC/LILE can more effectively manage and maintain landing gear parts by implementing AIT technologies. AIT technologies can: improve maintenance record management; improve overhaul record management; improve shipping record management; improve labor efficiency and productivity. AIT technologies can also help to automate manufacturing, assembly, and quality control processes. All of the improvements reduce cost and increase supportability. The improvements are accomplished primarily through reduced paperwork, reduced error, and faster data collection. However, AIT technologies cannot completely eliminate human error since AIT technologies only assist in automating data collection. Note that it is technically feasible to track landing gear parts using the manufacturer's part number and serial number without using AIT technologies.

AIT technology generally consists of a label, a reader, and a database. The label is attached to the part and identifies the part with a unique code. Some labels have variable memory. The reader scans or interrogates the label, decodes the label, and then transfers the label information to the database.

There are several basic labels for AIT which include bar code identification, radio frequency identification, and memory button identification. In addition, there are several basic readers for AIT which include readers that download data directly to the database, readers that store data in batch before downloading the data to the database, and readers that use radio frequency to immediately transmit data to a database. One type of label and/or one type of reader may provide a solution to the problem. However, different AIT technologies may be coupled together to provide a solution to the problem.

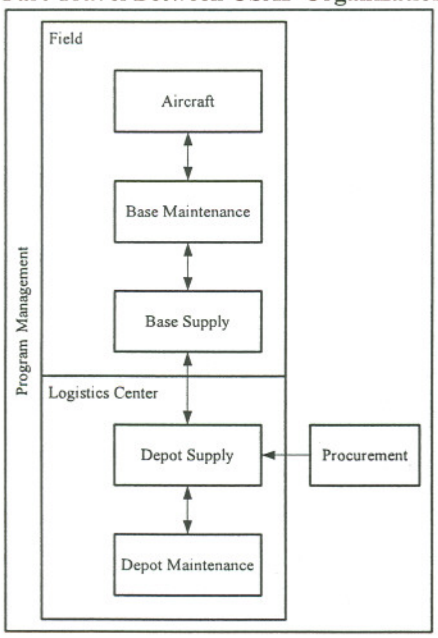
In all AIT problems, the solution depends on the data management system. Data management encompasses a broad range of functions but is primarily concerned with data collection, maintenance, and analysis. A data management system specifies a list of data fields to be collected, maintained, and analyzed. A data management system also delegates responsibility and authority to the entities that are responsible for collecting, maintaining, and analyzing the data.

To assist with the survey of existing and emerging AIT technologies, a simplified chart illustrating part travel within the USAF was created. The chart is in Figure 1. The chart depicts how parts may travel through USAF organizations. It also depicts how parts may travel within each organization. For example, in the field, parts may travel between aircraft. The field is primarily concerned with mission success that may be impacted by part failures, survivability, performance and availability. The chart indicates that the field operational requirements affect all the other organizations by determining the maintenance, supply, and procurement requirements. The chart provides a simplified overview of the USAF organizations that must be considered in order to develop a data management system.

OO-ALC/LILE has not provided a data management system description. Without a data management system description, only a partial solution to the OO-ALC/LILE AIT problem can be offered.

Figure 1: Schematic Diagram of Part Travel Between and Within USAF Organizations

Part Travel Between USAF Organizations



Field Requirements:
- Mission Success
- Flying Hours
- Sorties

Field Requirements Affected By:
- Part Failures
- Part Survivability
- Part Performance
- Part Availability

Field Requirements Determine:
- Maintenance Requirements
- Supply Requirements
- Procurement Requirements

Part Travel Within the Field

Aircraft Configurations Before Maintenance

Plane	A		
Assembly	a	b	c
Parts	1 2 3	4 5 6	7 8 9

B			Plane
d	e	f	Assembly
10 11 12	13 14 15	16 17 18	Parts

Aircraft Configurations After Maintenance

Plane	A		
Assembly	a	e	c
Parts	1 2 10	13 14 15	7 8 18

↔

B			Plane
d	b	f	Assembly
3 11 12	4 5 6	9 16 17	Parts

Part Travel Within Depot Maintenance

Disassembly

Assembly	a	b	c
Parts	1 2 3	4 5 6	7 8 9

→

Process Parts

- Wash
- Chemical Wash
- Plating/Paint Strip
- Bake
- NDI
- Machine/Grind
- Shot Peen
- Plate
- Anodize
- Paint

→

Reassembly

a	b	c	Assembly
1 4 7	5 8 9	2 3 6	Parts

OBJECTIVES

The objective was to survey existing or emerging AIT technologies to determine if it was technically feasible to track recoverable landing gear parts throughout the life of the part. A major objective was to find an AIT technology that would provide traceability for the entire life of a landing gear part. Readers were also considered in the survey. Tracking for recoverable landing gear parts includes, but is not limited to, field maintenance, base maintenance, base supply, depot maintenance, depot supply, and shipping.

A requirements list for labels for the survey was developed and is listed in Table I. The requirements list is prioritized and includes general requirements, engineering requirements, and specifications for labels.

Database development and data management for the AIT technologies were not considered. It is beyond the scope of this task to survey or develop database and/or data management systems to effectively use the AIT technologies.

Table I: AIT Technology Requirements

Requirements		
General Requirement	**Engineering Requirement**	**Specification**
Tracking		
Compatible with USAF Infrastructure		
Accommodate Technology Innovations		
Individual Identification	Unique Number Applied to Different Size Parts Applied to Different Materials	50 Characters 0.25 in x 0.25 in Steel/Aluminum/Titanium, Chrome/Cad Plate, Paint
Easily Read	Read Remotely (Distance) Applied Exterior Part Surface	12 in
Easily Maintained	No Cleaning No Charging No Field Replacements No Overhaul Replacements	
Operational Environment		
Maintain Original Design Requirements	Compatible with Different Materials No Stress Concentration Sites No Corrosion Sites No Heat Affected Zone No Electro-Magnetic Interference	Steel/Aluminum/Titanium, Chrome/Cad Plate, Paint MIL-STD-461/462/464
Survive Operational Environment	Wash Temperature Impact Vibration High Speed Rotation	H_20 / 100°F / 100psi 500°F / -100°F 500g 50g / 1000 Hz 50g
Overhaul Environment		
Survive Overhaul Environment	Wash Chemical Wash Plating/Paint Strip Bake NDI Machine/Grind Shot Peen Plate Anodize Paint Temper Etch	H_20 / 200°F / 100psi 250°F / Chemicals* Chemicals* 425°F 3000 A / Magnetic Fields Shot / 200psi 1000 A / Chemicals* 1000 A / Chemicals* Chemicals* Chemicals*
Shipping Environment		
Survive Shipping Environment	Impact Vibration Storage	100g 10g / 1000 Hz 100 Years
Economical		
Inexpensive/High ROI		

Chemicals*
Strong Organic Solvents
Strong Acids and Bases
Ammonium Nitrate
Hydrochloric Acid
Hydrofluoric Acid
Phosphoric Acid
Sulfuric Acid

SURVEY OF AIT TECHNOLOGIES

Labels

The candidate AIT labels are bar codes, memory buttons, and radio frequency identification (RFID) tags. The candidate AIT labels are illustrated in Figure 2.

Bar Codes

Bar codes are a pattern of light and dark elements that represent numbers, letters, or punctuation symbols. The encoding scheme defining the data represented by the patterns is called a symbology. Bar codes work on the principle of reflectivity. The reflectance differences of the light and dark elements are used to define a 0 or a 1. The pattern is interpreted by the reader as a digital string. Bar codes contain an invariant identification number.

There are one-dimensional bar codes and two-dimensional bar codes. A one-dimensional bar code is an array of parallel narrow rectangular bars and spaces. A two-dimensional bar code is an array of dots and spaces. Two-dimensional bar codes can encode more information than one-dimensional bar codes. Compared to a one-dimensional bar code, a two dimensional bar code can encode 100 times more in the same space. In addition, compared to one-dimensional bar codes, two-dimensional bar codes are able to sustain considerable damage and still maintain readability.

Bar codes have limitations related to the bar code and the reader. These include bar code size, reading distance, reading scan angle, and usefulness in environmentally adverse conditions. Currently, there are several standards for bar code symbologies. However, the USAF has not adopted any of the standards for part tracking.

Bar code labels may be applied to parts with an adhesive. Bar codes may also be applied to parts with direct part marking (DPM) processes such as dot peening, laser etching, chemical etching, and ink printing. For DPM, two-dimensional bar codes are usually adopted because of space and size limitations. For DPM, the two-dimensional bar code symbology Data Matrix™ is frequently adopted.

Memory Buttons

Memory buttons are computer chips that are mounted in a metal case. Memory buttons read or write data through direct physical contact with the reader. Memory buttons contain different amounts of information ranging from an invariant identification number to 64kB of variable memory that can be programmed by the reader. Typically, memory buttons have no computational power.

Memory buttons have limitations related to the button and the reader. These include button size and reading distance. Memory buttons are also limited by temperature operating range. An operating range from –4°F to 212°F is typical.

Memory buttons may be applied to parts with an adhesive. Memory buttons may also be countersunk into a part.

Radio Frequency Identification (RFID) Tags

RFID tags are transponders that communicate with RFID readers through the use of radio frequency signals. The reader sends out a radio frequency signal to the tag, and the tag transmits information back to the reader with another radio frequency signal. RFID tags may be read remotely with distances that range from a few inches to hundreds of feet. RFID tags contain different amounts of information ranging from an invariant identification number to 128kB of variable memory that can be programmed by the reader.

RFID tags have limitations related to the tag and the reader. RFID tags frequently do not read through metals and RFID tag antennas frequently detune when mounted to metals. RFID tags frequently do not operate in areas with high levels of electromagnetic interference. Currently, there are standards for RF transmitting devices. However, there is no international standard for RF transmitting devices and the Federal Communications Commission regulates the use of most RF transmitting devices in the US. Both issues could pose a potential problem for RFID tags.

RFID tags may be applied to parts with an adhesive. RFID tags may also be countersunk into a part, screwed into a part, or bolted onto a part.

Figure 2: Candidate AIT Labels

One-Dimensional Bar Codes

0 12345 67890 5

UPC

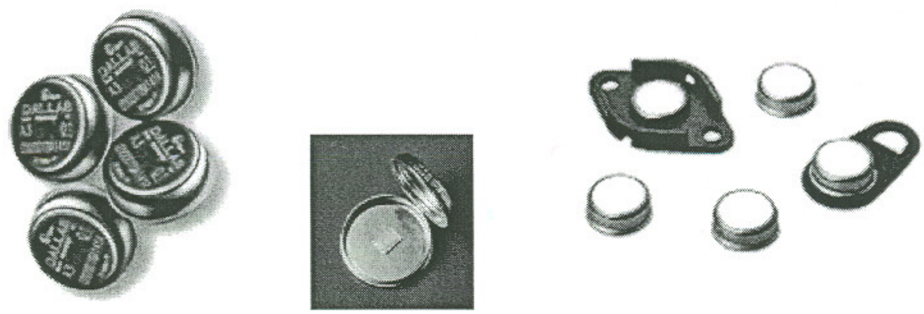
Code 39

Two-Dimensional Bar Codes

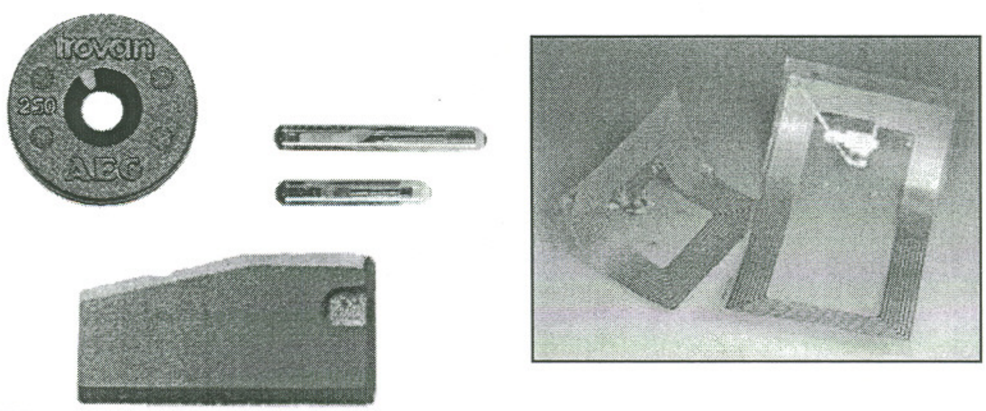
Data Matrix™

PDF 417

Memory Buttons



RFID Tags



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are several basic readers for part identification and tracking. They include readers that download data .y to the database, readers that store data in batch before downloading the data to the database, and readers .se RF to immediately transmit data to a database.

rently, there are not readers available that couple all of the different technology options. However, it is .nically possible to couple the technologies for various labels and readers. For example, currently there are ders for one-dimensional bar codes that use RF to transmit the data to the database, while there are readers for o-dimensional bar codes that are connected directly to the database. However, it is possible to couple a two-imensional bar code reader with RF.

One type of label and/or one type of reader may provide a solution to the problem. However, multiple AIT technologies may be coupled together to provide a solution to the problem.

Database Structures

There are several commercially available computer programs for data management. Database development and data management for the AIT technologies were not considered. It is beyond the scope of this task to survey or develop database and/or data management systems to effectively use the AIT technologies.

DISCUSSION

The existing AIT technologies were compared to the requirements that were generated for OO-ALC/LILE. A ranking method was developed to provide a method to compare, discuss, and evaluate the different labels. For the ranking method, numbers of 0, 5, and 10 were assigned to each requirement for respective estimates of improbable, unknown, and probable. The ranking method points out the advantages and disadvantages of the various AIT technologies and is listed in Table II.

Of the candidates, only bar codes that are applied with direct part marking (DPM) processes have the potential to provide traceability for the life of the part. None of the other candidates will provide traceability for the life of the part. Bar code labels, memory buttons, and RFID tags will not survive a landing gear overhaul environment. In addition, memory buttons and RFID tags have other limitations that prevent them from tracking parts for the life of the part. The limitations and benefits of memory buttons and RFID tags compared to bar codes are summarized in Table III.

Table II: AIT Technologies Compared to AIT Requirements

Requirements			Candidates*			
General Requirement	**Engineering Requirement**	**Specification**	**BC (DPM)**	**BC (Label)**	**MB**	**RFID Tag**
Tracking						
Compatible with USAF Infrastructure			10	10	5	0
Accommodate Technology Innovations			5	5	5	5
Individual Identification	Unique Number	50 Characters	10	10	10	10
	Applied to Different Size Parts	0.25 in x 0.25 in	10	10	0	0
	Applied to Different Materials	Steel/Aluminum/Titanium, Chrome/Cad Plate, Paint	5	5	5	5
Easily Read	Read Remotely (Distance)	12 in	5	5	5	5
	Applied Exterior Part Surface		5	5	5	5
Easily Maintained	No Cleaning		5	5	5	5
	No Charging		10	10	5	5
	No Field Replacements		10	5	5	5
	No Overhaul Replacements		10	5	5	5
			8	**7**	**5**	**5**
Operational Environment						
Maintain Original Design Requirements	Compatible with Different Materials	Steel/Aluminum/Titanium, Chrome/Cad Plate, Paint	5	5	5	5
	No Stress Concentration Sites		5	10	5	5
	No Corrosion Sites		5	10	5	5
	No Heat Affected Zone		5	10	10	10
	No Electro-Magnetic Interference	MIL-STD-461/462/464	10	10	5	0
Survive Operational Environment	Wash	H_2O / 100°F / 100psi	10	5	0	0
	Temperature	500°F / -100°F	10	5	0	0
	Impact	500g	5	5	5	5
	Vibration	50g / 1000 Hz	10	10	0	0
	High Speed Rotation	50g	10	10	5	5
			8	**8**	**4**	**4**
Overhaul Environment						
Survive Overhaul Environment	Wash	H_2O / 200°F / 100psi	10	0	0	0
	Chemical Wash	250°F / Chemicals*	5	0	0	0
	Plating/Paint Strip	Chemicals*	5	0	0	0
	Bake	425°F	10	0	0	0
	NDI	3000 A / Magnetic Fields	10	5	0	0
	Machine/Grind		5	5	5	5
	Shot Peen	Shot / 200psi	5	0	0	0
	Plate	1000 A / Chemicals*	5	0	0	0
	Anodize	1000 A / Chemicals*	5	0	0	0
	Paint	Chemicals*	5	5	5	5
	Temper Etch	Chemicals*	5	0	0	0
			6	**1**	**1**	**1**
Shipping Environment						
Survive Shipping Environment	Impact	100g	10	10	5	5
	Vibration	10g / 1000 Hz	10	10	5	5
	Storage	100 Years	10	5	5	5
			10	**8**	**5**	**5**
Economical						
Inexpensive/High ROI			5	5	5	5
			5	**5**	**5**	**5**
Overall Rank			7	6	4	4

Chemicals*

Strong Organic Solvents

Strong Acids and Bases

- Ammonium Nitrate
- Hydrochloric Acid
- Hydrofluoric Acid
- Phosphoric Acid
- Sulfuric Acid

Candidates*

Abbreviations

- BC (DPM) = Bar Code (DPM)
- BC (Label) = Bar Code (Label)
- MB = Memory Button
- RFID Tag = Radio Frequency Identification Tag

Ranking Method

- Improbable = 0
- Unknown = 5
- Probable = 10

Table III: Summary of Limitations of Memory Buttons and RFID Tags Compared to Bar Codes

Tracking

Compatible with USAF Infrastructure

The USAF is examining tracking avionics circuit boards with two-dimensional bar code labels.

The USAF is examining tracking of EGRES components with two-dimensional bar code labels and memory buttons.

The US Coast Guard determined that tracking aircraft parts in the field with two-dimensional bar code labels was feasible.

NASA is developing a standard to track parts with DPM two-dimensional bar codes.

Pratt and Whitney are tracking jet engine turbine blades with DPM two-dimensional bar codes.

Several commercial industries are using DPM two-dimensional bar codes to track parts.

Memory button technology is proprietary. The USAF would have to rely on a private company for support issues.

Accommodate Technology Innovations

All candidates may have technology innovations.

Two-dimensional bar code readers for DPM are being developed to read changes in mark depth which would allow impression marked two-dimensional bar codes to be read through a painted surface.

Individual Identification

Memory buttons may not be mounted to small components easily.

RFID tags may not be mounted to small components easily.

Easily Scanned

RFID tags may not transmit when mounted to metal or inside metal.

Operational Environment

Maintain Original Design Requirements

RFID would require qualification for electromagnetic interference to MIL-STD-461/462/464 for each aircraft.

Survive Operational Environment

Memory buttons have temperature operating ranges.

Memory buttons may not survive impact or vibrations.

RFID tags have temperature operating ranges.

RFID tags may not survive impact or vibrations.

Overhaul Environment

Survive Overhaul Environment

Memory buttons would not survive several overhaul processes including wash, chemical wash, baking, and plating.

RFID tags would not survive several overhaul processes including wash, chemical wash, baking, and plating.

CONCLUSIONS

Of the AIT candidates, only bar codes that are applied with direct part marking (DPM) processes have the potential to provide traceability for the life of the part by permanently marking a part.

The remaining AIT candidates, which were bar code labels, memory buttons, and RFID tags, will not provide traceability for the life of the part. However, with sufficient research and development efforts, with sufficient qualification testing, and also with an appropriate data management system, all of the AIT candidates have the potential to track parts within different USAF organizations.

RECOMMENDATIONS

General Recommendations

The general recommendations are provided to OO-ALC/LILE as a result of interviews with OO-ALC/LILE Landing Gear Engineers. Based on interviews, the central problem for OO-ALC/LILE is a lack of reliable engineering data such as the number of landings, the maintenance actions, the number of overhauls, and the overhaul actions for each landing gear part. The lack of reliable data is attributed to poor data collection throughout the USAF, and to fragmented USAF databases. These problems are problems with data management systems and the lack of a central database system for the USAF. Unfortunately, AIT technology cannot solve these problems. Based on the interviews, a proposed solution to obtain reliable engineering data is to store data with a device that is located on the part. It is questionable if storing data on the part will solve any problems. An additional database would likely be required for OO-ALC/LILE to perform the tasks of data management which include data collection, maintenance and analysis. The additional database would require data management for two sources of data, and it is questionable what additional information is provided by storing data with the part when the same information may be obtained with one database and a serial number tracking system.

Database development and data management are beyond the scope of this task. However, a serial number tracking system would have several benefits. The system may be used with all the USAF organization data systems and may unify tracking efforts within the USAF. The system may be used by different organizations to provide trigger mechanisms for their organizational function. The system would not collect redundant information. The system would not add unnecessary AIT technology to an aircraft. The system would be reasonably flexible because a minimum amount of information is stored with the part, and the data management would occur in a separate database. To obtain reliable engineering data, the system would track data for individual parts by tracking data for each aircraft by the aircraft tail number and by maintaining the configuration of each aircraft. Reliable engineering data for the number of landings, the maintenance actions, the number of overhauls, and the overhaul actions for each landing gear part would be obtained through the responsible USAF organization. Each organization would use bar codes to input data into their data management system.

It is recommended that OO-ALC/LILE focus its resources for database development, data management, and part tracking technologies to automate a serial number tracking system using bar codes. At the present time, a reasonable OO-ALC/LILE requirement would be to only consider AIT technologies other than bar codes if it can be demonstrated that a data management system and part tracking system with bar codes cannot provide OO-ALC/LILE with reliable engineering data. For a serial number tracking system, parts would be tracked with DPM bar codes and bar code labels that contain the serial number of the part. DPM bar codes have the potential to provide traceability for the life of the parts. Bar code labels have the potential to track parts except through an overhaul environment. Data would be transmitted to the database by downloading the data from the reader directly, or RFID technology may be coupled with the reader to transmit the data.

Specific Recommendations

The specific recommendations are provided to OO-ALC/LILE to assist them with an approach to improve and/or develop a data management system and a part tracking system for USAF Landing Gear Systems.

It is recommended that OO-ALC/LILE work with all the relevant USAF organizations including the AF AIT Program Office to improve and/or develop a data management system and a part tracking system for USAF Landing Gear Systems. The data management system should include reliability based management techniques and delegate responsibility and authority to the entities that are responsible for collecting, maintaining, and analyzing the data.

It is recommended that OO-ALC/LILE perform a detailed audit on the existing USAF data management system and part tracking system for landing gear parts. The audit should be geared towards improving the data management system and a part tracking system for USAF Landing Gear Systems.

It is recommended that OO-ALC/LILE perform a detailed audit on the existing commercial data management systems and part tracking system for landing gear parts. The audit should be geared towards improving the data management system and a part tracking system for USAF Landing Gear Systems.

It is recommended that OO-ALC/LILE improve the data management system and a part tracking system for USAF Landing Gear Systems based on the findings of the audits.

It is recommended that OO-ALC/LILE determine what AIT technologies are best suited to track landing gear parts based on the requirements for the data management system and the part tracking system.

It is recommended that OO-ALC/LILE test and evaluate DPM processes because bar codes that are applied with DPM processes have the potential to provide traceability for the life of a part. It is recommended that the research and development testing and evaluation occur in several phases including the evaluation of DPM overhaul process survivability, the evaluation of DPM operational survivability, and the evaluation of DPM effects on material properties.

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