



**AN ANALYSIS OF THE NATO E-3A COMPONENT'S END OF  
LIFECYCLE SPARE PARTS RECLAMATION**

GRADUATE RESEARCH PAPER

Amanda L. Zenner, Captain, USAF

AFIT-ENS-MS-17-J-055

**DEPARTMENT OF THE AIR FORCE  
AIR UNIVERSITY**

**AIR FORCE INSTITUTE OF TECHNOLOGY**

**Wright-Patterson Air Force Base, Ohio**

DISTRIBUTION STATEMENT A. APPROVED FOR PUBLIC RELEASE;  
DISTRIBUTION UNLIMITED

The views expressed in this thesis are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States Government. This material is declared a work of the U.S. Government is not subject to copyright protection in the United States.

AFIT-ENS-MS-17-J-055

AN ANALYSIS OF THE NATO E-3A COMPONENT'S END OF  
LIFECYCLE SPARE PARTS RECLAMATION

GRADUATE RESEARCH PAPER

Presented to the Faculty

Department of Operational Sciences

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics

Amanda L. Zenner

Captain, USAF

June 2017

**DISTRIBUTION STATEMENT A.**  
APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AFIT-ENS-MS-17-J-055

AN ANALYSIS OF THE NATO E-3A COMPONENT'S END OF  
LIFECYCLE SPARE PARTS RECLAMATION

Amanda L. Zenner

Captain, USAF

Committee Membership:

Dr. Kevin J. Gaudette  
Chair

**Abstract**

Faced with diminishing sources of supply for an aging aircraft, the NATO E-3A Component must examine sustainment options. The retirement of a portion of their aircraft fleet presents an opportunity to reclaim spare assets and return them to the supply system. At the same time, the Component must avoid reclaiming an excessive number of assets from retired aircraft, as NATO has decided to replace and retire the E-3A by 2035. An examination of the Component's processes and reclamation decisions highlights challenges, limitations, and strengths when it comes to sustaining the fleet for the remainder of its lifecycle.

## **Acknowledgements**

I would like to thank the men and women of the Logistics Wing and Logistics Support Squadron at Geilenkirchen Air Base who have provided me with the tools and insight to complete this research project. I would also like to thank my family, peers, and distance-learning cohort for providing support and encouragement over the course of this program.

Amanda L. Zenner

## Table of Contents

Abstract.....	ii
Acknowledgements.....	iii
List of Figures.....	vi
List of Tables.....	vii
I. Introduction.....	1
Background.....	1
Problem Statement.....	4
Research Objectives.....	4
Research Focus.....	5
Methodology.....	5
Assumptions and Limitations.....	6
Implications.....	6
II. Literature Review.....	7
Overview.....	7
Diminishing Resources and Obsolescence.....	7
Stock Level Optimization.....	9
End of Life Spares Reclamation.....	11
Department of Defense Guidance.....	15
III. Methodology.....	17
Overview.....	17
Hypothesis.....	19
Data Collection and Analysis.....	19
Summary.....	20
IV. Analysis and Results.....	21
Analysis.....	22

V. Conclusions and Recommendations.....	23
Conclusions.....	23
Recommendations.....	23
Future Research.....	23
Bibliography.....	24

## List of Figures

Figure 1. E-3A Component Organizational Structure.....	1
Figure 2-PAMELA's 3-D Model.....	12
Figure 3-Gomes and Ribiero's End of Life Model.....	13
Figure 4-Condemnation Rate Calculation.....	18
Figure 5-Repaired on Base Rate Calculation.....	18
Figure 6-Repaired off Base Rate Calculation.....	18
Figure 7-Safety Stock Calculation.....	18
Figure 8-C-Factor Calculation.....	19
Figure 9-Mean Time Before Failure Calculation.....	19
Figure 10-Sample of Data Calculations.....	20

**List of Tables**

Table 1-C Factor Analysis of Assets with Demand History.....21

# AN ANALYSIS OF THE NATO E-3A COMPONENT'S END OF LIFECYCLE SPARE PARTS RECLAMATION

## I. Introduction

### *Background*

The North Atlantic Treaty Organization (NATO) established the Airborne Early Warning & Control Force (NAEW&C) in 1980 to improve collective airspace defense for the alliance. The NAEW&C consists of three elements; the E-3A Component and Mission Systems Engineering Center (MSEC), both located at Geilenkirchen Air Base, Germany, and the E-3D Component at RAF Waddington, United Kingdom. The E-3A Component is a fully integrated multi-national unit. The original 18 E-3As at this base were financed by 17 NATO countries; with aircrew and support personnel coming from 15 NATO members. Today 16 aircraft remain in operation. These aircraft belong to NATO, contrasted with the E-3D component, which is owned, operated, and supported by the United Kingdom's Royal Air Force. NAEW&C reports directly to the Supreme Allied Commander Europe (SACEUR) (NAEW&C Public Affairs Office, 2016: 12-14).

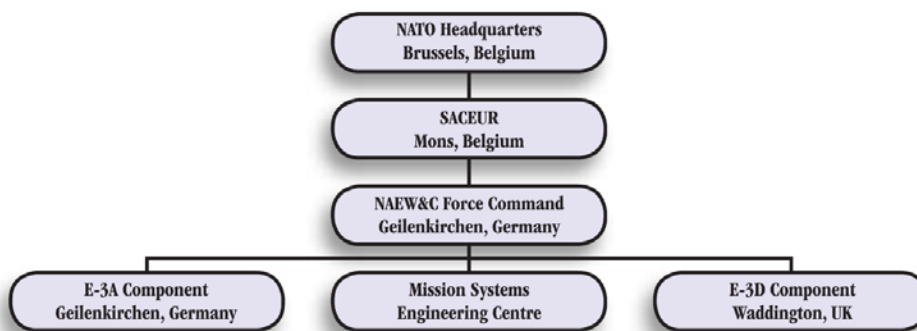


Figure 1. E-3A Component Organizational Structure (NAEW&C Public Affairs Office, 2016:12)

In 2016 alone, the E-3A Component flew 5,171 hours across 850 sorties in support of NATO Assurance Measure Missions, Tailored Assurance Measures for Turkey, Counter Islamic State of Iraq and the Levant (C-ISL) missions, 27 multi-national exercises, and training and evaluation of multi-national crews (Dunlop, 2017: 2).

The North Atlantic Council (NAC), NATO's political arm, hosts international summits and publishes directives that impact the military arm of the alliance. At the 2010 Lisbon Summit, the NAC published a new Strategic Concept and directed a modification of the NATO command structure, to include a 35% manpower reduction (NATO, 2010: 48). The 2012 Chicago Summit established a target completion date of 2015 for the restructure (NATO, 2012: 64). In 2016, the Warsaw Summit declared NATO's intention to have a replacement for the E-3A fully operational by 2035 (NATO, 2016: 77).

The NAC directives stemming from these summits have had a profound impact on the E-3A Component. First, the reorganization and directed manpower reduction resulted in the NAEW&C Force Headquarters moving from NATO Supreme Headquarters Allied Powers Europe (SHAPE) in Mons, Belgium, to Geilenkirchen Air Base, Germany. At the same time, 250 civilian Component members departed the organization (Civilian Staff Association, 2016:8). To cope with this manpower reduction, the Component was directed to retire 3 aircraft from the fleet and reduce the total to 14. The first, tail number 449, was sent to the 309th Aerospace Maintenance and Regeneration Group (AMARG) at Davis-Monthan Air Force Base in July 2015. The next two tails are planned to enter retirement in late 2017 and 2018.

Second, it established a requirement to keep the fleet flying for another 18 years. The E-3 is a modified Boeing 707 outfitted with surveillance and communications

equipment. It first rolled off the production line in 1977 and the final aircraft was completed in 1992. The E-3A fleet has undergone several modernization and lifetime extension programs over the last 35 years. The fleet is currently undergoing a major cockpit modernization will complete one final lifetime extension modification to upgrade select systems prior to retirement. The age of the aircraft presents challenges associated with Diminishing Manufacturing Sources and Material Shortages (DMSMS); that is, original manufacturers often no longer exist or produce required parts and limited opportunities exist for procuring assets through Foreign Military Sales (FMS). This presents a challenge for material managers in finding enough spare parts to keep the fleet flying until 2035. To help combat these challenges the E-3A Component has decided that aircraft sent into retirement will undergo a cannibalization process to reclaim parts for reintroduction into the supply system as spare assets.

The E-3A Component has a degree of autonomy when it comes to Asset Management; they operate like the air force of a singular nation. As they are the only aircraft fleet for that nation, they perform several item management functions at the base level, to include stock level determination, repairable and consumable item decisions, and storage of spare assets for base and depot level repair. Reclamation decisions are made by the Component's Logistics Wing Product Improvement Team, a working group chaired by the Logistics Wing Deputy Commander with representatives from supply, item managers, maintenance technicians, and subject matter experts. The overarching goal of this group is to determine what parts to salvage to maximize issue effectiveness and minimize costs.

A team of 25 individuals was sent to Davis-Monthan AFB for five weeks to remove and ship over 2,000 individual assets back to Germany. Due to time constraints, not all pre-identified assets were removed and some extra assets not originally identified were recovered. Should the Component encounter a situation where the only spare asset is in Arizona on the carcass of 449, there is a two-year window where AMARG technicians will pull the asset, with the contractual option to extend that window to ten years. Planning for the next aircraft retirement began in March 2017.

#### *Problem Statement*

Faced with diminishing sources of supply, a steady demand of operational requirements, and the approaching end of aircraft life, the E-3A Component must ensure that they select enough spare parts for reclamation to carry the airframe to the end of its lifecycle to minimize future repair or procurement costs. At the same time, they need to avoid selecting an excessive amount of spare parts that exceed remaining lifetime requirements. An analysis of the planned spares reclamation form will determine if the quantity of assets identified were the correct amount to support demand through the end of the E-3A's lifecycle, based on historical demand, forecasted demand, optimal stock levels, and repair capabilities.

#### *Research Objectives*

An examination of optimal and projected stock levels, as well as forecasted lifetime demand, will identify if the Component is reclaiming the proper number of assets. Specific research questions to be answered include:

Q1: How will the planned reclamation impact on-hand stock levels when compared against optimal stock levels?

Q2: Will the number of assets in inventory after reclamation sustain the E-3A through its remaining lifetime?

Q3: Should the Component adjust its reclamation plans?

#### *Research Focus*

While there are other E-3 fleets in operation, a few features make the E-3A Component a unique population. NATO is one of only two organizations still operating the A model of the aircraft (the other being the Saudi Royal Air Force). All other nations have upgraded or purchased B through G models. While similar, these models have structural and technological variations that do not permit interchangeability of all parts and components. Amplifying the issue of fleet singularity is NATO's shared industrial benefit concept. In return for investing in the E-3A program, alliance members are guaranteed to receive a certain amount of business. As such, repair facilities and sources of supply for the E-3A component are spread across Europe and North America. Due to the distinctive features of the fleet, research will be limited to data pertaining to the E-3A Component, and will exclude data on the other existing A model fleet and the B through G models.

#### *Methodology*

Information about the planning and retirement process was obtained through interviews with members of the Logistics Wing Product Improvement Team (LWIPT). The LWIPT provided access to spreadsheets, correspondence, and NAEW&C orders. Stock levels and historical demand data were obtained through mass data pulls in the Programme Integrated Logistics System (PILS) application (the Component's supply and maintenance management interface) and from Logistics Support Squadron Item Managers. A literature review focusing on the supply problems of Diminishing Resources

and Obsolescence, Stock Level Optimization, End of Life Spares Reclamation, and Department of Defense guidance provided the framework for analysis.

#### *Assumptions and Limitations*

This project operates under the assumption that the E-3A's replacement will achieve full operational capability by 2035, meaning that no E-3As are left flying at this time. As the replacement airframe has not actually been identified and no phase-in plans have been established, calculations were made to support 14 aircraft until the end of 2035.

Limitations to this project include an assumption that operational demand for the E-3A fleet will not increase beyond the number of flight hours accomplished in 2016. They also reflect the current configuration of the aircraft; that is, it does not take into account any part obsolescence that may occur due to fleet modifications and upgrades.

#### *Implications*

The findings of this analysis will be provided to the LWIPT to aid in reclamation planning for the remaining aircraft scheduled for removal from service. The analysis will assist Logistics Support Squadron Item Managers by highlighting assets that may require proactive stock level adjustments.

## II. Literature Review

### *Overview*

The literature review focused on three areas influencing spare asset reclamation decisions: diminishing resources and obsolescence, stock level management, and end-of-life aircraft recycling. Existing Department of Defense publications were also reviewed for military specific guidance on asset reclamation selection.

### *Diminishing Resources and Obsolescence*

The indefinite lifetime extension of products such as aircraft eventually results in obsolescence and diminishing resources. In this context, obsolescence “is defined as the loss or impending loss of original manufacturers of items or suppliers of items or raw materials” (Sandborn, 2013: 15). Sandborn discusses causes, impacts, and mitigation of obsolescence in the context of Diminishing Manufacturing Sources and Material Sources (DMSMS) in *Design for Obsolescence Risk Management* (Sandborn, 2013: 15-21). He cites multiple indefinite lifetime extensions as a primary cause of DMSMS obsolescence, especially in low volume systems that have no control over their supply chains (Sandborn, 2013: 17).

Three management strategies are highlighted: Proactive, reactive, and strategic. Proactive management revolves around forecasting parts that are at risk for obsolescence. Reactive management identifies immediate solutions and execution of mitigation plans. Strategic planning combines forecasting and solutions, often in the form of designing refresh plans, or updating systems to replace obsolete parts. Additional execution solutions can include lifetime buys of spare assets, part substitution, aftermarket procurement, or uprating of similar parts from other industries (i.e. commercial to

military specification). Because involuntary obsolescence is inevitable in long-life systems, Sandborn proposes that the appropriate mitigation strategy focuses on minimizing through-life costs, specifically focusing on lifetime buy and design refresh costs (Sandborn, 2013: 16).

Sandborn's assumption for lifetime buy is that the manufacturer will offer 6-12 months advanced notice before discontinuation. Lifetime buy decisions must then be based on expected lifetime or until a projected refresh that will render the part as no longer required. The decision ultimately relies on forecasting and optimization models. Forecasted demand in these decisions is based on observed failure rates and a buffer quantity based on organizational knowledge and experience. Sandborn also states that the penalties for overbuying (excess stock) and underbuying (stock out condition) are unequal, pushing the forecast towards overbuying (Sandborn, 2013: 18-19).

Sandborn discusses the Porter model for calculating the Net Present Value of lifetime buys to determine the cost of design refresh. If design refresh occurs earlier in a system's lifetime, the cost of the lifetime buy is low and the cost of the refresh is high, with the inverse being true for a later design refresh. To calculate optimal design refreshments, the Porter model must be applied after each individual design refresh of individual assets. To calculate multiple design refreshes for multiple parts simultaneously, Mitigation of Obsolescence Cost Analysis (MOCA) is more appropriate. MOCA uses cost analysis during initial fielding or refresh of a product to minimize obsolescence periods by projecting multiple overlapping mitigation strategies to minimize the cost of last time buys. The ultimate value of either of these DMSMS mitigation approaches is cost avoidance (Sandborn, 2013: 19-20).

Applications of these DMSMS obsolescence strategies can be observed in the fleet management of aircraft such as the Royal Canadian CF-18 program. The CF-18, modeled on the United States' F/A-18, has been flying since 1982. The Canadian government identified the F-35 as a replacement for the CF-18, but high program costs have delayed replacement while the original F-35 order is reviewed. The discontinuation of F-18 production lines has impacted part availability and has driven a sustainment strategy of preventative maintenance and obsolescence management focused on pre-emptive system upgrades, either extending contracts with original equipment manufacturers or sourcing certified after-market manufacturers (Howard, 2016: 10). Proactively planning and updating system refreshes for weapons systems mitigates costs associated with last-time buys and sourcing new manufacture or repair sources for out-of-production equipment by delaying part obsolescence, increasing use of in-production assets, and minimizing inventory holding costs.

#### *Stock Level Optimization*

Proper stock policy has a large impact on an organization's ability to achieve its goals. Too little stock can result in a work stoppage until materials are replenished. Too much inventory can consume financial and physical resources (such as manpower or storage facilities) that could be allocated elsewhere. Crandall and Crandall examine the causes of excess inventory spanning a product's entire life in *Managing Excess Inventories: A Life-Cycle Approach* (Crandall and Crandall, 2003: 101-102). Reasons highlighted include demand, supplier, and internal variation, sales and marketing decisions meant to respond rapidly to customer demands, engineering modifications, production planning errors, and accounting practices. The authors propose that excess

inventories are unavoidable, and to a certain degree necessary due to uncertain demand, but can be managed by taking different mitigation steps throughout a product's lifecycle. During product development, increased communication and collaboration between organizational elements to meet the same set of common objectives and inventory strategy can help highlight how one decision can impact the rest of the supply chain (e.g., deciding on the use of common components versus custom parts between engineers, finance, and production). Deriving the desired service level with inputs from all organizational entities and customers can also help determine the correct safety stock level at this time and improve demand forecasting. Improved demand forecasting will impact production scheduling, product phase outs, and refreshments. Throughout the life of the product, continuous evaluation and updates of forecasts can help identify obsolete and excess stock before they become a problem for the customer, and permit proactive disposal or modification actions. At the end of the lifecycle, excess inventory should be returned to suppliers, modified, used as spares, or disposed of in some other manner (Crandall and Crandall, 2003: 99).

*Spare Parts Inventory Risk for Decision Making in Plant Maintenance* (2016) by Sharif et al. proposes a risk-based formula for manufacturers to quantify and compare risk associated with stock outs and excess stocks when demand is uncertain. Their model assesses the probability of asset breaks, financial and production impacts of spare part stock-outs and excess spares (to include unit cost, handling cost, plant financial losses, and depreciation), and quantifies the total risk in dollars. This model has not yet been applied to any case studies, but Sharif et al. anticipate that it will aid inventory and maintenance managers in determining stock levels (Sharif et al., 2016: 020073 3-5).

### *End of Life Spares Reclamation*

A search of existing literature yields mostly articles and studies that approach aircraft end-of-life from an environmental sustainability standpoint, rather than operational sustainment. However, several of the concepts could easily be transferred and applied to spares reclamation for system sustainment.

*Proposed Framework for End-Of-Life Aircraft Recycling* by Gomes and Ribiero (2015) presents a model for managing end-of-lifecycle processes and supporting sustainability initiatives. The authors begin by highlighting seven phases of an aircraft's lifecycle, to include materials, design, supply chain, manufacturing, transport, operations, and end-of-life. Current end-of-life procedures focus on storing aircraft on landfill or graveyard sites without utilizing these decommissioned aircraft to satisfy increasing raw material demands. An increase in the number of retired aircraft and an increase in environmental awareness are cited as the primary influences to shift towards adding alternative re-use and recycling as additional end-of-life options (Gomes and Ribiero, 2015: 311-312). Gomes and Ribiero highlight the lack of existing literature or models for aircraft recycling; most focus on electronic or automotive industries. To support the development of their model, they focus on actions the aviation industry is taking, beginning with Airbus' Process for Advanced Management of End-of-Life Aircraft, or PAMELA project.

The PAMELA project was initiated in 2005 in conjunction with several other European organizations. Over the course of nearly three years, Airbus demonstrated the ability to recycle or repurpose 85% of an A300. The project was completed in accordance

with limited existing environmental legislation. Currently, there is no direct legislation for the aviation industry, but examining European Commission directives on vehicle recycling and the International Maritime Organization’s regulations on ship recycling provide areas that will likely be included in future legislation, especially chemical and hazardous materials handling. Airbus ultimately designed a three-step process for aircraft end-of-life known as “3-D” (Decommissioning, Disassembly, and Smart Dismantling) (Gomes and Ribeiro, 2015: 312-313).

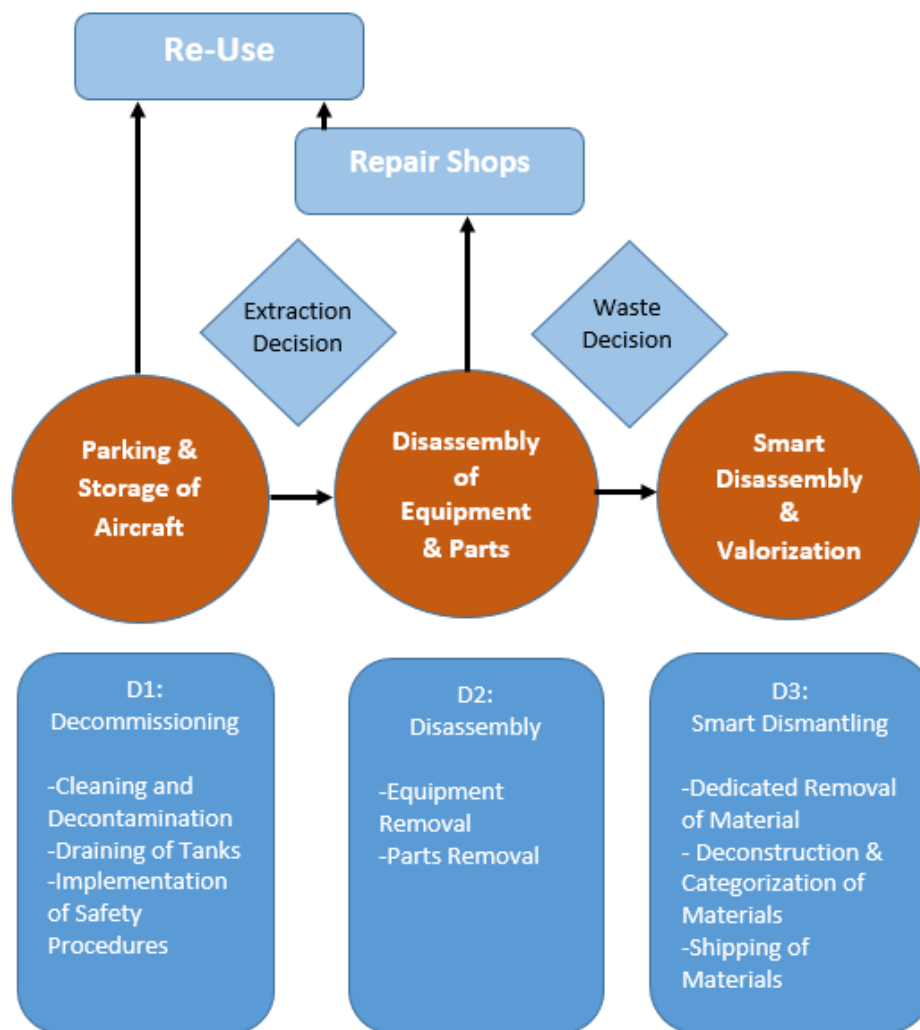


Figure 2-PAMELA’s 3-D Model (Gomes and Ribeiro, 2015: 313)

Gomes and Ribiero expand on this model, creating a closed recycling loop within the smart dismantling stage by adding a step to identify and dispose of non-disposable waste, as well as adding incineration with energy recovery as an additional recycling/re-use category.

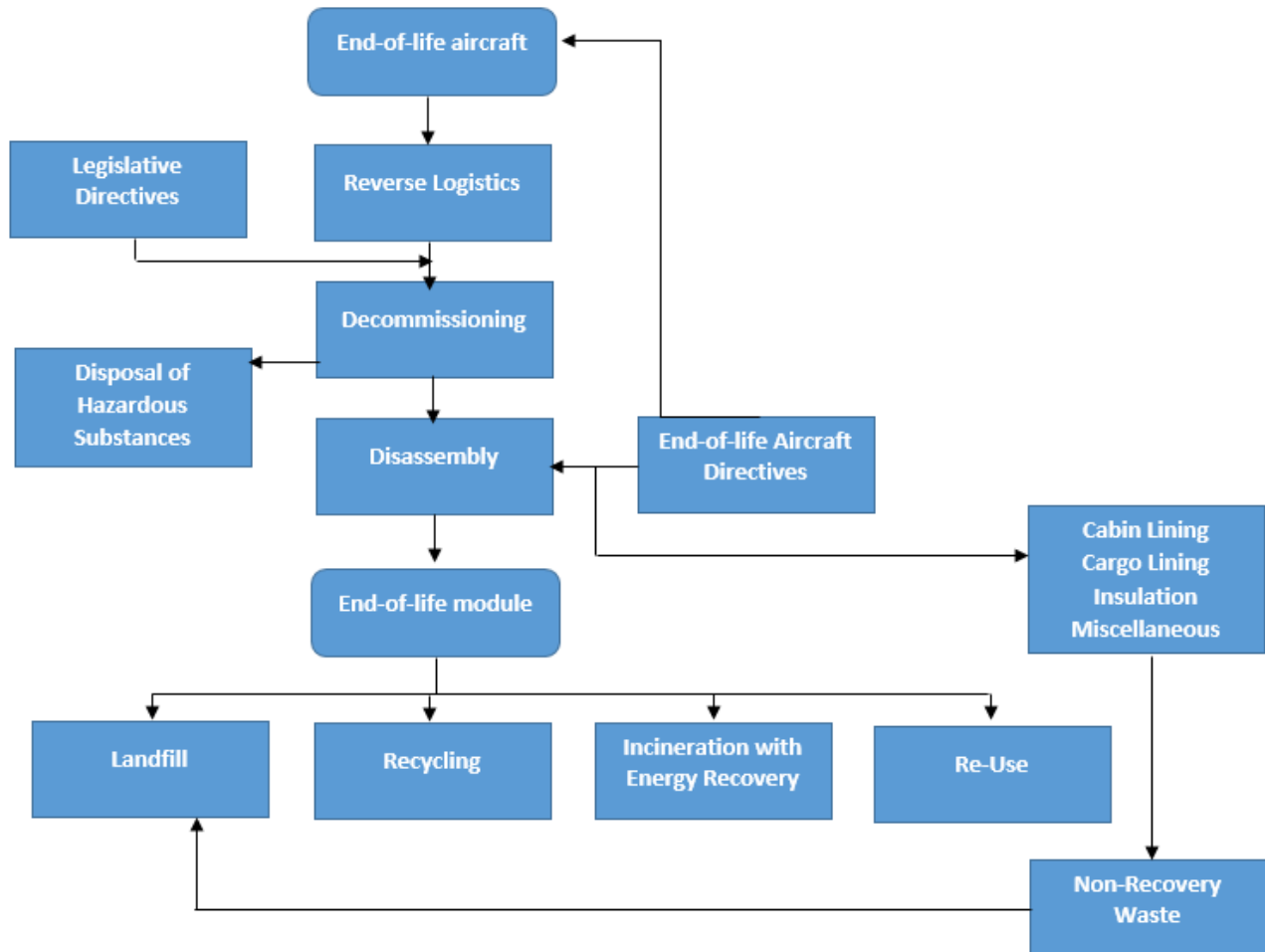


Figure 3-Gomes and Ribiero's End of Life Model (2015: 315)

Gomes and Ribiero's framework broadly encompasses reclamation decisions under End-of-Life Aircraft directives. This ultimately leads to the recycle, reuse, incinerate, or landfill decision, but does not expand on how these designations are made

aside from citing economic, environmental, and societal influences due to differing criteria from each stakeholder and conflicting selection criteria. They recommend maximizing economic and ecological value or the European Commission's end-of-life pyramid, prioritizing waste prevention, re-use, recycling, and then other recovery options. Neither of these suggestions offer a framework on how to assign economic, environmental, or societal values to prioritize the recovery option for an individual asset (Gomes and Ribiero, 2013: 315).

*In An Integrated Approach to Analysis and Modeling of End of Life Phase of the Complex Products*, Ait Kadi and Keivanpour (2016) address other EOL sustainment models, focusing on closed loop, Ladder of Lansink, and material flow. The authors address some of the same main concerns driving EOL recycling as Gomes and Ribiero: environmental concerns, anticipated legislation, and economic benefit. The closed loop method outlined in the article stems from Airbus' PAMELA project and mirrors the framework of Figure 3, but encompasses the total lifecycle of an aircraft and shows recycled alloys being used to manufacture new aircraft (Ait Kadi and Keivanpour, 2016: 1894). The Ladder of Lansink is a Dutch hierarchy model developed in the 1970s that prioritizes reclamation and reuse of parts on other aircraft over recycling, downcycling, energy recovery, and landfill. This approach has an inverse relationship between costs and environmental/social impacts, with reuse being the most expensive option but with the least impact on the environment or society (Ait Kadi and Keivanpour, 2016: 1894). The final model discussed is material flow, which focuses on the waste flow of different substances throughout different sub-processes. Information entered into this model is

subjective and requires a high degree of cooperation between different agencies (Ait Kadi and Keivanpour, 2016: 1895).

Ait Kadi and Keivanpour propose a framework for selecting an EOL model that is based on consideration of seven product characteristics (production, design, construction, technology & knowledge, suppliers, customers, and legislation), industry context (market trends), and sustainability principles. Like Gomes and Ribiero, they recommend expanding the group of decision makers to select an optimal EOL model but do not propose a quantitative method for selecting items for reclamation (Ait Kadi and Keivanpour, 2016: 1895-1896).

#### *Department of Defense Guidance*

Although the NAEW&C is not a United States DoD organization, it has used select DoD publications and forms as the basis for developing its own organizational guidance. An examination of Department of Defense Manual 4160.21, Volume 2- Defense Materiel Disposition: Property Disposal and Reclamation (2015), provides a procedural foundation for asset reclamation. General guidelines state that the decision to reclaim end items and components and the quantity to reclaim should be based on an analysis revolving around of anticipated and current requirements, number of repairable assets in inventory, facilities and capabilities. Reclamation can be classified as routine (removed prior to transfer to DoD), programmed (scheduled after transfer), non-programmed (recovery of crashed aircraft), or priority (no other sources of supply exist). Decisions regarding asset disposal are made by Item Managers and Inventory Control entities (Department of Defense Manual 4160.21 Vol 2, 2015: 40-44).

Air Force Materiel Command Instruction 23-111 (2014) expands on responsibilities and considerations for asset reclamation from excess aircraft. The majority of the publication revolves around interactions with AMARG. AMARG will preserve and store aircraft, and act as a source of supply for items no longer commercially before new procurement contracts are initiated.

Item Managers are responsible for editing save lists generated by the Air Force's Reutilization and Disposition (which identifies individual assets and quantity available per aircraft). When editing these lists, Item Managers must take several factors into consideration such as: economic feasibility, likelihood of successful reclamation, technical considerations, existing sources of repair and supply, and whether asset reclamation will impact any existing contracts. They must also continuously monitor save lists throughout the reclamation process, as a requirement increase or decrease after the initial computation date could result in over- or under-reclamation. Item Managers may also request additions to the save list that are based on experience with supporting the aircraft. If an asset is needed after preservation (priority reclamation), it is possible to retrieve the required item but there is potential for long-term degradation of the aircraft that could jeopardize future reclamation (Air Force Materiel Command Instruction 23-111, 2014: 16-41).

While useful in providing considerations for determining what assets should be reclaimed, neither publication provides a firm methodology or formula that could be used by the Item Managers at the E-3A Component when determining the identity or quantity of assets to reclaim to support fleet sustainment.

### **III. METHODOLOGY**

#### *Overview*

This section documents the Component's process for determining optimal stock levels and develops a method of selecting assets for reclamation upon Component aircraft retirement utilizing forecasted lifetime demand.

#### *Stock Level Calculations*

The Materiel Management Branch of the Component's Logistics Support Squadron updates optimal NSN stock levels on a semi-annual basis using C-Factor Calculations. The resulting C-Factor of 1 through 3 indicates the number of assets required to support different stock issue effectiveness rates (the percentage of time that a part will be able to be provided to a customer on demand). The C-Factor calculations incorporate historical consumption data including the condemnation rate, repaired on base rate, repaired off base rate, break rates, safety stock levels based on scheduled flying hours (a constant number derived from the Component's commitments), and number of aircraft. Item managers do not complete C-Factor calculations for slow moving NSNs that have had no demand signal for more than two years. Item Managers use the C-2 Factor as the optimal stock level target. Elements of the C-Factor formula can also be used to determine mean time between failure (MTBF) for an asset (Virt, J. 2017).

$$A = \frac{COND \times SCHED \times ACFT \times 12}{ACTUAL}$$

*COND = TOTAL NUMBER OF ASSETS CONDEMNED IN LAST 8 QUARTERS*  
*SCHED = NUMBER OF FLYING HOURS SCHEDULED MONTHLY*  
*ACFT = NUMBER OF AIRCRAFT IN INVENTORY*  
*12 = LEAD TIME IN MONTHS*  
*ACTUAL = TOTAL NUMBER OF HOURS FLOWN IN LAST 8 QUARTERS*

Figure 4-Condemnation Rate Calculation (Virt, J., 2017)

$$B = \frac{RTS \times SCHED \times ACFT \times RTS \text{ DAYS}}{ACTUAL \times 30}$$

*RTS = TOTAL NUMBER OF ASSETS REPAIRED ON STATION IN LAST 8 QUARTERS*  
*RTS DAYS = AVERAGE NUMBER OF REPAIR DAYS*  
*30 = AVERAGE NUMBER OF DAYS IN MONTH*

Figure 5-Repaired on Base Rate Calculation (Virt, J., 2017)

$$C = \frac{NRTS \times SCHED \times ACFT \times OBT}{ACTUAL \times 30}$$

*NRTS = TOTAL NUMBER OF ASSETS SENT OF STATION FOR REPAIR IN LAST 8 QUARTERS*  
*OBT = AVERAGE NUMBER OF DAYS OFF STATION FOR REPAIR*

Figure 6-Repaired off Base Rate Calculation (Virt, J., 2017)

$$D = \sqrt{3 \times (B + C)}$$

Figure 7-Safety Stock Calculation (Virt, J., 2017)

C-FACTOR FORMULA	STOCK EFFECTIVENESS
$C1 = A + B + C + D$	84%
$C2 = A + B + C + 2D$	97%
$C3 = A + B + C + 3D$	99%

Figure 8-C Factor Calculation (Virt, J., 2017)

$$MTBF = \frac{ACTUAL}{COND + RTS + NRTS}$$

Figure 9-Mean Time Before Failure Calculation (Virt, J., 2017)

### *Hypothesis*

This study will determine if the Component is reclaiming the right number of parts to support the remaining E-3As until fleet retirement without accumulating a large amount of excess stock that exceeds forecasted demand. If the component is reclaiming the appropriate number of assets, the projected stock levels will fall within the C-Factor calculations used by item managers to achieve between 84% and 100% stock effectiveness.

### *Data Collection and Analysis*

The most recent C-Factor calculations were completed in July 2016 for 16 aircraft and a monthly commitment of 46.56 flying hours (dictated by higher headquarters). To determine the new C-Factors for the remainder of the E-3A's lifespan, the C-Factors were re-calculated using the end fleet size of 14 and established flying hour assumptions.

Results were then applied to the list of NSNs that were subject to removal during the last aircraft retirement. Using the monthly flight hour commitment to compute the estimated remaining flying hours and MTBF for each asset, remaining lifetime demand for each asset was forecasted. Additionally, by using the documented number of days to accomplish on- and off-base repair for one asset of each NSN, the number of assets that could be repaired over the remaining lifetime was calculated and compared to forecasted stock levels and demand.

NSN	C2 Factor (Ideal Stock Level)	Stock On Hand Today	Stock After Reclamation	17 Year Lifetime Demand	17 Year Repair Capacity	17 Year Lifetime Stock	17 Year End of Life Surplus or Shortage
	Calculated locally by item Managers	Pulled from Accounting System	On Hand plus Planned Reclamation	Lifetime Flying Hours divided by MTBF	Lifetime Days divided by Repair Days	Repair Capacity (assuming only one asset in repair at a time) Plus Stock after Reclamation	Lifetime Stock minus Lifetime Demand
4543	14	23	35	160	1065	1100	940
4544	6	7	10	44	33	43	-1

Figure 10-Sample of Data Calculations

### *Summary*

The data analysis allowed the identification of where the E-3A Component's reclamation plans meet ideal stock levels, what NSNs will be excess at the end of the airframe's lifecycle, and where there will be asset shortfalls. This research will allow the Component to adjust and reduce its reclamation plans where appropriate, and begin planning mitigation actions for assets highlighted as future shortages. The entire data population is discussed in the next section of this paper.

#### IV. ANALYSIS AND DISCUSSION

An analysis of the data highlights shortages and excess reclaimed assets. There was no demand history or C-Factor calculations for 384 of 865 NSNs removed from the first retired aircraft. Of these 384 NSNs, 218 had plans for additional reclamation. The remaining 481 NSNs with a demand history will be the focus of the analysis.

Assets with Demand History	
Projected Stock Level Falls Between C1 and C3	144/481
Projected Stock Level < C1	9/481
Exceeds C3	328/481
Exceeds C3 by >2	249/328
Exceeds C3 by >10	80/328

Table 1-C Factor Analysis of Assets with Demand History

Only 30% of the assets eligible for reclamation have a projected stock level in the optimal range. Less than 2% fail to meet the minimum goal, however 68% exceed the upper goal boundary of C3, having the asset on hand 99% of the time.

While C-Factors establish goal stock levels and can help eliminate unnecessary assets, lifetime demand and repair capability projections highlight areas where it may be necessary to disregard and exceed C-Factors. 33 NSNs are not projected to have any further demands before the end of the airframe's life. 38 will experience shortages due to insufficient output from repair. Increasing the number of reclaimed assets on 12 of these NSNs would reduce lifetime shortages, but only eliminate one shortage. Lifetime repair capacity outpaces lifetime demand for the remaining 410 assets, with 289 of those items having lifetime availability through repair exceed over 100 units.

## *Summary*

The aim of this research was to answer three questions:

Q1: How will the planned reclamation impact on-hand stock levels when compared against optimal stock levels?

Q2: Will the number of assets in inventory after reclamation sustain the E-3A through its remaining lifetime?

Q3: Should the Component adjust its reclamation plans?

The current reclamation plan will result in an overage for 321 NSNs. Nearly a quarter of these overages will exceed optimal stock effectiveness levels by 10 units or more. Overall, these overages will sustain the E-3A through the remainder of its life and provides a cushion that could ease future procurement problems for obsolete parts.

However, this excess stock will cause the E-3A Component to incur unnecessary costs associated with asset removal, transportation, storage, maintenance, and disposal. Item Managers and the LWIPT should adjust their reclamation plans by focusing on an overall reduction and take note of the assets that will experience shortages by the end of the E-3A's lifetime.

## **V. Conclusions and Recommendations**

### *Conclusions*

This research paper attempts to establish a method of evaluating the identity and number of assets to reclaim when recycling an aircraft for operational sustainability, rather than environmental. The analysis of optimal stock levels, lifetime demand, and lifetime repair capabilities identified shortages and excesses for individual NSNs that will be provided to the LWIPT and Item Managers to aid in planning for the retirement of a second NATO AWACS aircraft.

### *Recommendations*

Overall, the Component should reduce the number of assets being reclaimed, especially ones with low or no demand history. Focusing on high demand and projected shortages would be more beneficial and have fewer reclamation costs associated with them. However, Item Managers are the subject matter experts for their assets when it comes to difficulty with procurement and repair timelines; their experience and judgement should be used to modify and finalize reclamation decisions.

### *Future Research*

As NATO continues to develop the timeline for bringing the E-3A's replacement online, further analyses should be conducted prior to the third aircraft retirement and after a phase-out schedule for the AWACS fleet is complete. Additionally, there is an opportunity to further refine optimal stock levels by examining ways to improve one of the key variables in C-Factor calculations; repair time. Any increases or decreases could yield changes to the optimal stock levels that could reduce the need for further reclamation projects.

## Bibliography

Air Force Materiel Command Instruction 23-111. (2014)

Ait Kadi, D. and S. Keivanpour. "An Integrated Approach to Analysis and Modeling of End of Life Phase of the Complex Products." *International Federation of Automatic Control Papers Online*, 49: 1892-1897 (2016).

Civilian Staff Association. "An Honourable Ceremony for 3,338 Years of Dedication," *NATO Air Base Geilenkirchen Skywatch*, 32(4) (29 April 2016), 8-9.

Crandall, R. and W. Crandall. "Managing Excess Inventories: A Life-Cycle Approach." *Academy of Management Executive*, 17 (3): 99-113 (2003).

Department of Defense Manual 4160.21 Volume 2. (2015)

Dunlop, Dawn. "Commander's Corner," *NATO Air Base Geilenkirchen Skywatch*, 32(13) (3 January 2017), 2-6.

Howard, C. "Extending Usable Life in the Face of Obsolescence," *Military & Aerospace Electronics*, (January 2014), 10-15.

NAEW&C Public Affairs Office. *NAEW&C Force Newcomer's Guide*, (2016), 12-14.

NATO. "Lisbon Summit Declaration." (20 November 2010), Retrieved 19 January, 2017, from [http://www.nato.int/cps/en/natolive/official\\_texts\\_68828.htm](http://www.nato.int/cps/en/natolive/official_texts_68828.htm)

NATO. "Chicago Summit Declaration." (20 May 2012), Retrieved 19 January, 2017, from [http://www.nato.int/cps/en/natolive/official\\_texts\\_87593.htm](http://www.nato.int/cps/en/natolive/official_texts_87593.htm)

NATO. "Warsaw Summit Declaration." (9 July 2016), Retrieved 19 January, 2017, from [http://www.nato.int/cps/en/natohq/official\\_texts\\_133169.htm](http://www.nato.int/cps/en/natohq/official_texts_133169.htm)

Ribeiro, J. and J. Gomes. "Proposed Framework for End-Of-Life Aircraft Recycling." *12<sup>th</sup> Global Conference on Sustainable Manufacturing*, (2015) 311-316.

Sandborn, P. "Design for Obsolescence Risk Management." *2<sup>nd</sup> International Through-life Engineering Services Conference*, (2013) 15-22.

Sharif, K., J. Ibrahim, and Z. Udin. "Spare Parts Inventory Risk for Decision Making in Plant Maintenance." *AIP Conference Proceedings*, 020073-1-6.

Virt, J. (30 Jan 2017). Personal interview.

# REPORT DOCUMENTATION PAGE

*Form Approved*  
*OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

<b>1. REPORT DATE</b> (DD-MM-YYYY) 15-06-2017			<b>2. REPORT TYPE</b> Graduate Research Paper		<b>3. DATES COVERED</b> (From - To) Jan 2014-Jun 2017	
<b>4. TITLE AND SUBTITLE</b>  An Analysis of E-3A Component's End of Lifecycle Spare Parts Reclamation					<b>5a. CONTRACT NUMBER</b>	
					<b>5b. GRANT NUMBER</b>	
					<b>5c. PROGRAM ELEMENT NUMBER</b>	
<b>6. AUTHOR(S)</b>  Zenner, Amanda L., Capt, USAF					<b>5d. PROJECT NUMBER</b>	
					<b>5e. TASK NUMBER</b>	
					<b>5f. WORK UNIT NUMBER</b>	
<b>7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)</b>  Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 Hobson Way Wright-Patterson AFB OH 45433-7765					<b>8. PERFORMING ORGANIZATION REPORT NUMBER</b>  AFIT-ENS-MS-17-J-055	
<b>9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</b> NAEW&CF E-3A Component Logistics Support Squadron LWS #16 Lilienthalallee 100 P.O. Box 408000 52511 Geilenkirchen Germany					<b>10. SPONSOR/MONITOR'S ACRONYM(S)</b> LWS	
					<b>11. SPONSOR/MONITOR'S REPORT NUMBER(S)</b>	
<b>12. DISTRIBUTION / AVAILABILITY STATEMENT</b>  Distribution Statement A. Approved for Public Release; Distribution Unlimited						
<b>13. SUPPLEMENTARY NOTES</b>  This work is declared a work of the U.S. Government and is not subject to copyright protection in the United States.						
<b>14. ABSTRACT</b> Faced with diminishing sources of supply for an aging aircraft, the NATO E-3A Component must examine sustainment options. The retirement of a portion of their aircraft fleet presents an opportunity to reclaim spare assets and return them to the supply system. At the same time, the Component must avoid reclaiming an excessive number of assets from retired aircraft, as NATO has decided to replace and retire the E-3A by 2035. An examination of the Component's processes and reclamation decisions highlights challenges, limitations, and strengths when it comes to sustaining the fleet for the remainder of its lifecycle.						
<b>15. SUBJECT TERMS</b> Diminishing Manufacturing Sources and Material Supply, DMSMS, Reclamation, End-of-Lifecycle, E-3, NATO						
<b>16. SECURITY CLASSIFICATION OF:</b>			<b>17. LIMITATION OF ABSTRACT</b>	<b>18. NUMBER OF PAGES</b>	<b>19a. NAME OF RESPONSIBLE PERSON</b> Dr. Kevin J. Gaudette, AFIT/ENS	
<b>a. REPORT</b> U	<b>b. ABSTRACT</b> U	<b>c. THIS PAGE</b> U			UU	35