IMPLEMENTING AN IN-SERVICE F-16 AVIONICS UNIQUE ITEM IDENTIFICATION PROGRAM

GRADUATE RESEARCH PROJECT

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Abstract

The office of the Undersecretary of Defense for Acquisition, Technology, and Logistics mandated the use of Unique Item Identification (UID) for all solicitations on or after January 1, 2004 for major modifications, equipment, and spares. This was only the first step toward uniquely identifying all DoD assets that meet certain cost and management criteria. Subsequent steps toward this goal include uniquely identifying DoD manufactured items as well as those assets currently in-service.

The purpose of this research was to identify factors the F-16 Unique Items Supply Chain Manager should consider to implement an effective and efficient UID program for its in-service F-16 avionics assets. The case study methodology was employed to capture lessons learned from previous in-service UID programs and evaluate alternative data label making and data label affixing strategies based on cost, timeliness, quality, and span of control. Research revealed a lack of senior leader support and poor communications as primary areas for improvement for future UID in-service programs. Considerations regarding which assets to mark, where to mark each asset, the possible need to alter technical drawings and acquire new air worthiness certification must also be calculated before marking activities commence. Analysis also revealed obtaining data labels from a printer service bureau and applying them using a seek and mark marking strategy as attractive alternatives for an F-16 asset marking effort. Although specifically focused on F-16 assets, the findings of this research are applicable to other organizations trying to establish their own in-service unique item identification program.

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Will Roberts

This Note is not to be included with the Acknowledgments – it is for information only: ***It is prohibited to include any personal information in the following categories about U.S. citizens, DOD Employees and military personnel: social security account numbers; home addresses; dates of birth; telephone numbers other than duty officers which are appropriately made available to the general public; names, locations and any other identifying information about family members of DOD employees and military personnel.***

Table of Contents

Page

List of Figures

List of Tables

IMPLEMENTING AN IN-SERVICE F-16 AVIONICS UNIQUE ITEM IDENTIFICATION PROGRAM

I. Introduction

Background

On 29 July 2003, the Department of Defense (DoD) established a policy mandating the use of Unique Item Identification (UID) within the DoD. The Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics issued the memorandum mandating UID for all solicitations on or after January 1, 2004 for new equipment, major modifications, and reprocurements of equipment and spares that fit the following criteria: (1) acquisition costs exceeds $5,000, (2) items that are either serially managed, mission essential or a controlled inventory piece of equipment or a reparable item, or consumable items or material where permanent identification is required, (3) items that are a component of a delivered item, if the program manager has determined unique identification is required, or (4) a UID or a Department of Defense-recognized UID equivalent is available (Wynne, 2003).

Unique identification is the ability to physically distinguish one item from another. Even though the items may be exact copies of each other, the unique identifier provides a means to distinguish between them. A unique identifier is a set of data for an asset that is globally unique and unambiguous. It ensures data integrity and data quality throughout the life of the item and supports multi-faceted business applications and users. UID provides the opportunity to differentiate an individual item from all other items throughout the DoD supply chain commencing with acquisition and terminating with disposal or reutilization (Leibrandt, 2004, Reboulet, 2004).

The Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics' UID policy issued on 29 July 2003 is only the first step toward a goal of uniquely identifying all DoD assets that meet certain cost and management directed criteria. Subsequent steps toward this goal include uniquely identifying DoD manufactured items as well as in-service assets. UID will be required for DoD-manufactured assets produced after 1 January 2005. And in the near future, UID policy will be expanded to include marking and reporting of in-service assets which is the focus of this research (Reboulet 2004). For the purpose of this research effort, in-service or legacy assets are defined as the culmination of items in a supply warehouse, in transit, undergoing repair or modification, or currently being used on a weapon system.

Although serial number tracking and product marking have been widely used in the aviation and technology industry for some time, in most cases the unique identifier is applied at the source of manufacture prior to end item sale (Vijayan, 2004). Air Force Material Command (AFMC) established a draft policy in May 2004 outlining how the Air Force's three Air Logistics Centers (ALCs) will uniquely identify the items each produces. This policy directs the use of a printer service bureau (contractor) to create data plates to be applied to the items manufactured by the Air Force depots that meet the criteria set forth in the DoD policy letter directing UID of tangible items (Reboulet, 2004). AFMC, however, has not fully investigated the potential challenges of implementing a service-wide UID strategy for identifying in-service assets. AFMC has also yet to consider the advantages and disadvantages associated with the alternative methods of procuring (purchasing the UID equipment and making the data labels in house or contracting out this requirement) UID data plates and the various strategies for affixing the labels once acquired.

Problem Statement

Air Force Material Command must develop policies and procedures to address how it will efficiently and economically uniquely identify the untold numbers of legacy assets in its vast inventories.

Research Objectives

There are two goals of this research. The first is to analyze how other organizations have implemented unique item identification programs and provide a roadmap for the Ogden Air Logistics Center's F-16 Unique Items Supply Chain Manager to implement its own UID program. Secondly, to analyze alternatives the F-16 Unique Items Supply Chain Manager located at the Ogden Air Logistics Center should consider when selecting the data label making and data label affixing strategies required to implement a UID program. This research provides background on the combined benefits of Serial Number Tracking (SNT) and Automatic Identification Technology (AIT) which comprise UID and analyze alternatives available to the Air Force to implement UID effectively and efficiently within one branch of one Air Logistics Center.

Research Question/Investigative Questions

The purpose of this research is contained within the overall research question, "What factors should the F-16 Unique Items Supply Chain Manager consider to implement an effective and efficient in-service UID program for the F-16 avionics LRUs it manages?" To answer this high-level, overarching question, four investigative questions must first be answered.

1. How have in-service UID programs been implemented before within the DoD and civilian communities?

2. What problems can be expected when starting an in-service UID program and what can be done about them?

3. What are the advantages and disadvantages associated with the data label making alternatives?

4. What are the advantages and disadvantages associated with the data label affixing alternatives?

Scope and Limitations of Research:

Although there are two broad methods available to uniquely identify assets (direct part marking and identification tags), this research explores the use of identification tags (data plates or data labels) as that is the desire of the USAF Automated Information Technology (AIT) Program Management Office, the sponsor of this research. Furthermore, this research only explores the cost implications of acquiring data plates or data labels for the end items managed by the Ogden Air Logistics Center's F-16 Unique Items Supply Chain Manager.

The scope of this research effort is limited is several ways. This research does not attempt to determine all possible Shop Replaceable Units (SRU) that could possibly be uniquely identified. Instead, the research focuses on uniquely identifying Line Replaceable Units (LRUs) only. Although the importance of where or how to apply data plates to assets will be addressed, it is discussed in general terms. Furthermore, this research only briefly discusses the importance of the computer systems required to capture, record, and aid analysis of data collected as a result of uniquely identifying assets. Specifics associated with where to place UID data labels on each avionics LRU and identifying the appropriate data label material for each LRU are left to the responsible engineering and equipment specialist personnel. Additionally, decisions concerning the acquisition and integration of computer systems and bar code scanning equipment required to make UID a viable program are left for the appropriate information technology personnel working in concert with maintenance, supply, and finance personnel.

Methodology

This research used a multi-case study methodology to address the research question and subsequent investigative questions. Leedy and Ormrod define case study as a research methodology where a particular individual, program or event (or perhaps a very small number) is studied in depth for a period of time (Leedy and Ormrod, 2001).

Information regarding the implementation of in-service UID programs by the commercial sector and the DoD was collected and analyzed. Information took the form of written reports and policy letters, and included data and opinions collected from interviews with members of organizations who implemented UID or related programs.

The responses from the interviews and other pertinent information was analyzed to identify areas to benchmark from as well as areas to improve upon.

The number and type of avionics assets requiring UID within the F-16 avionics LRU inventory was first established to scope the level or effort required to complete a 100 percent marking effort. To provide insight to the most economical method of procuring data plates, unofficial cost estimates from contractors for data plate manufacture were compared to costs associated with the ALC purchasing its own marking equipment.

Implications

The results of this research have the potential to impact not only the F-16 Unique Items Supply Chain Manager and its UID implementation activities, but may be relevant for any organization trying to uniquely identify in-service assets. The lessons learned from other UID implementation programs apply to most organizations within the DoD trying to implement their own UID programs. Although the analysis of the data label making and data affixing strategies focuses on F-16 avionics LRUs managed at the Ogden ALC, the findings of this research are applicable to other organizations trying to establish their own data label making and data label affixing strategy.

Research revealed a lack of senior leader support and poor communications as primary areas for improvement for future UID in-service programs. Considerations regarding which assets to mark, where to mark each asset, the possible need to alter technical drawings and acquire new air worthiness certification must also be calculated before actual marking activities commence. Analysis also revealed obtaining data labels from a printer service bureau and applying them using a seek and mark marking strategy as attractive alternatives for an F-16 asset marking effort.

Summary

This chapter discussed the background and problem, described the research and investigative questions, and provided an overview of the research's scope and methodology. The remaining four chapters include the Literature Review, the Methodology, the Analysis and Results, and the Conclusions.

The chapter two literature review explores why the DoD implemented its UID policy, provides a brief history and benefits of serial number tracking, AIT, and the various types of bar codes currently used by the DoD. It also focuses on lesson learned from cases where UID or related efforts have been implemented in the past.

Chapter three outlines the case study research methodology and describes how the data was collected and analyzed.

Chapter four addresses and answers each of the four investigative questions with supporting data. Data analysis, theories, and conclusions, based on the analysis are also presented.

Chapter five highlights limitations encountered during research, and provides recommendations for future research. Final recommendations are included within this chapter.

II. Literature Review

Overview

This chapter starts by providing background for why the DoD established its UID policy and outlines what the Department ultimately hopes to achieve by uniquely identifying its assets. Furthermore, since UID is essentially the combination of Serial Number Tracking (SNT) and Automatic Information Technology (AIT), it is important to fully understand both of these concepts, their asset management benefits, and their combined role in forming UID. Therefore, SNT and AIT are defined and the benefits derived from their use are presented. A brief history of AIT follows outlining the requirements of an AIT system and provides descriptions of the DoD approved bar code symbologies. Finally, specific cases where UID or related efforts have been implemented in the past are discussed with special emphasis placed on lessons learned from past implementation experiences.

Origin of UID

The General Accounting Office (GAO) and other audit agencies have repeatedly identified deficiencies with the Department of Defense's asset management program. Deficiencies cited by the GAO include: a lack of complete and reliable information on inventory, property and equipment, and the inability to verify the existence of inventory or substantiate the amount of inventory or property reported. These longstanding problems with visibility and accountability are a major impediment to the federal government achieving the goals of legislation enacted by the United States Congress in the1990s (GAO, 2002).

Designed to specifically address and correct accountability concerns, the Chief Financial Officers Act passed in 1990 was the first legislation to be enacted. Subsequent related legislation includes the Government Management Reform Act of 1994, the Government Performance and Results Act of 1993, and the Federal Financial Management Improvement Act of 1996. Each piece of legislation was intended to improve financial management, promote accountability and visibility, reduce costs, and emphasize results-oriented management within the Federal Government. Although, the DoD has worked hard to address the requirements of these laws, it remains challenged to provide useful, reliable, and timely inventory data required for a wide variety of daily management decisions. The GAO believes the lack of reliable information impairs the DoD's ability to:

(1) Know the quantity, location, condition, and value of assets it owns

(2) Safeguard its assets from physical deterioration, theft, loss, or mismanagement

(3) Prevent unnecessary storage and maintenance costs or purchase of assets already on hand, and

(4) Determine the full costs of the programs that use these assets.

Consequently, the risk is high that DoD decision makers are not receiving accurate information for making informed decisions about future funding, oversight of programs involving inventory, and operational readiness (GAO, 2002). To date, no major part of the Department of Defense's operations has passed the test of an independent financial audit because of pervasive weaknesses in the Department's financial management systems, controls, and operations. Despite genuine progress, ineffective asset accountability and lack of internal controls continue to adversely affect visibility over inventories and weapon systems. Additionally, unreliable cost and budget information negatively affect the Department's ability to effectively measure performance, maintain adequate fund control, and reduce costs (GAO, 2001). The DoD hopes to assuage many of its accountability and visibility problems by implementing UID.

The DoD’s logistics community has actively advocated the use of various bar coding schemes for several years to improve visibility and configuration management. Under the auspices of the Future Logistics Enterprise initiative, giants in the wholesaling, commercial retailing, and transportation industries were benchmarked to determine the methods they have used to effectively manage their supply chain and inventories. Use of bar codes and other AIT was defined as one important element. The DoD, together with industry, evaluated various bar code standards and their underlying technology and a consensus was reached on some key fundamentals (Sumpter and Will, 2004).

These UID fundamentals are similar to the practices employed by the United States Social Security Administration to assign and track social security numbers to U.S. citizens. Every UID mark placed on an asset will be unique and must remain with the asset for its entire life. Additionally, the mark can not change over the life of the item. When the item is marked, a “birth record” is created and recorded to ensure its uniqueness. When the asset reaches the end of its useful life, either through destruction or disposal, its UID can not be reused. To capture the "birth records", the DoD is developing a UID registry which entered its final testing stage in February 2004 (JRIB, 2004).

UID Expected Outcomes

By uniquely identifying assets that meet certain cost and management criteria, the DoD hopes to reap several benefits. These include:

(1) Enabling faster production ramp-up and accelerated engineering change processes by achieving a seamless transfer of product data (specifications or bills of material) into the supply chain

(2) Achieving clean audits on item portions of DoD financial statements

(3) Reducing the risk of undetected theft and loss, unexpected shortages of critical items, and unnecessary purchases of items already on hand by providing physical controls and accountability over tangible items

(4) Improving asset visibility and life-cycle management

(5) Providing the industry supply chain with the ability to supply innovative tailored products and strengthen customer relationships, fostering better buyer-vendor partnerships (Leibrandt, 2004).

One way to achieve an asset's uniqueness is through the application of serial numbers. Although many DoD assets already possess a serial number, most of these assets are not tracked by their serial number. Consequently supply and maintenance related activities associated with a particular asset are not captured by existing data systems. As we shall see, Automatic Information Technology can initiate and augment current efforts to track data associated with assets uniquely identified by serial number.

Serial Number Tracking

The ability to track repairables, selected consumables, and other designated property from purchase to disposal is a goal that has existed since the beginning of repairables management. SNT can provide just such a capability. SNT is the closed-loop cradle-to-grave tracking and data capture of maintenance critical serialized parts that facilitates their management through the supply chain (Bearing Point, 2004; NSSC, 2000). SNT of assets is not new to the DoD or commercial industry. The DoD has serially tracked numerous items, such as weapons (conventional and nuclear), cryptographic equipment, and high-cost reparable parts since the 1970s. Although helpful, many DoD serial number tracking systems are currently paper-based, making SNT a tedious, error-prone task (Oliver, 2003). Despite its current limitations, tracking assets by serial number remains a beneficial concept that can offer many benefits to both the supply and maintenance communities if performed correctly. Tracking assets by serial number can identify poorly performing items, decrease premature disposal of items, drive reliability management, and enable warranty management.

Identify Poor Performing Items

By having visibility of individual items rather than groups of like items, item managers are able to gain visibility of trends in items that fail. Increased visibility enables the development of management metrics to better monitor mean time between failures (MTBF) and patterns of similar repair work. Proper monitoring and analysis of MTBF and repair data is the first step to implementing corrective actions that can increase the time between failures, prevent unnecessary down time for maintenance, and free maintenance resources for other needs (USAF DSC/IL, 2003). This concept is the heart of the Air Force's Bad Actor Program.

Defined by Technical Order 00-25-258, the Bad Actor program was specifically created to identify problematic assets. These include assets that have a lower MTBF than the general population, have a history of failures that indicate a latent, unidentifiable defects, and parts that fail on the weapon system, but repeatedly retest Okay. The Air Force’s Bad Actor program currently fails to identify all poorly performing assets that fit the definition of a bad actor. One of the primary reasons for the program's lackluster results lies in the inability to collect complete and accurate information associated with individual repairable assets (Atherton, 1997). In order to track individual repairable assets, serial numbers must be used. Without their use, the Bad Actor Program will continue to fall short of its intended purpose.

Decrease Premature Disposal of Items

Individual item visibility allows more informed decisions on individual retention rather than fleet based decisions that are often generalized and can lead to the disposal of useful items (USAF DSC/IL, 2003). When disposing of excess inventory, accurate maintenance and usage history allows managers to target items with the lowest reliability or highest operating hours or cycles, thereby saving the most reliable items for continued use (USN SNT, 2004). In addition, improvements may be made to simplify the process of validating the receipt of material shipped for disposal which can reduce the risk of property loss, undetected theft, and fraudulent or counterfeit parts (Bearing Point, 2004).

Drive Reliability Improvement

SNT can provide reliability improvements through asset visibility of faulty equipment. Asset visibility allows unreliable equipment to be immediately removed from service in order to eliminate additional parts malfunction and further use of potentially hazardous equipment. This can improve management of the manpower required to correct faulty equipment while enabling additional time to help ensure the use of reliable parts (Bearing Point, 2004). Furthermore, the improved visibility of assets can enable decision makers to more accurately determine reliability and maintainability metrics and establish maintenance policies to improve the fleet health of a weapons system (USAF DCS/IL, 2003).

Enable Warranty Management

Many newer weapon systems have industry logistics support arrangements that require the Air Force to specifically manage the use, repair, and storage of items subject to a commercial warranty (USAF DSC/IL, 2003). Although localized efforts exist, the Air Force does not have an effective service-wide warranty management program. Generally speaking, it is currently impossible to identify items under warranty and issue them from supply according to their warranty expiration date. Consequently, asset warranties may expire while in inventory prior to their first use (US Navy SNT, 2004). Additionally, some assets under warranty are being repaired by the Air Force instead of the Original Equipment Manufacturer (OEM) as identified under the terms of the warranty agreement. As a result, the Air Force, in effect, is paying to repair assets for which the repair costs have already been prepaid as part of the purchase price. Quality SNT can enable effective warranty management and eliminate its position as a high cost driver in the Air Force today (Bearing Point, 2004).

Because of the inherent benefits of SNT, the Navy and the Air Force each established their own SNT programs in recent years. The Navy was first by establishing their concept of operations in September 2000 (NSSC, 2000). The Air Force developed its concept of operations in February 2003 (USAF DSC/IL, 2003).

Effective SNT

Most of the potential benefits associated with serial number tracking discussed above are currently not being realized. This shortcoming can be attributed to two sources. First, the limited number of existing databases designed to record data by serial number do not contain accurate data. And second, an excessive amount of time and labor is required to enter the maintenance or supply data related to the serial numbered assets. To be truly effective, serial number tracking must be combined with the inherent advantages of automatic identification technology to improve data accuracy and reduce the amount of time and effort required to capture the desired data related to serial numbered assets.

Automatic Identification Technology

AIT is a suite of technologies that enables and facilitates the automatic capture and transmission of source data, thereby enhancing the ability to identify, track, document, and control material and maintenance processes (DUSDL, 1997). The primary benefits of AIT lay in improved data entry accuracy, increased data entry speed, and enhanced item identification ability. In relaxed and ideal working conditions, key punch operators typically make one mistake for every 30 - 300 character entries. This error rate can increase dramatically when workers are operating under less than ideal conditions, (e.g., increased work loads, time constraints, uncomfortable temperatures, etc.) (Air Force AIT, 2004; SystemID, 2004; Krizner, 2000; Weiss, 1997). Automatic identification systems provide higher processing rates than human data entry and have a data recording accuracy rate of almost 100 percent with some scanners documenting error rates as low as one error per many millions of characters scanned (Chaneski, 2000; Singer, 1999). In addition to the cost savings associated with increased speed and accuracy in automating data collection, data transfer, and the effort associated with error correction, many other benefits can result from item identification. Because of its recognized benefits, the DoD established a logistics automatic identification technology concept of operations in November 1997 to develop a DoD-wide framework for the use of AIT within the logistics community (DUSDL, 1997).

AIT encompasses a variety of read/write data storage technologies that can be used to capture an asset's identification information. These technologies include bar codes, magnetic strips, integrated circuit cards, optical memory cards, contact memory buttons, and radio frequency identification tags. AIT also includes the hardware and software required to create the storage devices, read the information stored on them, and integrate the stored data with other logistics data (DUSDL, 1997). Bar Codes are the oldest and most dominant form of AIT medium used by the DoD and Commercial industry (Csorba, 2002). Weiss even goes so far as to proclaim the introduction and use of bar codes as one of the most significant technological advances in business and industry (Weiss, 1997). To implement its new UID policy, the DoD is relying on the maximum extent possible on international standards and commercial item markings or bar codes already in existence (Leibrandt, 2004). To understand UID, it is important to comprehend the technology associated with bar codes, the various types of bar codes, the equipment required to produce and read bar code labels, as well as the guidance provided by the DoD for using bars codes to identify assets.

Bar Codes

The technology associated with bar codes is not new. The concept was created in 1952 by Norman Woodland and Bernard Silver, but it took more than 20 years for the idea to be implemented in the U.S. (Scanlon, 2003; Saccomano, 2003). More than five billion bar codes are scanned each day around the world and that number is increasing rapidly as the codes' uses are extended beyond the checkout counter and into a wide variety of everyday applications (Scanlon, 2003). Today, bar codes are stamped on every conceivable product, from disposable razors to heavy equipment. One reason for their overwhelming acceptance is their ability to offer the simplest, most accurate, and most cost-effective approach to accurately encode a host of information about an asset and its ownership (Weiss, 1997). For this reason, much attention and effort has been applied toward further development of bar codes.

Bar Coding Requirements (Printers or Marking Equipment)

Four primary components are required to establish a basic bar code system for automatic data collection. They include: a bar code printer or marking equipment, a label or mark for item tracking, scanning or reading equipment for data collection, and an external database for bar code data capture and relay (SystemID, 2004).

The bar code printer or marking equipment provides the first vital component part in tracking information by creating the bar code utilized in item tracking (SystemID, 2004). The importance of precise bar code printing or marking can't be overstated since success or failure of the whole set of integrated technologies comprising the entire bar code system depends on the print or mark quality of the bar code. Bar code printers come in a wide range of configurations and use a wide variety of label mediums or substrates and marking technologies to produce labels with vastly different durability and chemical resistance properties (Shipco, 2004). To have a successful bar code system, it is important for the bar code labels to be suited to the environment in which they will be used and stay affixed to the item for the desired amount of time (SystemID, 2004). Thermal transfer, direct thermal, ink jet printing, laser printing, screen printing, and engraving are a few of the more common application types. The thermal transfer process uses heat to transfer a resin or wax-based ink from a ribbon coated on one side to a blank label. The thermal transfer method of mark application is the most effective way of producing rugged labels (SystemID, 2004). Direct thermal printers selectively heat a coated plastic or paper label stock to form a label. These printers are inexpensive and are consequently increasing in popularity, but do not produce a rugged label that tolerates outdoor use. Ink jet printing can be accomplished using a standard office printer and appropriate software loaded on a personal computer. Although deficiencies in outdoor durability are being addresses, this printing method remains inexpensive but best suited for indoor use. Laser printing is another inexpensive label producing technique that produces labels that when coupled with an overlaminate has excellent outdoor durability. Engraving is one of the more expensive marking technologies. Accomplished by scratching the appropriate symbology into metal or two-ply plastic, this system provides good outdoor durability and fair chemical resistance. The most durable of all printing techniques is screen printing. This process applies a very thick layer of pigment (both solvent and ultra violet inks) that extends outdoor life and imparts good chemical resistance (Polyonics, 2004). As with bar code printers, there are many different types of bar codes.

Bar Code Labels/Marks

Over the years, approximately 225 bar codes have been developed, but fewer than a dozen are currently in common use. The different types of bar codes are known as "symbologies" and are tailored to particular industry functions (Saccomano, 2003). Bar code symbologies come in two general varieties. They can either be linear or two dimensional in configuration. A linear bar code symbology consists of a single row of dark lines and white spaces of varying but specified height and width (SystemID, 2004). In its most familiar form, a linear bar code is nothing more than a pattern of alternating dark stripes or blocks and white spaces. Information is encoded into these patterns by varying the width of the spaces and stripes. The amount of information that can be encoded by linear bar code symbology is more limited than that of the two dimensional symbology (Singer, 1999). The most common type of linear bar code is the Universal Product Code (UPC).

LINEAR

Figure 1. Linear Bar Code Example

Two Dimensional Bar Codes

Two dimensional bar code symbology is more sophisticated than linear bar code symbology. A two dimensional symbology can either be configured in a stacked or matrix format and in many ways is superior to linear symbology. Two dimensional bar codes are special codes which “stack” information in a manner allowing for up to 100 times more information storage in a similar amount of space as linear codes (SystemID, 2004; Vijayan, 2004). Another advantage of two-dimensional symbologies are their built-in error correction capability for reading damaged symbols. Redundancy and error correction logic are built into two dimensional labels that enable the readers to capture the data, understand it is damaged, and determine what data should be in the damaged location (Trebilock, 2003). This use of code redundancy and error correction means that in most cases a two-dimensional bar code can suffer up to 30 percent damage and still remain readable (Worlidge, 2002).

In recent years, due to their increased capabilities, two dimensional bar codes have received more intense focus and an increased developmental effort. Several types of two dimensional bar codes have been developed and include Code 49, Denso, Snowflake, Dot CodeA, and Data Matrix. Data Matrix is currently regarded as being technologically superior and is the symbology now recommended by organizations representing the electronics, automotive, aerospace, and semiconductor manufacturing industries.

2-D SYMBOLOGY

Figure 2. Stacked Bar Code Example

Figure 3. Data Matrix Bar Code Example

A Data Matrix bar code is characterized by continuous lines along two adjacent sides (finder bars) and alternate marks and spaces (density bars) along the other two sides. Finder bars are used by the reading software to orientate the code while the density bars are used by the software to check the printing density. The area enclosed by the finder and density bars consists of marks and spaces in a matrix that contains the encoded data. Almost any size data matrix can be created. Current sizes range from 500 micros in diameter at the small end of the scale, and can be as large as 356mm in diameter, but the majority of codes are between 3 and 175mm. Depending on size, Data Matrix bar codes can contain between one and 36 data regions. Coding algorithms can encode numerical sequences, alphanumeric character strings, or 8-bit ASCII code. This coding on newer symbologies allows a maximum data capacity of 3,116 numeric digits, 2,335 alphanumeric characters, or 1,556 8-bit ASCII characters (Worlidge, 2002). Different bar code symbologies require different devices to read the code.

Scanning/Reading Devices for Data Collection

The data collection phase occurs through the use of readers and scanners that instantly and accurately read, capture, and decipher the information contained in the bar code symbology (SystemID, 2004). The two general categories of bar code readers are contact and non-contact. Contact readers are usually hand held units, while non-contact readers can be either stationary or hand held. Since contact readers must either touch or come very close to the bar code symbol, they are a good choice when the item can’t be moved past a scanner or where the label cannot be placed where it is easily seen. Light pens or pen wands are the most popular type of contact readers and have the ability to replace the traditional clipboard and keyboard data entry collection methods of yesteryear (Weiss, 1997).

Non-contact readers include stationary and hand-held units. A non-contact reader does not have to come in contact with the bar code symbol in order to read it. In fact, some scanners can read bar codes up to a distance of several feet, depending on the code's size and scanner design. Since non-contact scanners emit either a moving or stationary beam, they are often referred to as laser scanners although not all of them use laser beams as a light source (Weiss, 1997). Once the information contained on the bar code is scanned, it must be recorded.

Data Capture via an External Database

The fourth and final component to establishing a bar code system is the external data base. Existing bar code applications commonly rely on the availability of external data computer systems to identify a unique bar code with pertinent information about the asset from a related database. The computer collects and interprets the data transmitted from the scanner/reader and links the bar code reference point information to a detailed data file on that item. The data files can contain a wide variety of information about the item to include manufacturer, date of manufacture, purchase price, and lot number. This information can be specified to the needs of the owning agency and is only limited by the storage capability of the bar code symbology (SystemID, 2004). The DoD has already taken steps to standardize the type of data contained within and appearance of the bar code symbologies it uses.

Military Standard 130L

In October 2003, the DoD updated Military Standard (MIL-STD) 130L, Identification Marking of U.S. Military Property. MIL-STD 130L provides insight and guidance for the implementation of Machine-Readable Information (MRI) processes for item identification marking. MIL-STD 130L identifies two general methods of applying MRI to DoD assets and the minimum set of data that must be included within the mark. The required marking can be applied to an identification plate, tag, or label and then securely fastened to the item. Conversely, the MRI may be applied directly to the surface of the item which is called direct part marking. Direct part marking applications include dot peen, laser, and electrical-chemical etch marking (MIL-STD 130L, 2003).

As with most technological applications, bar code symbology is standardized by the International Organization for Standardization/International Electrotechnical Commission (ISO/IEC). The DoD along with its international partners clearly prefers using the constructs described in ISO/IEC 15434 to achieve interoperability in business intelligence. However, adding human readable text to the existing format requires ISO approval. During the two year approval cycle, the DoD allowed interim use of the desired format. On 20 May 2004, the International Coordinating Group approved the use of ISO/IEC 15434 syntax with Text Element Identifiers (TEIs) as an alternative item marking method (UID, 2004).

The DoD's desired marking format includes Data Matrix, linear bar code, and human-readable information (Figure 4). When space is limited, the linear bar code portion may be omitted. And to accommodate severe space limitations, supplemental human readable information may also be omitted leaving only the data matrix bar code (MIL-STD 130L, 2003).

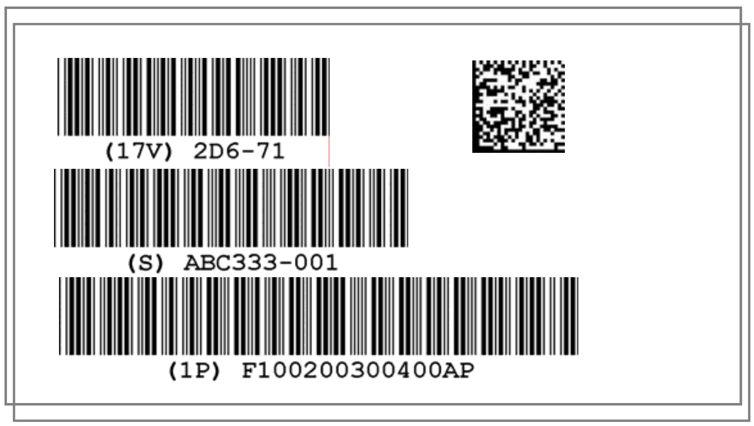

Figure 4. MIL-STD Data Matrix, Linear Bar Code, and Human-Readable

A UID number is a combination of four data elements. These elements include the assigning agency for manufacturer identification, the manufacturer identification, the part number, and the serial number (Reboulet, 2003). MIL-STD 130L identifies two constructs to uniquely identify assets: serialization within the enterprise identifier, Construct #1; and serialization within the part number, Construct #2. Under construct #1, the UID is established by using a two-part label. The manufacturer's identification and a unique serial number for that manufacturer are permanently recorded in the top label, while the part number is captured in the bottom label. When an item is modified and the part number is changed, the bottom portion of the UID label is replaced with a label containing the current part number (MIL-STD 130L, 2003).

Figure 5. Marking Construct #1 Example (Modified Part)

Under Construct #2, the item UID is established by using the manufacturer's identification, product part number, and a serial number unique for that part number. All three data elements are included on a single permanent label. If the part is modified, an additional bottom label containing the new part number is affixed to the asset (Figure 6) (MIL-STD- 130L, 2003).

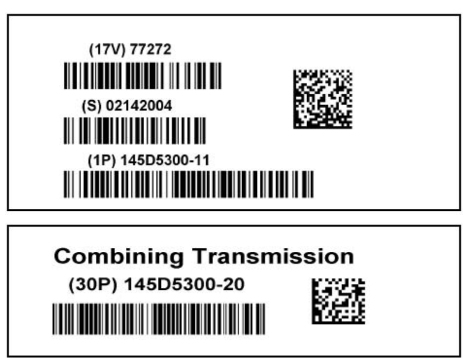

Figure 6. Marking Construct #2 Example (Modified Part)

Data Label Affixing Strategies

While it is normally best (easiest) to have the vendor mark the item at the time it is produced, there are other opportunities where items may be marked (Sumpter and Will, 2004). Items can also be marked using opportunistic, seek and mark, or intercept gate strategies. Each retrofit alternative has its own advantages and disadvantages (USAAPMD, 2001).

Opportunistic parts marking can be carried out anywhere access can be gained to the assets. These assets could be in the field, factory, storage facility, or on the weapon system or support equipment itself. The seek and mark strategy employs teams of trained personnel equipped with pre-made data labels or marking equipment to travel throughout an agency marking assets as they go. The intercept gate strategy establishes supply chain gates as a method of intercepting and marking parts as they transit through the supply chain. This can be achieved in a variety of ways: (1) Returning parts back to vendors if they attempt to enter the supply chain without being marked, (2) marking unmarked parts as they enter the supply chain or transition through gates within it, (3) marking parts in the field prior to use by marking at local forward supply organizations (USAAPMD, 2001).

With an understanding of the various bar codes, equipment required to produce and read bar code labels, the guidance provided by the DoD for using bars codes to identify assets, and data label affixing strategies, we can now examine specific cases of where UID or UID-related programs have been implemented.

UID-Related Implementation Programs

The concept of combining AIT with SNT to uniquely mark assets has existed for several years. In the absence of DoD guidance, some Air Force agencies/organizations have created and implemented their own "programs" to uniquely identify in-service assets in an attempt to improve their supply, maintenance, and life cycle programming operations. Although they differ in name and type of data captured or collected, the concept is very close in concept to the DoD's UID direction.

Defense Repair Information Local Server (DRILS)

Although not completely identical to the DoD's UID initiative, the Defense Repair Information Local Server (DRILS) initiative was one of the first programs to combine SNT with AIT to help resolve maintenance and supply problems. DRILS evolved out of the Ogden Air Logistics Center's flexible sustainment business practice (FALCON FLEX) in April 1997. The goal of the program was to encourage program managers to use performance-based specifications to develop innovative and cost effective life cycle solutions to support the F-16. One of the first FALCON FLEX efforts was a search for information associated with high LRU failures in legacy F-16 avionics systems.

Contracting personnel from Total Quality Systems (TQS) initially used information contained within the Computer Aided Maintenance System (CAMS) and Reliability and Maintenance Information System (REMIS), but the data from these systems proved unable to discern which SRUs within LRUs were failing. After discussing the dilemma with avionics repair technicians, the TQS personnel found most technicians maintaining their own maintenance log book to record serial number-specific data. This data was transferred to work control documents and filed away for periods up to one year. After one year, the data was supposed to be transferred to REMIS and discarded, but the data was being discarded without ever being put into REMIS. According to the technicians, it took longer to enter the data into the system than it took to repair the unit (Oliver, 2003). To work around this obstacle, the contractor manually collected repair data from work control documents and created a database to record the information (Oliver, 2003). Later in the FALCON FLEX effort, data collection migrated from a manual effort to a semi-automated effort. Eventually, permission was granted from Air Force engineering personnel to install adhesive-backed plastic bar code labels to F-16 avionics assets and an interface was added to link the asset's bar code with the related data in the maintenance database.

U.S. Navy SNT Program

Although it does not share the same name, the Navy's SNT program embodies most of the attributes the DoD wants to achieve with its UID program. It integrates serial numbers with automatic identification technology to provide visibility of selected assets. In 1998, the Navy initiated their SNT project in response to the Aviation Supply-Maintenance Readiness review which determined a SNT system was required to assist in determining the factors causing increasing costs and decreasing reliability of Aviation depot level repairables (USN SNT, 2004). The Navy assessed several commercial off the shelf products to determine the viability of replacing legacy supply and maintenance information systems to allow tracking of serial numbers. In the end, the Navy decided to enhance their legacy systems to accommodate SNT through a single web-based portal, Virtual Shared Data Warehouse. After much development, this portal now directly accesses multiple disparate maintenance and supply databases to provide responses to queries concerning asset visibility, maintenance history, and warranty status (USN SNT, 2004).

The Navy is currently using both bar codes and Contact Memory Buttons (CMB) in their SNT program. Bar codes are used where only nameplate data is required and contact memory buttons are used where data storage capability is desired. CMB range in price from $10 - $15, allow for data storage of up to 32K of memory, and are useful for storing warranty and maintenance data where access to a central database is readily available (USN SNT, 2004).

The Navy is engaged in a five-year contact memory button installation plan for each of its Type/Model/Series aircraft. It started the program by applying contact memory buttons to its fleet of H-53 aircraft and is working through its fleet of E-2/C-2, F/A-18, and P-3 aircraft. Eventually more than 1.25 million aviation and depot level repairables will be equipped with contact memory buttons (USN SNT, 2004).

Significant Challenges Encountered

The Navy encountered resistance when they implemented their SNT program. Navy supply and maintenance professionals both recognized the need to uniquely identify certain assets and both supply and maintenance communities as a whole also recognized changes would be required to have a universal solution. But, while the need for serial number tracking was prevalent, the desire to implement and accept the changes to computer systems to accommodate the need was not. Paradigm shifts were necessary. New business practices were applied to various existing information management systems that crossed many internal and external organizations. In many cases, the individual serial number was already embedded in the maintenance philosophy, but not in the supply system which was not established to record serial numbers. To aid the paradigm shift and overcome the functional silos, the Navy dedicated a staff of three people to educate, communicate, preach, cajole, task, and refine various requirements to bring SNT to fruition. This team conducted site surveys, oversaw many administrative tasks, and helped identify the information architecture necessary that made the Navy's SNT program a reality (NSSC, 2003).

Current Use of UID (US Army)

While items currently in use and in inventory are not immediately affected by the 29 July 2003 UID policy, the acting Undersecretary of Defense (Acquisition, Technology, and Logistics) has encouraged component acquisition executives to identify, promote, and fund pilot programs to apply UID to in-service assets. One notable example of in-service application of UID is the Army's effort in marking flight and maintenance critical parts on the CH-47 Chinook helicopters (Leibrandt, 2004).

In 1999, the cargo helicopter Program Management Office (PMO) at Redstone Arsenal located in Huntsville, Alabama, initiated a test program to uniquely identify CH-47 parts. Although, the cargo helicopter PMO used a direct part marking strategy and contractors and their equipment to mark a handful of assets in the field (Reno, Nevada), much can be learned from their experience.

The Cargo Helicopter PMO fully admits that the concept of affixing a bar code to an item might seem to be an easy solution for identification. Successful implementation of this new capability within their existing acquisition and information systems, however, required new thinking and new processes. The PMO found changes were required to government technical data, vendor and Original Equipment Manufacturer (OEM) engineering drawings, contract language, and most importantly, their own information systems (Crosby and Sautter, 2004).

The first step was to determine the cost and effort required to mark parts. While the requirement can be easily covered contractually for a development program or new acquisition as directed by the current DoD UID policy, this can be an extremely expensive proposition for legacy weapon systems. The Army discovered that a simple requirement for the OEM to change a drawing to incorporate a part mark could incur charges of 40 to 80 billable hours from the contractor. This factor made previous efforts at legacy parts marking prohibitively expensive. The cargo helicopter PMO worked closely with manufacturers and utilized best commercial practices from the aviation sector. In the end, the cargo helicopter PMO was able to negotiate and tentatively adopt process changes that reduced billable hours to less than four hours per part number (Crosby and Sautter, 2004).

Other concerns also needed to be addressed before costs could be determined for marking legacy assets. These concerns included:

(1) Determining what physical location (depot, flight line) the parts could be marked

(2) Determining where to place the machine readable code on each part

(3) Determining what techniques are required to create part marks for each family of parts and

(4) Establishing a method of controlling the data included on the marks.

To address these concerns the PMO conducted a pilot project, the U.S. Army Aviation Parts Marking Demonstration Program with the U.S. Army Aviation Applied Technology Directorate (AATD) at Fort Eustis, Virginia. During this effort, the Army:

(1) Determined the engineering effort required to obtain approval and air worthiness qualification to mark parts

(2) Experimented with marking a cross section of sample parts based upon a range of criteria, including different materials, paint, location, and operating environment of the part

(3) Studied direct part marking as well as various data labels (Crosby and Sautter, 2004).

Lessons Learned

Crosby and Sautter identified the most difficult aspect of implementing a successful UID program as the need to maintain existing legacy data systems while simultaneously establishing new AIT systems. They predict it will take an extended period of time (10 years is the accepted timeframe) for all assets in a relatively large weapon system's inventory to be uniquely identified and captured in an AIT database. During this period, reliance on legacy systems will be required. The inability of most legacy systems to capture AIT data is a driving factor behind the need for parts to be marked with human-readable text as well as machine-readable code. The continued use human-readable code allows for manual data entry into legacy systems and is a requirement until all assets are marked with machine-readable code and the infrastructure is in place to support the AIT.

Another hurdle successfully solved through contractor support was the requirement to register the part's mark in a database to ensure it uniqueness. Since the UID registry had not yet been created or approved, the Army contracted with ID Integration for a mobile parts marking facility to mark their parts as well as record the part marks of the assets that were marked. This concept of using a contractor to mark assets and record the part marks worked well and was developed during the U.S. Army Aviation Parts Marking Demonstration Program (Crosby and Sautter, 2004).

Conclusion

This chapter provided background for why the DoD established its UID policy and outlined what the Department ultimately hopes to achieve by uniquely identifying its assets. The interrelationship and combined role of SNT and AIT that enable UID were also explained. SNT and AIT were each defined and their benefits were outlined. In addition, examples of DoD-approved bar code symbologies were provided. Finally, specific cases of where UID or related in-service marking efforts have been implemented were narrowly discussed because of the limited amount of printed literature available on this relatively new process.

The remainder of this study expands on the limited UID related literature to capture lessons learned of UID and related processes and provides analysis to aid the decision of how to uniquely mark assets.

III. Methodology

Overview

This chapter discusses the methodology used to conduct this research. This research effort employed the case study methodology to explore in-service UID implementation programs as well as analyze the various data label making alternatives and data label affixing strategies available to the F-16 Unique Items Supply Chain Manager. The methodology included both qualitative and quantitative methods. Qualitative methods were used to analyze how other organizations have implemented UID programs within their organizations. While a combination of qualitative and quantitative methods were used to compare the data label making alternatives and the data label affixing alternatives.

First, the case study methodology is described and demonstrated why it is an appropriate methodology for this research effort. Second a detailed scope of the research is presented. Third, data sources and the manner in which the data was collected are presented. Finally, data analysis procedures are provided detailing the method of data comparison of qualitative and quantitative factors used to draw conclusions and make generalizations.

Case Study

In his book, Case Study Research, Design and Methods, Robert K. Yin suggests that, in general, case studies are the preferred strategy when “how” or “why” questions are being posed, when the investigator has little control over events, and when the focus of the research is on contemporary phenomenon within some real life context. He proposes case studies can be exploratory, descriptive, or explanatory in nature and can either involve the study of one or several cases. Yin also suggests a case study strategy allows an investigator to retain the holistic and meaningful characteristics of real life events that include individual life cycles and organizational and managerial processes (Yin, 1994).

To determine what type of research methodology to use, Yin suggests examining three conditions: 1) the type of research question posed, 2) the extent of control an investigator has over the actual behavioral events, and 3) the degree of focus on contemporary as opposed to historical events (Yin, 1994). Yin's criteria for selecting a research methodology are shown in Table 1. This research entails an exploratory question being asked about a contemporary phenomenon of which the researcher has no control.

Table 1. Relevant Situations for Different Research Strategies

Strategy	Form of Research Question	Requires Control Over Behavioral Events?	Focuses on Contemporary Events?
Experiment	how, why	yes	yes
Survey	who, what, where, how many, how much	no	yes
Archival Analysis	who, what, where, how many, how much	no	yes/no
History	how, why	no	no
Case Study	***how, why***	***no***	***yes***

This research primarily addresses questions of “what” and “how”. What questions are either exploratory or used to form a “how many” or “how much” line of questioning. The goal of exploratory “what” questions is to develop pertinent hypotheses and propositions for further inquiry. The goal of “what” questions that form a “how many” or “how much” line of questioning is to describe the incidence or prevalence of a phenomenon about certain predictive outcomes. “How” questions are usually explanatory in nature and can lead to the use of numerous research strategies including the case study. This is because “how” questions deal with operational links requiring tracing over time rather than frequencies or incidence (Yin, 1994). The “what” questions presented in this research is exploratory while the “how” question is explanatory. Based upon these criteria and the nature of the investigative questions, the case study strategy is the best research methodology to analyze how other organizations have implemented UID programs as well as compare the data label making and data label affixing alternatives available to the Ogden ALC’s F-16 Unique Items Supply Chain Manager.

Scope of Research

Case studies can rely on the use of quantitative data, qualitative data, or a combination of both and may include the examination of a single case or multiple cases. The single case study is appropriate for testing a well formulated theory when the case represents extreme or unique situations, or when an investigator has an opportunity to observe and analyze a phenomenon previously inaccessible to scientific investigation. Multiple-case designs have advantages and disadvantages in comparison to single-case designs. Evidence from multiple cases is often considered more compelling, making the overall study more robust. By using multiple cases, the researcher strives to observe similar data across several cases to draw generalizations and conclusions and to ensure that the observed phenomenon is not a unique case. Conversely, multiple-case study can require extensive resources and time beyond the capabilities of a single researcher (Yin, 1984).

Hamel and Yin argue that the number of cases is not important. What is important to case study research is the type of cases selected (Hamel, 1993; Yin, 1984). Although cases may be chosen randomly, random selection is neither preferable nor necessary. The goal of theoretical sampling is to choose cases that are likely to replicate or extend the subject under study. Although the researcher is confident some form of in-service UID program is being implemented in the commercial sector, no cases of commercial legacy asset marking programs were located. The researcher only identified and analyzed cases where in-service assets were "uniquely identified" by government agencies. Although non-government in-service UID programs may exist, their presence was unknown to experts in the UID field and not documented in current literature. Of these cases, only one case specifically addressed an agency within the DoD uniquely identifying assets in concert with the DoD's UID policy. The other two were cases where DoD agencies (Navy and Air Force) implemented their own SNT programs. Because these SNT programs were very similar in nature to UID and because the lessons learned from their implementation were relevant to UID implementation, the researcher included these cases for analysis. The researcher selected the F-16 Avionics portion of Ogden

ALC's workload as a potential testbed for two reasons. The Requirements Analysis Section of the F-16 Logistics Operations Division at the Ogden ALC proved a readily available source of accurate and timely F-16 related data required for the quantitative portion of the analysis. And, the F-16 Unique Items Supply Chain Manager would be well suited to initiate the Air Force's in-service UID program, based on their involvement with the Depot Repair Information Local Server (DRILS) initiative.

Data Sources

Yin identifies six sources of evidence for conducting research that can be used separately, together, or in any combination to achieve the goals of the research effort. The six sources are documents, archival records, interviews, direct observations, participant-observation, and physical artifacts. The sources are complementary and a good case study will use as many sources as possible (Yin, 1994). The sources of evidence may be qualitative, quantitative, or both (Eisenhardt, 1989). A combination of documents, archival records, participant-observation, and interviews, were used as data sources for this study. Since the data simply does not exist to monetize all costs associated with a full cost-benefit analysis of a UID implementation program, a less stringent analysis was performed (Boardman et al.). Cost estimates from printer service bureau contractors and equipment costs from bar code equipment manufacturers were used to compare data label making and data label affixing strategies.

Documents can take a variety of forms to include letters, memorandums, meeting minutes, agendas, news articles, formal studies and journal articles (Yin, 1994). For this study, an assortment of documents was used almost exclusively in the literature review to provide a background of SNT, AIT and their combined role in forming UID. Documentation was also used to identify the requirements of the UID policy set forth by the DoD. And finally, documentation, although limited, was the primary source of information used to identify where and how in-service UID programs have been implemented. Documents for this research effort included journal articles, government reports, memorandums, and formal studies.

Archival records were also used to compare the data label making and data label affixing strategies available to the F-16 Unique Items Supply Chain Manager. Archival records included information generated from various databases to capture the number and type of F-16 avionics LRUs managed by the F-16 Unique Items Supply Chain Manager, number and locations of F-16 units, and LRU repair locations and quantities.

Archival records, like other data sources, can take many forms. Yin warns that when archival evidence has been deemed relevant, the investigator must be careful to ascertain the conditions under which it was produced as well as the accuracy of the information (Yin, 1984). For this study, much of the quantitative data related to F-16 avionics assets to include asset quantities, repair data, repair contractors, and repair percentages (contractor versus Air Force-direct repair) was provided by the Chief, Requirements Analysis Section of the F-16 Logistics Operations Division at Hill Air Force Base, Utah and the Headquarters Air Force Material Command's LGIR office. Because the researcher does not have the ability to verify the accuracy of the information provided by the subject matter experts at Hill AFB or AFMC, the data was presumed to be accurate. Direct observation was also used to a limited extent for this research effort.

Direct observation can range from casual to formal data collection activities. Casual observations can be made during a field visit including occasions during which other activities such as interview data is being collected. Formal observation protocols can be developed as part of the case study protocol and the investigator may be asked to measure the incidence of certain types of behaviors during certain periods of time in an environment. This can involve observations of meetings, factory work, classrooms, and the like (Yin, 1994). Direct observation of marking equipment was accomplished to a limited extent during the in-person interview with Mr. Chris Sautter from the Cargo Helicopter Program Management Office at Red Stone Arsenal while discussing the Army CH-47 UID program. As just mentioned, interviews were also used for the case study portion of this research effort.

Yin stresses the interview as one of the most important sources of information for a case study. Interviews can take several forms and can be open-ended, focused, or structured. In an open–ended interview, the investigator is free to ask the respondent about the relevant facts of the matter as well as the respondent's opinions about events. In some situations, the investigator may even ask the respondent to propose his or her own insights into certain occurrences and then use the responses as the basis for further inquiry. In a focused interview, a respondent is interviewed for a short period of time. In such cases, the interviews may still remain open-ended and assume a conversational manner, but the interviewer is more likely to follow a certain set of questions derived from the case study protocol. The third type of interview entails a highly structured approach. During a structured interview, the interviewee only asks predetermined questions. The questions are much less open-ended and may almost take the form of a survey (Yin, 1994).

For this research effort, three open-ended interviews (two telephonic and one in-person) were conducted to gain insight into the lessons learned during the various implementation processes. Mr. Fred Smullin from Total Quality Systems was interviewed about his experience with the FALCON FLEX project and bar coding F-16 avionics assets at the Ogden Air Logistics Center. Commander Matthew Mullins provided insight into the Navy's ongoing SNT program. And Mr. Chris Sautter provided valuable information in-person about the Army's challenges implementing UID within their fleet of CH-47 helicopters.

Data Analysis

Data analysis consists of examining, categorizing, tabulating, or recombining the evidence, to address the initial propositions of a study. Yin stresses that historically case study data analysis is one of the most challenging aspects of using the case study methodology. This is because data analysis strategies and techniques are ill defined. To combat this challenge, the researcher must rely on his or her own style of critical thinking and prior knowledge to further the analysis and present the evidence in various ways. None the less, every investigation should start with a general analytical strategy to determine what to analyze and why (Yin, 1984, Yin, 1994). Leedy and Ormrod suggest using the following five steps when analyzing case study data.

1. Organization of details about the cases – specific facts about the cases are arranged in a logical order.
2. Categorization of data – categories are identified to help group the data into meaningful groups.
3. Interpretation of single instances – occurrences, documents, and other data are examined for specific interpretation that might have relation to the case.
4. Identification of patterns – data and their interpretation are scrutinized for patterns that characterize the case in a broad sense.
5. Synthesis and generalizations – an overall picture of the case is presented and conclusions are drawn that could have implications beyond the specific cases studied (Leedy and Ormond, 2001).

Organization of details about the cases

For this research effort, the details about the cases were organized into two main sections. The first portion dealt with analyzing how in-service UID programs were implemented in the past in order to capture lessons learned for the Ogden ALC's F-16 Unique Items Supply Chain Manager's eventual implementation of UID. The second portion of the research dealt with identifying and assessing the various data label and data label affixing alternatives available to the F-16 Unique Items Supply Chain Manager.

Categorization of data

For the purpose of this study, the data label making alternatives and data label affixing alternatives were analyzed and assessed individually in an attempt to provide a clear picture of the advantages and disadvantages associated with each alternative. Three different data label making alternatives were identified and include:

1. Purchase data labels from a printer service bureau
2. Purchase the label making equipment and make data plates utilizing government or contract employees
3. Use a combination of printer service bureau and government owned equipment

Additionally, four possible alternatives for affixing the data plates to avionics LRUs were also identified. These alternative methods include:

1. Affix using an intercept gate strategy as LRUs transition through the ALC for repair/overhaul
2. Affix using a seek and mark strategy, by sending teams to supply centers and F-16 units
3. Affix using an opportunistic strategy, by enabling F-16 units to mark their own assets
4. Use a combination of the strategies above.

In addition to identifying the known quantitative costs associated with each of the data label making and label affixing strategies, three qualitative factors were used to evaluate each strategy. Identification and evaluation of the qualitative factors was based on a combination of discussions with interviewees as well as the experience of the researcher with depot repair, contractor repair, and field operations. The qualitative factors evaluated for this study include timeliness, quality, and span of control. Each factor was evaluated separately for each data label making strategy and each data label affixing strategy.

Timeliness. This factor, as it relates to data label making, evaluates the speed at which data labels can be produced and made available to affix to assets. It considers the time required for the data labels to be manufactured, but includes equipment setup times and the time to forward them to the affixing location as well. Timeliness, as it relates to label affixing strategies, assesses the timeframe required to mark all F-16 avionics LRUs.

Quality. As it relates to data label making, quality evaluates the ability of an organization to produce high quality data labels that meet government specifications. It also considers the ability to maintain an accurate online database of UID data, and accurately format and transmit UID data to the DoD UID registry once the birth record is created. Quality, as it relates to label affixing strategies, assesses the ability of an organization to affix the data labels in accordance with engineering drawings and directives.

Span of Control. This factor, as it relates to data label making, evaluates the ability of the F-16 Unique Items Supply Chain Manager to effectively manage the process. It takes into account the ability of the organization making the data labels to react to unplanned changes in the label making process. Span of control, as it relates to label affixing strategies, assesses the amount of effort required by the F-16 Unique Items Supply Chain Manager to provide and update guidance for marking each asset.

Interpretation of single instances

Although only a single case of a "true" in-service UID program implementation was studied, the researcher chose to include two other UID related cases that were implemented that have much in common with UID.

Identification of patterns

Because UID for in-service assets has not yet been mandated by the DoD, the amount of available literature related to this topic is extremely limited. That said, every effort was made to scrutinize and interpret the available data from the three cases examined for patterns that might characterize the cases.

Synthesis and generalizations

Although this research effort only studied the considerations for implementing an in-service UID program within the F-16 LRU community, the researcher made every attempt to provide an overall picture of each case and present conclusions that could have implications beyond the specific cases studied.

Summary

This chapter presented a description of the methodology selected for this research. Justification for choosing the case study method, a detailed scope of the research, the data sources and data collection methods along with the data analysis procedures were also discussed. The following chapter will document the results of this methodology.

Through analysis of the findings documented in chapter four, the researcher will present recommendations and conclusions in chapter five of this research.

IV. Analysis and Results

Overview

This chapter provides the analysis and results of this research study. It discusses the considerations the Ogden Air Logistics Center's F-16 Unique Items Supply Chain Manager should address when implementing an in-service UID program. It answers each of the original investigative questions using data gathered from the literature review, interviews, and other sources. The first portion of this chapter provides an analysis of the cases where UID or UID related programs have been implemented. Next, analysis and evaluation of the qualitative and quantitative data associated with data label making alternatives and data label affixing strategies are presented were possible.

Investigative Question One

How have in-service UID programs been implemented before within the DoD and civilian communities?

To date, only one organization has started uniquely identifying in-service assets in accordance with the initial criteria set forth in and MIL-STD 130L and the 29 July 2003 memorandum from the Undersecretary of Defense (Acquisition, Technology, and Logistics) concerning UID of tangible assets. The other two organizations studied for this research effort have each independently initiated a UID related program that incorporates AIT and SNT to improve their data capture and analysis capability. Documented cases where the commercial industry has implemented in-service UID programs could not be located.

The DRILS effort was initiated to encourage program managers to use performance-based specifications to develop innovative and cost effective life cycle solutions to support the F-16. The DRILS initiative uses a single intercept gate marking strategy. F-16 avionics assets are intercepted as they transition through the Ogden ALC for repair. When intercepted, adhesive-backed, thermally-transferred, polyester data labels are applied to the F-16 avionics to uniquely identify the asset (Smullin, 2004).

The Navy's extensive SNT program was developed to help determine the factors causing an increase in cost and a decrease in reliability of the Navy's aviation depot level repairables. The Navy's program currently uses a combination of bar code labels and contact memory button automated information technologies to capture and record the maintenance history of aircraft parts. In addition, the Navy uses a seek and mark strategy to mark their assets. A field team travels to aviation squadrons as well as each depot applying bar codes or contact memory buttons to predetermined assets. These desired assets are sought out and marked either on the aircraft or while stored in a supply facility (Mullins, 2004).

Because the Army's UID program is still in relative infancy, it has been able to adapt to meet the marking requirements identified in MIL-STD 130L. The Army is also currently using 'direct part' marking and a 'seek and mark' marking strategy to mark select CH-47 assets. They are accomplishing this by purchasing portable trailers equipped with a variety of marking equipment and traveling to CH-47 field locations to mark assets. These trailers are equipped to create data labels, directly mark parts, verify the accuracy of the marks, as well as record and transfer the mark data via the internet to a centralized database (Sautter, 2004).

Investigative Question Two

What problems can be expected when starting an in-service UID program and what can be done about them?

Although the method of uniquely identifying assets, the marking strategy, the type of data captured, and the driving force behind each program was unique to each case studied, each of these organizations experienced many of the same challenges when they implemented their own marking programs. A problem area common to all three cases was lack of support for implementing the new program. For the F-16 Unique Items Supply Chain Manager, the lack of support was brought on by a lack of communication.

At the inception of the program, the F-16 Unique Items Supply Chain Manager did very little to inform F-16 field units and repair contractors that bar code labels would soon be affixed to various F-16 avionics assets. As a result, many of the bar code labels were removed from avionics assets after they left the depot, but before the assets returned for depot maintenance. In some instances, technicians in the field removed the bar code labels simply because the maintainers did not recognize the labels and assumed they were placed on the assets by mistake. In other situations where maintenance technicians were informed about the process, the bar code labels were removed when the field unit modified the avionics asset's software to meet their unit's needs thereby changing the part number of the asset and invalidating the bar code label (Smullin, 2004). The DoD recognized this issue and provides guidance in MIL-STD 130L on how to uniquely identify an asset that may require a new part number as a result of modification or alteration.

MIL-STD 130L addresses the challenges associated with an asset changing part numbers over the course of its service life and offers two provisions or constructs for its unique identification. Under construct #1, the UID is established by using a two-part label. The manufacturer's identification and a unique serial number for that manufacturer are permanently recorded in the top label, while the part number is captured in the bottom label. When an item is modified and the part number is changed, the bottom portion of the UID label is replaced with a label containing the updated part number (MIL-STD 130L, 2003). Under Construct #2, the item's UID is established by using the manufacturer's identification, product part number, and a serial number unique for that part number. All three data elements are included on a single permanent label. If the item is modified, an additional bottom label containing a new part number is affixed to the asset (MIL-STD- 130L, 2003).

Repair contractors also removed bar code labels. Contractors removed the labels when they discovered the labels were not depicted on their engineering drawings and were hesitant to return assets to the field that were not in compliance with their drawings. This problem was eventually resolved when a statement was added to the bottom of the bar code labels indicating the labels were an Ogden ALC-approved form of identification (Smullin, 2004).

The Navy was also challenged to gain support for their SNT program at the onset of the program's implementation. The Navy's main challenge was altering the mindset of their own maintenance and supply personnel. The change in mindset was required in order to get personnel to accept and adopt modifications required to existing data collection systems and business practices to create a viable SNT program. The Navy eventually overcame this problem over time thanks to the efforts of a dedicated team specifically charged with resolving the program's implementation challenges.

One of the Army's biggest challenges is gaining detailed support from senior leaders in both the commercial sector as well as the military. From the commercial perspective, manufacturing companies are willing to support the initiative, but less than willing to find economical solutions for changing technical drawings to reflect the added part marks. To compound matters, although Army senior leadership is very supportive of the general UID concept, many leaders tend to oversimplify the process and underestimate the numerous challenges associated with its implementation. They unknowingly equate UID to simply slapping a UPC on an asset when, in fact, uniquely identifying assets can be much more involved than merely applying bar code labels to parts (Sautter, 2004).

UID Program Implementation Considerations

Several factors must be considered when implementing a UID program. Each of the three organizations studied had some degree of difficulty determining the following:

1. Which parts to mark
2. Where to apply the mark to each asset
3. Determining if changes to engineering drawings and technical orders are

required and accomplishing this economically

4. Determining if air worthiness certification is required as a result of the added label

One of the first decisions that must be made in a UID program is to decide which parts to mark. In the absence of specific guidance from the DoD or the Air Force for marking in-service assets, several factors should be considered. The first consideration is the amount of time and money required to mark a particular asset compared to the potential benefits achieved by marking it. In general, assets that have a limited Air Force-wide inventory may not require the application of a UID mark to distinguish one asset from another. On the other hand, where hundreds or thousands of like items exist in an inventory, UID makes much more sense. On a similar note, the anticipated lifespan of a particular asset should also drive the marking decision. For example, it would be a waste of time, funding, and manpower to uniquely identify items unique to the C-141 since this fleet of aircraft is scheduled to be retired in 2006 (Askew, 2004). In contrast, it is more feasible to mark assets on the F-15 which is programmed to continue flying through 2015 (Neely, 2002).

The solution is to resolve these issues long before they ever become a problem. Solutions to these issues can not be made in a vacuum by one or two influential decision makers at the Headquarters level. Doing so would likely lead to disastrous results. The best course of action is to form teams of experts from several diverse fields to discuss all of these matters before the first asset is ever marked. At a minimum, the teams should consist of item managers, equipment specialists, engineers, maintainers, program managers, repair technicians, and representatives from the OEM if possible. The asset specific team should collectively decide if the asset should be marked, the best location for the mark, the type of mark it should receive (direct part or data label), the best strategy for marking the asset, and the marking construct that makes the most sense for that item. If a data label is to be used, the type of label medium and how the mark should be applied (thermal transfer, etch, silk screen, etc.) must also be determined. Additionally, senior military leadership and contractor leadership should be thoroughly briefed on the potential benefits of the program as well as the level of effort required to uniquely identify assets in order to gain their support for the endeavor.

Investigative Question Three

What are the advantages and disadvantages associated with the data label making alternatives?

Before an analysis and evaluation of label making or label affixing alternatives can take place, it is important to understand the scope of the effort required to uniquely identify the F-16 LRUs managed by the Ogden ALC's F-16 Unique Items Supply Chain Manager. According to the Chief, Requirements Analysis Section, F-16 Logistics Operations Division, and AFMC/LGIR, the F-16 Unique Items Supply Chain Manager manages 143 different F-16 LRUs comprising 257,505 individual assets. A listing of these LRUs and their respective quantities are presented in Appendix A.

Appendix A also includes LRUs owned by foreign countries, but managed by the USAF. Depending on the country-specific contract, these LRUs are either repaired under a "repair and return" or a "repair and replace" concept. When an asset is identified for repair under the repair and replace concept, the foreign owned asset is sent to a repair facility, refurbished, and a similar serviceable asset from the existing U.S. Air Force inventory is returned to the foreign country. When a repair and return asset is sent in for repair, the LRU is refurbished and the same asset is returned to the foreign country (Jackson, 2004).

On average, 2,500 of F-16 LRUs are repaired each month. Approximately 70 percent are repaired at the two government facilities with the Ogden ALC repairing 65 percent and the Support Center Pacific located at Kadena Air Base, Japan, repairing 5 percent. The remaining 30 percent are repaired by the following nine contractors: Northrop Grumman Corp., General Dynamics, Honeywell, International Enterprises Incorporated, EFW, BAE Systems, CPN, and Raytheon. Furthermore, these LRUs support F-16s operating at 90 bases in 21 countries around the world (Jackson, 2004).

This study identified three possible data label making alternatives for in-service assets:

1. Purchase preprinted data labels from a printer service bureau
2. Purchase the label making equipment and make data plates in house using government or contract employees
3. Use a combination of printer service bureau and government owned equipment

Each strategy has its own advantages and disadvantages and is objectively evaluated where possible based on cost, timeliness, quality, and span of control. The ideal combination of factors is low cost, low timeliness or a quick turnaround, high quality, and high span of control.

Printer Service Bureau

There are a host of companies that offer a wide variety of products and services to organizations requiring bar code printing or marking services. A cursory internet search revealed over 300 label making companies that may or may not be able to produce data labels in accordance with government directives. The cost involved with producing data labels that meet the standards in MIL-STD 130L ranges across a wide spectrum and depends on the size of the label, the number of labels produced, the label medium or substrate used, and the marking technology employed. Adhesive-backed thermally transferred paper labels are on the low end of the cost spectrum and can be purchased with the appropriate UID bar codes and human readable text applied for approximately $0.05 each. But as mentioned in chapter two, paper does not necessarily afford the same durability properties of other label mediums.

Price per label generally increases with the sophistication of the label material and marking technologies employed. Adhesive-backed, thermally transferred polyester labels can be purchased with the appropriate UID bar codes and human readable text applied for approximately $0.06; while adhesive-backed aluminum labels produced using laser additive bonding technologies cost approximately $10.00 each. These prices do not include potential price breaks for quantity discounts, applicable government rates or additional charges associated with equipment setup and shipping the labels to the location of application.

Unfortunately, an objective evaluation of the costs associated with purchasing data labels for all 257,505 F-16 avionics assets is extremely difficult. To date, sufficient analysis has not been conducted on each of the 143 different F-16 avionics LRUs to determine the most cost effective label medium or marking technology appropriate for each LRU. Consequently the exact label requirements are not known. In addition, all printer service bureaus are not equipped to record the birth records associated with each UID. The added requirement to track UID birth records could significantly increase the cost of each data label. In an attempt to estimate the relative cost of purchasing "preprinted" data labels, informal price quotations were obtained from printer service bureaus. Table 2 displays the informal per label price quotations received from printer service bureaus for selected combinations of substrates and code application processes. Every code application process can not be used with every label substrate. For example, engraving or etching paper is not feasible; therefore, costs are only presented for substrate and application process combinations that are practical. Price quotations reflect the per label cost of purchasing 1,000 1 x 2 inch "preprinted" labels containing serially sequenced linear and data matrix bar codes along with human readable text.

Table 2. Approximate Printer Service Price per Preprinted Label

	Code Application Process		
Substrate	Laser Jet	Thermal Transfer	Etched / Ingraved
Paper	$0.03	$0.05	N/A
Polyester	N/A	$0.06	N/A
Aluminum	N/A	N/A	$1.50
Stainless Steel	N/A	N/A	$1.80

Table 3 displays the approximate cost of purchasing 257,505 labels for each of the feasible label substrate and code application process combinations presented in table 2. These values were derived by multiplying the cost per label in Table 2 by 257,505 labels to obtain an approximate cost to purchase all "preprinted" bar code labels from a printer service bureau. Prices do not reflect discounts for purchasing quantities in excess of 1,000 labels, charges to record and transmit "birth records", shipping, set up fees required to accommodate the 143 different LRUs, or the eventual need to reprint labels that are applied incorrectly, applied to the wrong item, damaged/lost in shipping, etc..

Table 3. Approximate Cost to Purchase 257,505 Preprinted Labels from a Printer Service Bureau

	Code Application Process		
Substrate	Laser Jet	Thermal Transfer	Etched / Ingraved
Paper	$7,725	$12,875	N/A
Polyester	N/A	$15,450	N/A
Aluminum	N/A	N/A	$386,258
Stainless Steel	N/A	N/A	$463,509

Although it would cost at a minimum 8,000 to 465,000 dollars to purchase 257,505 preprinted labels from a printer service bureau, the factor of "cost" was evaluated as low. Unlike purchasing required equipment and making labels in house, training, labor, and expendable equipment (toner and printer ribbons) costs are already factored into the printer service bureau price quotations above.

One of the potential drawbacks of using a contractor to produce data labels is timeliness. Although a priority system may be arranged through a contract, orders received at most printer service bureaus will simply be filled in the order they are received. Turn around time can be further delayed when equipment set up time and label shipping times are factored into the equation. For these reasons, the factor of 'timeliness' was evaluated as medium.

The potential drawbacks associated with timeliness may be offset by the advantages associated with quality and control of the process. Printer service bureaus are in the business of producing labels. They hire and train personnel for the sole purpose of operating equipment to make various labels. Furthermore, the equipment they own and operate is generally industrial grade, capable of producing very high quality labels. Furthermore, since printer service bureaus are generally equipped to produce labels using various label mediums, marking technologies, and numerous sizes, they are well suited to react to possible changes in label making requirements. Therefore, the factors of 'quality' and 'span of control' were each evaluated as high.

Government Owned and Operated Equipment

As described previously, there are a wide variety of label mediums, related marking technologies, and label making equipment associated with each label making process. In addition to the variations in label making equipment, the lack of asset specific label requirements discussed above make computing accurate cost estimates associated with the Air Force producing its own labels extremely difficult.

The equipment required to produce adhesive-backed paper labels consists of a $50 to $300 software package for a personal computer, a $500 to $5,000 printer capable of producing high quality printed images, and blank, adhesive-backed labels that can be purchased for less than a $0.01 each depending on label size and vendor. As with purchasing printed labels, costs increase dramatically as the sophistication of the label and marking technology increase. Equipment required to produce aluminum or stainless steel labels varies from several thousand dollars to half a million dollars or more depending on the marking technology employed. In addition, blank labels can range in cost from a few cents for adhesive-backed flexible aluminum labels to a few dollars for stainless steel blank labels depending on the size of the label size and vendor. Table 4 provides approximate costs involved with purchasing the computer software and printer/engraver hardware required to produce bar code labels using the same label substrates and code application processes identified in Table 3 (Approximate Cost to Purchase 257,505 Preprinted Labels from a Printer Service Bureau). Because the quality of software and printer/engravers varies widely among manufacturers, the cost of these items varies widely as well; hence a price range is presented. Here again since every substrate is not conducive to being used by every code application device, costs are not provided for every substrate/device combination.

Table 4. Approximate Hardware and Software Equipment Costs

	Code Application Device		
Substrate	Laser Jet Printer & Software	Thermal Transfer Printer & Software	Etching / Engraving Equipment
Paper	$550 - $5,500	$1,000, $2,000	N/A
Polyester	N/A	$2,000 - $4,500	N/A
Aluminum	N/A	N/A	$5,000 - $30,000
Stainless Steel	N/A	N/A	$5,000 - $30,000

In addition to purchasing the appropriate hardware and software, blank labels must be purchased as well. Table 5 displays the approximate per label cost of purchasing blank labels for each of the selected label substrates and code application processes. Prices represent average costs for 1 x 2 inch labels from several bar code label vendors and do not include quantity discounts or shipping charges.

Table 5. Approximate Cost per Blank Label

	Per Label Price		
Substrate	Laser Jet Suitable	Thermal Transfer Suitable	Etching / Engraving Suitable
Paper	$0.01	$0.02	N/A
Polyester	N/A	$0.03	N/A
Aluminum	N/A	N/A	$0.55
Stainless Steel	N/A	N/A	$0.65

Table 6 depicts the approximate range of costs associated with purchasing one complete set of computer software and printer/engraver hardware along with 257,505 blank labels to produce bar code labels for each feasible combination of label substrate and marking processes. Costs do not include, training costs, labor costs, or the cost of expendable equipment such as toner or printer ribbons.

Table 6. Approximate Cost for the Air Force to Produce Labels

	Code Application Process		
Substrate	Laser Jet	Thermal Transfer	Etching / Engraving
Paper	$3K - $8K	$5K - $6K	N/A
Polyester	N/A	$10K - $12.5K	N/A
Aluminum	N/A	N/A	$146K - $171K
Stainless Steel	N/A	N/A	$173K - $197K

As mentioned above, additional costs must also be considered when trying to compute the total cost associated with the Air Force producing its own labels. In addition to equipment costs, training costs, labor costs, wastage costs, and facility and utility costs must also be considered. Furthermore, since a data label affixing strategy has not been determined, the number of label producing equipment sets required to produce labels is unknown. It is conceivable that the F-16 Unique Items Supply Chain Manager could centralize its label making capability and become a de facto printer service bureau. This option would limit equipment and training costs, but increase shipping costs and potentially degrade timeliness. On the other hand, multiple label making locations could be established thereby increasing equipment costs.

At first glance, the cost associated with the Air Force purchasing and operating its own equipment to produce its own data labels appears less expensive than purchasing preprinted labels from a printer service bureau. For example, Table 6 shows the approximate cost of producing 257,505 polyester data labels using thermal transfer technology to be between 10,000 and 12,500 dollars. Purchasing the same type and quantity of preprinted labels from a printer service bureau would cost approximately 15,450 dollars. However, one must remember that training, labor and expendable equipment costs for toner or printer ribbons are not reflected in the government owned and operated equipment alternative. When labor costs (which include direct pay, retirement pay, taxes, and medical and retirement benefits) are included, the costs associated with the Air Force producing its own labels can exceed the costs of using a printer service bureau. For example, it would cost the government more than $100,000 to employ two workers at the GS-5 pay grade to make labels on a full time basis. This cost includes a $40,091 annual salary plus an additional $14, 633 per person to pay for fringe benefits such as civilian retirement, post retirement health and life insurance costs (SAFFM, 2004). For these reasons, the factor of "cost" was evaluated as medium.

The 'timeliness', 'quality', and 'span of control' achieved by 'owning' the process may offset the costs associated with the initial outlay of funds required to purchase label making equipment. There are inherent advantages achieved by the Air Force purchasing it own label making equipment, training personnel to operate the equipment and oversee the label making process. In theory, an Air Force operated label making operation would be more responsive to time sensitive requests for labels. The more label making facilities established, the quicker labels could be produced. In addition, through experience and proper training, the quality of the labels produced would be comparable to commercially produced labels. For the reasons stated above, timeliness was evaluated as medium, quality was evaluated as high, and span of control was evaluated as high.

Combination

Using a combination of both printer service bureau and government owned and operated equipment may be deemed appropriate after further study. However, the net result is that the positive attributes associated with one alternative are nullified by the negative attributes associated with the other alternative. In the end, the factors of 'timeliness', 'quality', and span of control' were evaluated as medium.

The results of the analysis and evaluation presented above are summarized in Table 7 below. Here again, the ideal combination of factors is low cost, low timeliness or a quick turnaround, high quality, and high span of control. When all factors are considered, using a printer service bureau to prepare labels appears to be the most attractive alternative given the number of F-16 assets requiring unique identification. Although there may be some costs savings achieved by making lower grade labels in house at one facility, purchasing multiple sets of label making equipment and paying employees to operate it becomes much more cost prohibitive. Outsourcing the label making requirement to a printer service bureau allows the Air Force to concentrate on its area of expertise; fixing and operating weapon systems. As discussed previously, printer service bureaus are in the business of making data labels. They are staffed, trained and equipped to produce high quality labels and would not require time to "spin up" to produce labels like the Air Force would.

Table 7. Label Making Alternatives

Alternative	Cost	Timeliness	Quality	Span of Control
Printer Service Bureau	***Low***	***Medium***	***High***	***High***
Gov't Owned & Operated Equipment	Medium	Medium	High	High
Combination	Medium	Medium	High	High

Investigative Question Four

What are the advantages and disadvantages associated with the data label affixing alternatives?

The four strategies for affixing labels to in-service assets (intercept gate, opportunistic, seek and mark, and combination) were described in chapter two. And like the label making alternatives, each label affixing strategy has its own advantages and disadvantages.

Intercept Gate

As described in chapter two, the "intercept gate" strategy establishes a gate within the supply system to intercept and mark parts as they transition through the supply chain. This can be achieved by returning assets back to vendors if they enter the supply chain without being marked, marking unmarked assets as they enter the supply chain or transition through gates within it, or marking parts in the field prior to use (USAAPMD, 2001). The evaluative factors, including cost, associated with the 'intercept gate' strategy can vary greatly depending on the number of gates established thereby making an objective evaluation associated with the costs of this alternative challenging at best.

For F-16 avionics LRUs, several options exist for establishing intercept gates. Gates could be established at one or both of the government repair facilities, the government repair facilities and the nine contract repair facilities, or a combination of repair facilities and field units. In general, the more intercept gates established, the higher the costs. These higher costs can be the result of several factors to include equipment costs, shipping costs, and training costs. If the decision to make labels is selected and the F-16 Unique Items Supply Chain Manager decides to produce labels at multiple locations, label making equipment costs rise quickly. However, the F-16 Unique Items Supply Chain Manager could reduce equipment costs by centralizing the label making capability. Furthermore, more gates involved in the process require additional funds be spent on training people how and where to apply the labels. Without knowing the number of desired label making facilities or intercept gates, it is impossible to accurately assess the cost associated with this label affixing alternative.

Likewise, the number of gates established under this strategy also impacts the timeliness, quality, and control over label affixing processes. Multiple marking locations or gates established in a system permits greater exposure to assets transitioning through the supply chain and therefore enables all identified assets to be marked more rapidly than if gates were only established at a limited number of intercept gates. However, the reduced time required to mark all F-16 LRU avionics assets using a multiple gate strategy incurs other challenges. The probability of marking assets incorrectly increases with the number of gates involved in the label affixing process. For example, with only a limited number of facilities involved in the process, quality and control could be high. Adding more gates increases the potential to decrease the quality and control of the affixing process. Because the evaluative factors associated with 'timeliness', 'quality', and 'span of control' of process can vary so greatly with the number of gates established, each factor was evaluated as medium.

Opportunistic

Opportunistic asset marking can be carried out anywhere access may be gained to assets. Assets can be located in the field, central storage facilities, repair facilities, or directly on a weapon system or piece of support equipment (USAAPMO, 2001). Regardless of the strategy used to procure data labels, an opportunistic label affixing strategy requires a relatively low amount of manpower at any one location, but a relatively large number or personnel across an organization. In the case of the F-16 community, an undetermined number of personnel at 90 bases and 11 different repair facilities would potentially need to be trained on how and where to apply data labels on up to 143 different type of assets depending on the Model/Design/Series of F-16 assigned at each base. Furthermore, if an opportunistic marking strategy was implemented at every base and repair facility, training documents, and marking procedures would need to be prepared in multiple languages to accommodate different countries that employ the F-16. Since the evaluative factors, including cost, associated with the 'opportunistic' strategy can vary greatly depending on the number of locations applying the bar code labels, an objective evaluation associated with the costs of this alternative are challenging at best.

The factor of ‘timeliness’ was evaluated as high. By definition, using an opportunistic marking strategy only requires assets to be marked when the opportunity presents itself, in other words, when it is convenient. Opportune times to mark assets under this strategy include when supply warehouse inventories are performed, when an asset is received by or returned to supply, or when an asset is removed from a weapons system for repair or replacement.

Because this marking strategy involves many different parties (multiple field units, repair facilities, storage facilities) that span multiple countries, the ability to control the marking process and the quality of the workmanship has the potential to be degraded. Although marking standards and procedures must be developed for each asset regardless of who performs the actual marking, the more people involved in a process, the greater the opportunity for problems to occur. Additionally, when changes are made to established marking processes, it would be much more difficult to control and implement the changes across multiple locations than within a single or few data label affixing locations. For this reason, the factors of ‘span of control’ and ‘quality’ were evaluated as low.

Seek and Mark

The ‘seek and mark’ strategy employs teams of trained personnel which may or may not be equipped with marking equipment traveling throughout or within an agency marking assets. Although using a ‘seek and mark’ approach potentially reduces the amount of equipment required to mark assets and eliminates some of the standardization and training issues involved with opportunistic marking, it is subject to its own drawbacks. For the F-16, less marking equipment may have to be purchased if the decision was made to make labels. But the costs saved in equipment purchase and training could easily be consumed and overcome by travel costs incurred by the traveling marking teams. On a similar note, seek and mark teams could be comprised of a group of people designated at each base to track down and mark each F-16 avionics LRU on that installation. This option would eliminate any costs involved with travel. Here again, however, since a number of teams and the amount or potential travel of each team is unknown, an objective evaluation of cost was deemed impossible.

The ‘seek and mark’ strategy has definite advantageous when evaluating timeliness, quality and span of control. Depending on the number of teams fielded, a ‘seek and mark’ strategy could be a relatively quick method of labeling assets. Multiple teams could be sent to F-16 installations with the sole task of labeling assets. Furthermore, as described above, local teams could be formed at each installation to label assets. For these reasons, “timeliness” was evaluated as low.

Because the number of people involved in a ‘seek and mark’ strategy could vary from a limited number (a handful of marking teams established) to a moderate number (people on every installation involved), the degree of quality and control over the process can vary greatly. For these reasons, quality and span of control were evaluated as medium.

Combination

Just like the label making alternatives, using a combination of intercept gate, opportunistic, and seek and mark affixing strategies may prove in the final analysis to be ideal when all marking requirements are identified. This alternative has the effect of nullifying the negative and positive attributes associated with each of the other alternatives. In the end, cost and timeliness were evaluated as medium, while quality and span of control were evaluated as high.

The results of the analysis and evaluation presented above are summarized in Table 8 below. Of the four label affixing alternatives, the 'seek and mark' strategy is the most appealing. It provides the quickest method of marking all assets while retaining reasonable quality and span of control over the process. The 'intercept gate' and 'combination' strategies are a close second due only to the expected increased time required to mark every asset. The 'opportunistic' strategy was perceived as the worst label affixing alternative. Time, quality, and span of control all potentially suffer under this strategy.

Table 8. Label Affixing Alternatives

Alternative	Cost	Timeliness	Quality	Span of Control
Intercept Gate	N/A	Medium	Medium	Medium
Opportunistic	N/A	High	Low	Low
Seek and Mark	***N/A***	***Low***	***Medium***	***Medium***
Combination	N/A	Medium	Medium	Medium

Summary

This chapter provided an analysis of the data collected for the research study. It identified where UID programs have been implemented before within the DoD and identified problems and provided corrective measures when starting an in-service UID program. The chapter provided an evaluation of label making alternatives and label affixing alternatives. Evaluation was based on factors of cost, timeliness, quality, and span of control. For F-16 avionics assets, analysis revealed obtaining data labels from a printer service bureau and affixing them using a seek and mark strategy to be most advantageous.

V. Conclusions

Overview

This chapter summarizes the research effort. It answers the research question and discusses the factors that limited the research. Recommendations for uniquely identifying F-16 avionics LRUs are provided as well as topics for future research.

Research Summary

The purpose of this research was to answer the question: what factors should the F-16 Unique Items Supply Chain Manager consider to implement an effective and efficient in-service UID program for the F-16 avionics LRUs it manages? Four investigative questions were developed to address the issues associated with this question.

The first two investigative questions focused on how in-service UID programs have been implemented before and attempts to capture the lessons learned from their implementation. The majority of this data was collected through a limited literature review of DoD organizations who implemented UID or similar programs. The literature review was supported by interviews with members of organizations responsible for implementing the programs. Although non-government in-service UID programs may exist, their presence neither was known to experts in the UID field nor documented in current literature.

The last two investigative questions attempted to evaluate the advantages and disadvantages associated with the various data label making alternatives and data label affixing alternatives. Despite the researcher's use of price quotations from vendors to derive approximate costs associated with label making alternative and opinions obtained during interviews to evaluate label affixing alternatives, the researcher's personal experience weighed heavily in the evaluative process. The number of alternatives within each label making and label affixing strategy made evaluating cost, timeliness, quality, and span of control highly subjective and in some cases impossible.

Research Conclusion

This research discovered that the process of uniquely identify a group of assets is much easier in theory than it will be in reality. The task of uniquely identifying all F-16 avionics LRUs will be long and arduous and take years even under ideal circumstances to complete. During this time, many people and organizations will be required to drastically change their operating style and business practices. One important hurdle must be overcome before specific decisions about the actual marking process can be considered. This hurdle involves gaining support for the UID process from both internal as well as external parties. This support can only be achieved through communication at all levels. Support must come not only from senior leaders, but from everyone who will be working to label the assets and working with the assets when labeled. Without this support, a viable in-service UID program does not stand a chance of being launched and maintained successfully.

Once support for the concept is achieved, the real work will start. A multitude of decisions must be made early on in the UID in-service implementation process.

Although many of these decisions may seem trivial at first glance, the final determination can significantly impact the cost and timeframe to complete a 100 percent marking effort. One of the first decisions that must be made is to determine which assets warrant unique identification. To make this decision, the tradeoffs between costs and benefits associated with marking should be evaluated. Although the requirement to uniquely identifying in-service assets within the DoD is expected to become a reality soon, program managers should strive to make logical choices and only uniquely identify those assets where the expected monetary benefits of marking exceed the costs of marking.

Other decisions include determining where and how to mark each asset, determining the best type of label medium and marking technology to employ to achieve a long label life, limit label replacement, and prevent interference with the asset's operation. Other technical considerations include the potential need to change engineering drawings and technical orders to reflect the new data label as well as the need to obtain air worthiness certification. These decisions can not be made in a vacuum.

A team of experts from several diverse fields should be formed to discuss each of these matters before the first asset is ever marked. At a minimum, the team should consist of item managers, equipment specialists, engineers, maintainers, program managers, repair technicians, and representatives from the Original Equipment Manufacturer if possible for each and every LRU being considered for unique item identification. Only after these decisions are made will it be possible to decide the most efficient and cost effective method of procuring the data labels and affixing them to the various assets identified for unique identification.

Table 9 outlines some of the more common data label substrates and the applicable code application processes. This is not an exhaustive list of substrates or application processes. Many companies have specialized substrates and have developed their own proprietary application processes. In addition, the equipment associated with bar coding is expanding rapidly with new technologies being introduced frequently.

Table 9. Common Label Substrates and Applicable Code Application Processes

Substrate	Ink Jet	Laser Jet	Thermal Transfer	Direct Thermal	Screen Printing	Photo Application	Laser Bonding	Laser Engraving
Paper	X	X	X	X	X	X	X	
Vinyl			X		X	X	X	
Polyester			X		X	X	X	
Polypropylene			X		X	X	X	
Aluminum					X	X	X	X
Stainless Steel					X	X	X	X

Research Limitations

The major limitation associated with this research was evaluating the third and fourth investigative questions, determining the advantages and disadvantages associated with the data label and data label affixing alternatives. Because the ideal label material and marking technology has yet to be identified for each of the 143 F-16 avionics LRUs, it was impossible to determine the exact cost associated with procuring labels for all U.S. Air Force managed F-16 LRUs. Without accurate technical requirements, not only was it challenging to obtain accurate quotes from printer service bureaus, it was also difficult to estimate the costs associated with the F-16 Unique Items Supply Chain Manager purchasing label making equipment required to make data labels. A lack of actual requirements also made it infeasible to determine the exact cost associated with the various label affixing strategies.

Evaluation of the factors of timeliness, quality, and span of control, can be highly subjective. In most cases, the absence of any type of historical data made a truly objective evaluation impossible. Of the cases studied during this research, only the DRILS effort used data labels exclusively and their effort did not uniquely identify each type of F-16 avionics LRU. Although the researcher incorporated the viewpoint of the interviewees during the evaluation process, the researcher's own experience and opinion weighed heavily in the assigned evaluations and may prove inaccurate when all label requirements are known and an actual costs benefit analysis can be performed.

Recommendations for Uniquely Identifying F-16 Avionics LRUs

Although it is dangerous to offer advice without having all the facts surrounding the requirements to uniquely identify F-16 avionics LRUs, I offer the following recommendations to the F-16 Unique Items Supply Chain Manager:

1. The exact label requirements for each LRU and desired label affixing strategy must be identified before a realistic cost comparison can be achieved. The exact size, label medium, and mark application process best suited for each LRU should first be determined. With this information, a rational comparison could be made between the cost of procuring data labels from a printer service bureau versus purchasing the equipment and making the labels in house.

2. The second recommendation piggybacks on the first. I would encourage the UID implementation team to limit the different types of label mediums and marking technologies used in the marking process. Limiting these variables will make the logistics of acquiring labels much easier and potentially limit the costs.

3. Uniquely identifying approximately 257,000 assets can not be accomplished overnight. The more funding allocated toward the project will obviously expedite a 100 percent marking effort. That said, a 100 percent marking effort using intercept gates at the government and contract repair facilities with an average of 2,500 LRUs being repaired monthly would take approximately nine years to complete under ideal circumstances. To achieve a 100 percent marking effort more quickly, a combination of all available alternatives may need to be employed which may strain the resources of the F-16 Unique Items Supply Chain Manager. Furthermore, be prepared to maintain existing legacy data systems and new UID data systems simultaneously. This dual effort will need to continue until a time that legacy systems can be replaced with or modified to utilize data collected from the UID effort.

Recommendations for Future Research

In the past, the DoD has either not had the means to capture asset specific maintenance related data or the effort required to capture it was too laborious and not accomplished. The advent of in-service UID opens many doors for in-depth, asset specific analysis.

One area of further research could explore the types of data that should be captured given the advantages imparted through UID. This research effort could help determine and standardize the fields in the database and the search capabilities associated with it. For example, it may be useful to not only capture the maintenance activities performed on a particular asset, it may also be beneficial to identify where the maintenance was performed, who performed the maintenance, the unique identifier of the weapon system (e.g. tail number) the asset was installed on, as well as the components or Shop Replaceable Unit (SRUs) used within it.

The advent of uniquely identifying assets opens doors to collecting other interesting and potentially fruitful information. An additional area of possible research could focus on studying the feasibility of adding elapsed time indicators to certain uniquely identified electronic assets. For years, maintenance personnel and analysts have not only wanted to know how often specific assets fail, but when they failed. Except in rare circumstances, the Air Force does not capture the "on time" of electronic assets. The addition of elapsed time indicators on problematic uniquely identified assets could provide valuable insight into current maintenance challenges and potentially resolve many longstanding, unresolved issues.

Before any UID program can be implemented, the number of assets involved in the process must be known. In the absence of an exact number, a good estimate is required at a minimum. Although accounting for U.S. Air Force-owned F-16 LRUs was accomplished for this study with relative ease, obtaining the number or foreign owned, U.S. Air Force-managed F-16 was more difficult. One area for future research would be to determine the possibility of creating or merging existing databases (DoD, contracting, foreign military sales, etc.) to establish a total inventory position for any asset managed by the Air Force. The existence of such a database would provide decision makers with the information necessary to implement a cost effective and efficient UID program.

Important Considerations

Uniquely identifying individual in-service assets is an excellent concept. A 100 percent marking effort for a single major weapon system will be relatively expensive and take years to accomplish. After the marking effort is complete, it will take several more years to institute policies that change existing business practices to capitalize on benefits derived from the UID marking effort. Despite its benefits, UID is not a panacea for all the DoD's current visibility and accountability deficiencies identified by the General Accounting Office. Merely uniquely identifying assets does not necessarily guarantee improving the ability to know the quantity, location, condition, or value of assets or enable the DoD to achieve clean financial audits. Nor will simply uniquely identifying assets improve the quality of a weapon system's Bill of Material (BOM), improve asset visibility or reduce the risk of unexpected shortages of critical items or the unnecessary purchase of items already on hand. Resolving these issues will require the creation of modern and integrated data systems updated and maintained with current and accurate data by a workforce committed to excellence and the implementation of new management and business practices that can capitalize on the data collected through UID.

Appendix A. USAF Managed F-16 LRUs

	NOUN	PN	NSN	Total Serv	Total Unserv	Total Installs	Total USAF Owned Assets
1	Horizontal Situation Indicator	75500000-1	6605-01-018-2184	55	96	4019	4170
2	Accelerometer	16C0715-3	6680-01-039-7817	18	88	4014	4120
3	Inertial Navigation Unit	K160A030-20	6605-01-042-3133			109	109
4	Radar Electro-Optical Electronics Unit	29500-89	5841-01-042-4721	0	1	72	73
5	Horizontal Situation Indicator	622-0290-004	6605-01-042-4831	185	74		259
6	Rate Gyroscope Assembly	16C0705-3	6615-01-042-7834	64	154	12042	12260
7	Pneumatic Sensor Assembly	1281B2	6685-01-042-7835	2	85	4014	4101
8	Amplifier Detector (C/D)	312300-2	5865-01-045-0837	0	3		3
9	Fire Control Computer	7560500-021	1270-01-045-3976	36	20	6	62
10	Fire Control Navigation Panel	K330A034-21	6605-01-046-3533	19	175	156	350
11	FSRS RCVR	31-051909-02	5865-01-048-9029	1	7		8
12	Jettison Remote Interface Unit	16E1606-827	5998-01-051-6308	0	0	402	402
13	Transmission Line Coupler	A05A0223-2	5915-01-053-5396	141	1237	3032	4410
14	Horizontal Situation Indicator	126460	6605-01-058-0975	195	173	4019	4387
15	Rate Sensor Unit	12-018-05	6615-01-078-4943	32	101	4014	4147
16	Radar Electro-Optical Indicator Unit	29200-89	5841-01-078-9070	0	8	144	152
17	Conventional Remote Interface Unit	16E1608-875	1290-01-080-0203	49	43	603	695
18	Jettison Remote Interface Unit	16E1606-831	5998-01-080-3978	147	152	8028	8327
19	Amplifier Detector (C/D)	312300-3	5865-01-080-5675	228	1090	201	1519
20	Inertial Navigation Unit	K160A030-21	6605-01-087-6645	3	221	109	333
21	Central Air Data Computer	4025116-905	6610-01-089-1018	0	6	129	135
22	Antenna	682R707G01	5985-01-093-2174	0	57	201	258
23	Transmitter	682R669G01	1270-01-093-2256	6	216	201	423
24	Horizontal Situation Indicator	118550M	6605-01-094-3627	13	5	4019	4037
25	Radar Control Panel	682R742G01	1270-01-094-6872	9	120	201	330
26	Head Up Display - Programmable Display Unit	79-049-12	1270-01-094-8505	0	0	2	2
27	Radar Electro-Optical Indicator Unit	29200-99	5841-01-096-3945	13	215	273	501
28	Radar Electro-Optical Electronics Unit	29500-109	5841-01-096-4833	20	98	201	319
29	Low Power Radio Frequency	681R622G02	1270-01-102-2962	7	101	50	158
30	Low Power Radio Frequency	681R622G04	1270-01-102-2963	4	97	50	151
31	Low Power Radio Frequency	681R622G01	1270-01-102-2965	2	75	50	127
32	Low Power Radio Frequency	681R622G03	1270-01-102-2966	6	75	50	131
33	Azimuth Indicator	4030132-902	5985-01-107-4586	58	281	4629	4968
34	Missle Remote Interface Unit	16E1607-875	1290-01-109-1499	44	1437	3292	4773
35	FSRS RCVR	31-051909-03	5865-01-110-6043	206	650	4014	4870
36	Identification Friend or Foe Receiver / Transmitter	154000	5895-01-112-6380	359	586	3796	4741
37	Stores Control Panel	16E1201-853	1280-01-121-6879	1	65	273	339
38	Head Up Display - Electronics Unit	51-026-02	1270-01-122-9955	0	0	11	11
39	Electronic Component Assembly	16C0851-837	5998-01-123-0046	16	96	201	313
40	Flight Control Panel	16C0605-825	6615-01-127-3160	23	74	201	298
41	CD BAND ANT	27000-1	5985-01-128-7134	17	0	159	176
42	Manual Trim Panel	16C0650-801	6615-01-129-7445	3	15	201	219
43	Attitude D Indicator	135070	6610-01-132-1898	7	148	4629	4784
44	Digital Signal Processor	750R088G01	1270-01-133-6494	27	141	10	178
45	Data Entry Display	10-01125-08	5895-01-143-5443	121	65	6555	6741
46	Antenna	750R400G01	5985-01-146-4630	0	47	161	208
47	CD BAND ANT	27130-1	5985-01-146-9283	138	43	3855	4036
48	Electronic Component Assembly	16C0851-839	5998-01-148-0712	1	22	33	56
49	Advanced Central Interface Unit	16E1535-835	1290-01-148-6286	2	1	0	3
50	Pneumatic Sensor Assembly	2101382-3-1	6685-01-149-6398	25	19	4014	4058
51	Amplifier Detector (EJ)	31-032599-04	5895-01-154-9125	486	3604	16056	20146
52	Signal Processor	327390-1	5865-01-163-1669	0	31	0	31
53	FSRS Receiver - Controller	31-051910-05	5865-01-168-9397	3	0		3
54	Advanced Conventional Remote Interface Unit	16E10100-831	5945-01-170-9363	55	72	12042	12169
55	Flight Control Computer	460700-08-01	6615-01-172-0136	5	7	7	19

	NOUN	PN	NSN	Total Serv	Total Unserv	Total Installs	Total USAF Owned Assets
56	Advanced Missle Remote Interface Unit	16E10150-3	5998-01-189-6233	8	60	2884	2952
57	Multi-function Display	8000284-921	6610-01-193-8861	40	43	0	83
58	Data Transfer Unit		7025-01-196-3702	61	35	6	102
59	Head Up Display - Programmable Display Unit	79-049-13	1270-01-199-7430	148	62	201	411
60	Data Entry Display Power Supply	10-01126-06	6130-01-207-2734	0	0	6621	6621
61	Antenna	758R800G01	5985-01-212-2950	5	123	3813	3941
62	Digital Signal Processor	750R908G01	1270-01-212-2990	26	93	201	320
63	Expanded Fire Control Computer	7560500-041	1270-01-222-3829	19	182	131	332
64	Expanded Central Interface Unit	16E10180-5	1290-01-224-8924	2	78	3	83
65	Advanced Central Interface Unit	16E1535-837	1290-01-227-9260	4	11	0	15
66	Data Entry Electronics Unit	16E10140-811	7025-01-230-1075	66	70	1651	1787
67	Inertial Navigation Unit	880200-34	6605-01-231-9754	1	29	0	30
68	Programmable Signal Processor	758R875G01	1270-01-231-9800	0	2	2026	2028
69	Modular Low Power Radio Frequency	758R888G01	1270-01-233-0011	36	288	3813	4137
70	Enhanced Fire Control Computer	7565700-031	1270-01-235-2370	6	7	0	13
71	Voice Message Unit	5173100-002	6340-01-235-3351	0	2	0	2
72	Dual Mode Transmitter	758R990G01	1270-01-238-3662	241	220	3813	4274
73	Extended Capability Data Entry Electronics Unit	16E10090-805	7025-01-242-2033	0	0	76	76
74	Expanded Data Transfer Cartridge		7045-01-248-9012	154	103	129	386
75	FSRS Receiver - Controller	31-051910-07	5865-01-249-0130	0	8		8
76	Programmable Display Generator	8000282-931	1260-01-251-1150	15	10	3270	3295
77	Programmable Display Generator	8000282-932	1260-01-251-1150	15	10	3270	3295
78	Inertial Navigation Unit	880200-35	6605-01-256-2380	62	563	0	625
79	Programmable Signal Processor	765R010G01	1270-01-256-6538	0	3	76	79
80	Expanded Central Interface Unit	16E1235-647	1290-01-262-0461	0	0	201	201
81	RADC	536R268G14	1270-01-273-3859	11	54	201	266
82	Head Up Display - Electronics Unit	51-026-10	1270-01-274-0543	0	0	72	72
83	Expanded Central Interface Unit	16E1235-649	1290-01-280-4855	44	29	201	274
84	RADC	759R961G01	1270-01-282-7914	8	72	0	80
85	Antenna	768R063G01	5985-01-293-5451	8	29	3	40
86	AIFF I/T	164750	5895-01-294-1053	0	0	2	2
87	Enhanced Central Interface Unit	16E10080-809	1290-01-297-8068	5	1	0	6
88	Enhanced Missle Remote Interface Unit	11302-3	1290-01-304-1615	85	1	7	93
89	Advanced Interference Blanker Unit	5188110-005	5895-01-308-0933	26	24	1335	1385
90	Central Air Data Computer	4025116-907	6610-01-308-1859	80	176	4014	4270
91	Antenna	768R109G01	5985-01-308-3647	0	98	161	259
92	General Avionics Computer	8908450-505	1270-01-309-3077	10	24	3270	3304
93	Antenna	768R192G01	5985-01-309-4084	0	8	201	209
94	Signal Processor	327390-2	5865-01-310-0163	2	32	0	34
95	FSRS Receiver - Controller	31-051910-08	5865-01-310-2157	9	759	0	768
96	Voice Message Unit	5173100-006	6340-01-315-0626	20	15	4014	4049
97	AIFF LOWER BFN	163950-0005	5985-01-316-4588	8	32	2	42
98	AIFF UPPER BFN	163950-0006	5985-01-316-4589	7	47	2	56
99	Enhanced Central Interface Unit	16E10080-811	1290-01-322-3711	7	3	76	86
100	Head Up Display - Electronics Unit	51-026-12	1270-01-322-5249	0	0	72	72
101	Flight Control Computer	460700-11-01	6615-01-324-6374	65	29	3737	3831
102	Signal Processor	327390-3	5865-01-324-9103	7	560	0	567
103	Advanced Programmable Signal Processor	765R800G01	1270-01-326-4573	1	0	11	12
104	Electronic Component Assembly	16C0851-843	5998-01-330-9073	91	54	3813	3958
105	Advanced Interference Blanker Unit	5188110-008	5895-01-331-0720	33	1	38	72
106	Diffractive Head Up Display Unit	79-081-13-02C	1270-01-333-3608	8	34	0	42
107	Head Up Display - Electronics Unit	51-026-11	1270-01-338-1707	0	0	201	201
108	Expanded Central Interface Unit	16E10180-801	1290-01-340-6317	7	114	201	322
109	Upgraded Programmable Display Generator	8515143-920	1260-01-351-0592			3270	3270
110	Flight Control Computer	460700-13-01	6615-01-352-8570	5	66	82	153

	NOUN	PN	NSN	Total Serv	Total Unserv	Total Installs	Total USAF Owned Assets
111	Inertial Navigation Unit	890500-202	6605-01-354-0467	0	2	2489	2491
112	Extended Capability Data Entry Electronics Unit	16E10090-807	7025-01-355-8414	155	183	1699	2037
113	Flight Control Computer	460700-14-01	6615-01-356-6851	18	42	157	217
114	Upgraded Central Air Data Computer	8518930-901	6610-01-372-8170	28	19	0	47
115	Enhanced Central Interface Unit	16E10080-817	1290-01-376-5449	0	6	0	6
116	Advanced Programmable Signal Processor	783R300G01	1270-01-396-3088	31	14	703	748
117	Programmable Signal Processor	783R230G01	1270-01-396-6750	6	18	3110	3134
118	Multi-function Display	8000284-940	1260-01-397-6973	184	194	8080	8458
119	Programmable Signal Processor	783R240G01	1270-01-399-8233	6	5	3110	3121
120	Data Transfer Cartridge	3961000001-12	7045-01-406-3579	232	9	7626	7867
121	Data Transfer Cartridge	3962000000-12	7045-01-406-3579	232	9	7626	7867
122	Head Up Display - Electronics Unit	51-026-14	1270-01-418-0115	21	206	201	428
123	Enhanced Central Interface Unit	16E10080-819	1290-01-420-4197	0	1	267	268
124	Enhanced Central Interface Unit	16E10080-821	1290-01-420-4200	1	0	610	611
125	Enhanced Central Interface Unit	16E10080-823	1290-01-420-4201	0	7	572	579
126	Advanced Central Interface Unit	16E1535-841	1290-01-420-4789	0	5	1868	1873
127	General Avionics Computer	8917311-505	1270-01-420-9450	58	268	1699	2025
128	Programmable Display Generator	8517625-931	1260-01-421-5304	172	47	3067	3286
129	Programmable Display Generator	8517625-932	1260-01-421-5304	172	47	3067	3286
130	Enhanced Fire Control Computer	7579884-031	1270-01-421-5847	23	35	0	58
131	Digital Flight Control Computer	3757528-1	6615-01-448-6152	130	88	76	294
132	Wide Area Conventional Head Up Display Unit	1-79-077-06-01K	1270-01-462-3962	111	84	1825	2020
133	Enhanced Central Interface Unit	16E10080-829	1290-01-465-3027	50	47	572	669
134	Advanced Central Interface Unit	16E1535-843	1290-01-465-3028	116	45	1868	2029
135	Enhanced Central Interface Unit	16E10080-825	1290-01-465-3030	22	69	267	358
136	Enhanced Central Interface Unit	16E10080-827	1290-01-465-3032	75	57	610	742
137	Programmable Signal Processor	811R940G01	1270-01-466-5918	72	26	3110	3208
138	Programmable Signal Processor	811R930G01	1270-01-466-7426	193	35	3110	3338
139	Wide Area Conventional Head Up Display Electronics Ui	51-036-10-06E	5999-99-027-0039	0	2	3291	3293
140	Wide Area Conventional Head Up Display Unit	79-077-06-01K	1270-99-251-2706	30	36	0	66
141	Wide Area Conventional Head Up Display Unit	79-077-10-01K	6605-99-370-8249	3	7	0	10
142	Wide Area Conventional Head Up Display Unit	79-077-05-01J	1270-99-771-4187	0	2	0	2
143	Wide Area Conventional Head Up Display Electronics Ui	51-036-10-06B	5999-99-891-9910			576	576
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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Office of the Undersecretary of Defense for Acquisition, Technology, and Logistics mandated the use of Unique Item Identification (UID) for all solicitations on or after January 1, 2004 for equipment, major modifications, and spares. This was only the first step toward uniquely identifying all DoD assets that meet certain cost and management criteria. Subsequent steps toward this goal include uniquely identifying DoD manufactured items as well as those assets currently in-service.

The purpose of this research was to identify factors the F-16 Unique Items Supply Chain Manager should consider to implement an effective and efficient UID program for its F-16 avionics assets. The case study methodology was employed to capture lessons learned from previous in-service UID programs to evaluate alternative data label making and data label affixing strategies based on cost, timeliness, quality, and span of control. Research revealed a lack of senior leader support and poor communications as primary areas fro improvement for future UID in-service programs. Considerations regarding which assets to mark, where to mark each asset, the possible need to alter technical drawings and acquire new air worthiness certification must also be calculated before actual marking activities commence. Analysis also revealed obtaining data labels from a printer service bureau and applying them using a seek and mark marking strategy as attractive alternatives for an F-16 asset marking effort. Although specifically focused on F-16 assets, the findings of this research are applicable to other organizations trying to establish their own unique item identification program.

15. SUBJECT TERMS

Unique Item Identification, Automatic Identification Technology, Bar Codes, Serial Number Tracking

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