F-16 MAINTENANCE METRICS AND MISHAPS:
IS THERE A CORRELATION?

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IVAN A. PENNINGTON, MAJOR, U.S. AIR FORCE
B.S., Embry Riddle Aeronautical University, Daytona, Florida, 1997

Fort Leavenworth, Kansas
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Name of Candidate: Major Ivan A. Pennington

Thesis Title: F-16 Maintenance Metrics and Mishaps: Is there a Correlation?

Approved by:

____, Thesis Committee Chair
Ethan S. Rafuse, Ph.D.

____, Member
Lt Col Daniel L. Longwell, M.S.

____, Member
Maj Julio E. Rodriguez, M.S.

Accepted this 8th day of June 2012 by:

____, Director, Graduate Degree Programs
Robert F. Baumann, Ph.D.

ABSTRACT

F-16 MAINTENANCE METRICS AND MISHAPS: IS THERE A CORRELATION?, by Major Ivan A. Pennington, 67 pages

F-16 aircraft maintenance metrics and F-16 unit mishaps are examined in an effort to determine if there is a correlation between the two sets of data. Using active duty units from 2000-2008, nine common U.S. Air Force maintenance metrics of similar F-16 units are considered in an effort to evaluate if any of the studied maintenance metrics can be used as a predictor of aircraft mishaps. This study did not find any correlation between the metrics examined and the mishaps experienced.

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TABLE OF CONTENTS

ACRONYMS

AFI	Air Force Instruction
AFPAM	Air Force Pamphlet
AFSAS	Air Force Safety Automated System
FSE	Flying Scheduling Effectiveness
LIMS-EV	Logistics, Installations, Mission Support Enterprise View
MC	Mission Capable
TNMCM	Total Non-Mission Capable Maintenance
TNMCS	Total Non-Mission Capable Supply
USAF	United States Air Force

ILLUSTRATIONS

Page

TABLES

Page

CHAPTER 1

INTRODUCTION

Background

In an era of dwindling defense budgets and scarce resources, maintaining and preserving combat power for the nation's defense is an important task for the United States Air Force (USAF). Since fiscal year (FY) 2000, the USAF has lost 102 fighter aircraft at a cost of over $2.4 billion in various mishaps and aircraft accidents.[1] More importantly, the USAF also lost 32 fighter pilots. While the cost of training replacements for the 32 lost airmen exceed $83 million,[2] the pain and suffering of the families and units of those airmen cannot be calculated. The USAF aircraft maintenance community must do all it can to prevent aircraft mishaps and retain both the human and physical capital invested in our nation's fighter force.

The primary job of an USAF aircraft maintenance organization is to provide safe, serviceable, and properly configured aircraft to the pilots who fly them.[3] This task is the backbone of airpower production and cannot be executed haphazardly. Maintenance tasks performed on ground vehicles, computer systems, radar systems, and many other systems are equally important to mission accomplishment. Failure in tasks outside of aircraft

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[1]U.S. Air Force Safety Center, "F-16 Aircraft Statistics," http://www.afsc.af.mil/organizations/aviation/aircraftstatistics/index.asp (accessed 24 February 2012).

[2]Eric Tegler, "Air Force Flight Simulators May Help Cut Training Costs," *Defense Media Network*, 11 November 2011, http://www.defensemedianetwork.com/stories/virtual-bargain/ (accessed 3 March 2012).

[3]Department of the Air Force, Air Force Instruction (AFI) 21-101, *Aircraft and Equipment Maintenance Management*, para 1.3. (Washington, DC: Government Printing Office, 2010), www.e.publishing.af.mil (accessed 15 May 2012).

maintenance can lead to mission degradation, in various areas of communication, information flow, and logistical capabilities. Failure to adhere to technical orders published for aircraft maintenance can lead to catastrophic and sometimes fatal results.

In an incident in March 2001, an F-16C flying over a training range in New Mexico lost thrust, forcing the pilot to eject and abandon a $30-$35 million jet. An investigation determined that faulty maintenance actions were responsible for the engine failure.[4] In a similar incident in April 2005, an F-16D was flying a training mission near Charleston, South Carolina. After the engine lost thrust, the pilots on board steered the aircraft away from the city and ejected prior to the aircraft crashing into the Charleston marshland. It was subsequently determined that key blade seals were not installed on the engine's turbine section.[5] These blade seals are a vital part of the engine's turbine section and necessary to maintain appropriate air pressure and airflow through the engine. They prevent air from leaking through gaps, ensuring the efficiency and thrust of the motor. This is especially important in a single-engine aircraft like the F-16.

From FY 2001 through 2006, a total of ten Class A mishaps were directly attributed to aircraft maintenance failures. Since FY 2007, the USAF has grouped maintenance and logistics into a single category for Class A mishap tracking. Since that time the USAF has determined 34 Class A mishaps were a result of maintenance and logistics.[6] Combining these two areas highlights the need to focus efforts, not only across

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[4]Miguel Navrot, "Workers blamed in F-16 Crash," *Albuquerque Journal,* 31 August 2001.

[5]Ron Menchaca, "F-16D laced seals, crash report finds," *The Post and Courier*, 24 August 2005.

[6]U.S. Air Force Safety Center, "F-16 Aircraft Statistics."

the maintenance enterprise from the lowest organizational levels back to depot maintenance levels, but also through supply and support chains, to prevent mishaps.

The USAF devotes significant resources to investigating and preventing mishaps. It offers eight different courses devoted to aviation safety, investigation, and prevention that target officers and senior non-commissioned officers. The USAF also trains international students on mishap prevention and investigation.[7] Each flying wing has a Chief of Safety position, as well as dedicated Flying Safety Officers devoted to aviation mishap prevention and responsible for the initial stages of an investigation should one be required. The Chief of Safety position is important enough to have a prerequisite assigned, requiring the individual assigned to the position to currently be on or have been on a previous squadron commander list. If the individuals Wing Commander intends to support his or her nomination to the next squadron commander list he or she would also be eligible for this important position. This requirement underscores the value the USAF places on the position and the caliber of individual's desired to fill front-line safety positions.[8]

While a culture of maintenance discipline and proper maintenance actions is difficult, if not impossible to fully quantify, this paper seeks to identify measures that may prove useful in determining if a given unit is headed toward a catastrophic mishap. Many arguments can be supported with respect to maintenance culture being the most important factor in preventing mishaps. A "by the book" mentality is what every

[7]Ibid.

[8]Department of the Air Force, Air Force Instruction (AFI) 91-202, *The US Air Force Mishap Prevention*, para 2.1.1.1. (Washington, DC: Government Printing Office, 2011), www.e-publishing.af.mil (accessed 15 May 2012).

maintenance leader strives for; however, quality assurance functions and mishap reports often reveal a failure to adhere to technical maintenance requirements or orders. The safety investigation process searches for the cause or causes of a mishap, often focusing on material failure, pilot error, or failure of maintenance personnel to perform their jobs correctly. This paper seeks to find correlation between maintenance metrics and the number of unit mishaps.

Aircraft maintenance performance metrics have been tracked since the inception of the USAF.[9] The requirement to maintain our nation's fleet of combat aircraft is arguably the lynchpin for successful operations. Many operations depend on the ability of the USAF to provide strategic airlift across the globe. Reliable and safe aircraft maintenance is the cornerstone of the USAF maintenance community. In 2001 the USAF produced the *Metrics Handbook for Maintenance Leaders*.[10] This relatively short handbook captured and explained many of the pertinent maintenance metrics, how to interpret them, and the importance of trends in a given area of measurement of aircraft maintenance. Dividing the metrics into leading and lagging indicators, this pamphlet provides the basis for rating an aircraft maintenance unit's performance over time, in specific and quantifiable measures. These metrics, the definitions of the processes they measure, and their applicability to maintenance management will be explained in detail in chapter 4. One unit's apparently positive performance metrics measured against a higher

[9]Barbara L. Harris, "Challenge to United States Tactical Air Force Aircraft Maintenance Personnel: Past, Present and Future" (Thesis, Air Force Institute of Technology, 1991), 44.

[10]Air Force Logistics Management Agency, *Metrics Handbook for Maintenance Leaders,* http://www.aflma.hq.af.mil/shared/media/document/AFD-100107-055.pdf (accessed 15 May 2012), 2.

headquarters mandated scale is one indication of performance; however, when measured against the unit's number of mishaps experienced, it may present a different picture. Additionally, chapter four will describe USAF mishap reporting categories and classes to provide context to the reader. Chapter 5 will explain findings and their significance.

Problem Statement

The USAF is entering a period of fiscal constraints as the national economy forces the entire country to reexamine priorities and expenditures. As major weapons systems acquisition programs are curtailed, reduced, or eliminated, the need to preserve and maintain current combat aircraft becomes more important than ever. The challenge to the USAF is figuring out how to utilize maintenance metrics to prevent aircraft mishaps. The purpose of this thesis will be to assess if any correlation exists between its maintenance performance metrics, and the unit's mishap record.

Research Question

Specifically, this thesis will attempt to answer this question: Does a discernible, statistically relevant relationship exist between any one of nine specific active-duty F-16 maintenance performance indicators and active-duty F-16 mishaps?

Scope and Limitations

The scope of the paper was purposefully focused on F-16 aircraft based upon the author's personal experience with the airframe, the availability of data for the aircraft, and the sample size of the number of units flying and maintaining the aircraft. The F-16 has also been in service since 1979, providing a reasonable data sample.[11] The scope of research for this paper will be restricted to current active duty, F-16 units for the period of FY 2000 through FY 2008. The reason for ending the study at FY 2008 was due to a Class A mishap criteria change across the Department of Defense, raising the threshold for Class A monetary losses to two million dollars.[12] In order to keep the comparisons equal, the sample of active duty unit's maintenance metrics was restricted to FYs 2000 through 2008. Additionally, units deactivated, or given a new mission or aircraft mission design series will not be reviewed due to a shortage of data from the time period studied. Air National Guard and Air Force Reserve units on Title 10 orders deployed or participating in training exercises, while technically considered active duty, will also be excluded to maintain a comparable data sets. Deployed aircraft mishaps are also removed from the data set, regardless of the unit maintaining those aircraft, because the reporting tool consistently fails to identify the specific home unit in a deployed setting.

The reason for excluding Air National Guard and Reserve data is to ensure comparable data set. To further illustrate this reasoning, active-duty units are traditionally more focused on the "holy grail" of maintenance metrics, the Mission Capable (MC) rate, for it describes from one point of view the degree to which the unit is successful in maintaining assigned aircraft. The MC rate traditionally has been the yardstick for

[11]Inside AF.mil, *F-16 Fighting Falcon fact sheet*, http://www.af.mil/information/factsheets/factsheet.asp?id=103 (accessed 17 May 2012).

[12]Department of the Air Force, Memorandum for All MAJCOM/SE and All NAF/SE, Subject: AFI 91-204 and AFMAN 91-223 Immediate Action Guidance, 14 October 2009.

measuring a unit's performance.[13] While it does show the number of flyable aircraft and condition of those aircraft may be mission capable, they may not be in the best possible condition for long-term fleet health. Guard units not as focused on the MC rate (or many maintenance metrics to the extent the active duty is) may devote extra time to fix pilot reported or ground discovered discrepancies. Another factor making the active duty versus guard comparison problematic is the different standards to which each are held. For example, in FY 2005 the USAF F-16 MC rate standard was 82 percent for active duty units and 72 percent for Air National Guard and Air Force Reserve units.[14] The previous FY (2004) the active duty units maintained their F-16 fleets at 82.4 percent MC rate while their guard and reserve counterparts' fleets were maintained at 68.6 percent MC. This almost 14 percent difference is the result of many factors, but the difference in the two rates makes comparisons problematic. Additionally, the Total Non-Mission Capable Maintenance (TNMCM) rates for the active duty versus guard and reserve units for FY 2004 were 12.2 to 27.8 respectively. The subsequent TNMCM standard for FY 2005 was set for active duty units at 11 percent TNMCM, while the guard and reserve units were allowed a 28 percent TNMCM standard.[15] This 17 percent difference in standards allowed guard and reserve units significantly more time to allow aircraft to remain in a non-mission capable status based solely on maintenance requirements. The

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[13]Air Force Logistics Management Agency, *Metrics Handbook for Maintenance Leaders*, http://www.aflma.hq.af.mil/shared/media/document/AFD-100107-055.pdf (accessed 15 May 2012), 40.

[14]Christopher Burke, *Operational Based AF Maintenance Standards*, www.acq. osd.mil/07_USAF%20MX%20Standards%20Brief3.ppt (accessed 17 May 2012).

[15]Ibid.

effect of these different standards translates into more pressure on active duty units to meet a higher standard of readiness and therefore would not represent a fair comparison of the units maintenance metrics and number of aircraft mishaps experienced.

The use of aggregate USAF data for FYs 2001 through 2010 is shown only as a comparison of data sets and as an overall tool for understanding the entire F-16 community. This much larger data set includes all F-16 units regardless of status (active duty, guard or reserve), size, or mission.

Expected research value

The ultimate value of this study is how it may provide maintenance managers at all levels and possibly the USAF in general with trend data and increased awareness of the importance of maintenance metrics and the prevention of F-16 mishaps. This study is not intended to advocate for or argue against the value of maintenance metrics. The purpose of this paper is to study the metric’s intrinsic value in predicting aircraft mishaps through an examination of nine specific maintenance metrics and whether or not they correlate to the number of mishaps experienced by a unit. If any correlation is found between maintenance metrics and mishap rates in the study, it could be expanded to other airframes in an effort to predict future aircraft mishaps across the entire fleet of USAF aircraft.

CHAPTER 2

LITERATURE REVIEW

Aviation Mishap Prevention

With respect to aviation mishap prevention, extensive literature exists, most of which is focused on prevention of the next mishap through risk mitigation, increasing awareness, and using lessons learned after determining factors that caused current mishaps. In the United States the Federal Aviation Administration, the Department of the Interior, and all services in the Department of Defense, administer and resource robust mishap prevention programs. A multitude of government agencies across the globe maintain programs aimed at preventing aviation mishaps. The International Civil Aviation Organization's website lists 191 member states in the organization[16] and places aviation safety at the core of its objectives.[17] At any of the organization websites listed, safety and mishap prevention bulletins, are provided.

Post Mishap Investigation in the USAF

The standard USAF mishap investigation procedure, as outlined in Air Force Instruction 91-204, focuses on finding the failed part, procedure, or cultural factor so that it can be rectified through engineering, maintenance or operations technical orders, or through changes in the organization's culture. As stated in Air Force Pamphlet 91-211: "The purpose of every safety investigation is to determine all factors (human, materiel,

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[16]International Civil Aviation Organization, *ICAO Member States*, http:// www.icao.int/MemberStates/Member%20States.English.pdf (accessed 17 May 2012).

[17]International Civil Aviation Organization, *Strategic Objectives*, http:// www.icao.int/safety/Pages/default.aspx (accessed 17 May 2012).

and environmental) that directly or indirectly contributed to the mishap. This information is used by aircrews, equipment operators, supervisors, commanders, staffs, and designers to eliminate cause factors and thus help prevent recurrence of similar mishaps."[18]

Extensive information exists regarding F-16 maintenance performance indicators and almost all other USAF aircraft on the Logistics Installations and Mission Support – Enterprise View (LIMS-EV) database. This database serves as the primary source for all maintenance metrics for this thesis. Through its Weapons System View, it provides USAF leaders a one-stop-shop for supporting details and a single source for viewing analytical metrics for current and historical weapon systems information.[19] Normally used as a tool for identifying focus areas for management efforts in sustaining aircraft fleet logistic support areas, LIMS-EV can also be used as a historical database to compare past performance indicators and units.

F-16 mishap data is available from the USAF Safety Center through the Air Force Safety Automated System or AFSAS, as is all aircraft mishap data for the USAF. This data is used throughout the USAF, but usually is most effective immediately after an incident as the convening authority considers any recommendations from the Safety Investigation Board. These recommendations often suggest changes to maintenance technical orders or pilot checklists to prevent similar situations or events from occurring again.

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[18]Department of the Air Force, Air Force Pamphlet 91-211, *USAF Guide To Aviation Safety Investigation,* para 1.2. (Washington, DC: Government Printing Office, 2011), www.e-publishing.af.mil (accessed 15 May 2012).

[19]Headquarters United States Air Force, A4IS, *LIMS-EV 101 Brief*, http://www.acq.osd.mil/log/mpp/cbm+/Briefings/LIMS-EV_OSD_CBMPlus_AG_Brief.pdf (accessed 7 April 2012).

Predicting Mishaps

A search was conducted in an attempt to find indicators of any kind past or present, used in aviation mishap prevention. While extensive programmed maintenance practices exist to prevent system or equipment failure, use of such programs is aimed at finding failures in material parts and systems, usually identified by past failures or mishaps. Specific literature regarding the use of metrics in predictive mishap prevention exists in the form of a paper I. A. Herrara and J. Hovden presented at the 3rd Resilience Engineering Symposium, in October of 2008 in Antibes-Juan Les Pins, France. This seven page paper, titled "Leading Indicators Applied to Maintenance in the Framework of Resilience Engineering: A Conceptual Approach" specifically focused on aviation maintenance indicators and their usefulness in mishap prevention.[20] This paper identified desirable characteristics for potential indicators, such as objective measurement, easy comprehension, positive or negative improvement or deterioration, and readily available, while failing to actually identify specific indicators.[21] The USAF identifies 19 specific metrics as leading indicators and 13 metrics as lagging indicators for the maintenance manager.[22]

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[20] I. A. Herrera and J. Hovden, "Leading indicators applied to maintenance in the framework of resilience engineering: A conceptual approach" (Paper presented at The 3rd Resilience Engineering Symposium, 28-30 October 2008), http://www.sintef.no/project/Building%20Safety/Publications/2008-Resilience%20Engineering%20Symposium-Leading%20indicators-herrera-hovden.pdf (accessed 15 May 2012).

[21] Ibid.

[22] Air Force Logistics Management Agency, *Metrics Handbook for Maintenance Leaders,* http://www.aflma.hq.af.mil/shared/media/document/AFD-100107-055.pdf (accessed 15 May 2012), 15-16.

Herrera and Hovden note, “Traditionally, improvements in aviation have been based on incident reporting analyses and learning from failures. This traditional approach measures safety performance based on lagging indicators.”[23] Their search for a predictive metric is a rare one. It is also the purpose of this thesis.

[23]Herrera and Hovden, “Leading indicators applied to maintenance in the framework of resilience engineering: A conceptual approach” (Paper presented at The 3rd Resilience Engineering Symposium, 28-30 October 2008), http://www.sintef.no/project/Building%20Safety/Publications/2008-Resilience%20Engineering%20Symposium-Leading%20indicators-herrera-hovden.pdf (accessed 15 May 2012).

CHAPTER 3

RESEARCH METHODOLOGY

Overview

This thesis uses a quantitative comparison of maintenance performance indicators for all active duty F-16 units for the FYs 2000-08. This information will be compared to the mishap rates for the same units for the same years in an attempt to determine if the data shows any relevant correlation with the unit's Class A mishaps. Following a summarization of the entire USAF F-16 fleet's maintenance metrics versus Class A mishaps from FYs 2001 through 2010, a comparison of all active duty F-16 unit performance metrics with their respective mishaps by year will follow, covering FYs 2000-08. Unit data was also compiled and analyzed for applicability and subjected to correlation tests to determine if a unit's performance metrics versus mishap rate was statistically relevant using Pearson's correlation coefficient. While a significant number of variables exist among the units studied, all were F-16 and active-duty from FY 2000-08.

Data Sources

The data considered for this thesis is derived primarily from two sources: The first is the USAF's Air Force Safety Automated System. The second source is maintenance performance indicators pulled from the Logistics Installations and Mission Support - Enterprise View (LIMS-EV) system of databases. These systems compile relevant information for their respective areas from across the USAF. A discussion of the meaning of maintenance performance indicators will open chapter 4 as an explanation of the data analysis process followed throughout the study, citing data pulled from LIMS-EV and the USAF Maintenance Metrics pamphlet and appropriate Air Force Instructions. Any holes or incongruent data will be explained. The use or exclusion of a specific set of data will also be explained in chapter 4.

Air Force Safety Automated System

Drawn from the restricted AFSAS database, reporting tools specifying FYs, bases, units, and mission design series aircraft were used, searching only for Class A mishaps. These comprehensive reports enabled the author to report on 37 specific mishaps from over 69 Class A F-16 mishaps from the FYs studied. The limitations and scope of this paper as described in chapter 1 necessitated the reduction in data and allowed the scope of study to be maintained.

Logistics, Installations and Mission Support-Enterprise View

LIMS-EV data was provided in part by USAF maintenance analysts and examined for specific F-16 metrics, focusing on the most commonly used metrics in the F-16 maintenance community. These metrics include: Mission Capable Rate, Total Non-Mission Capable Maintenance Rate, Total Non-Mission Capable Supply Rate, Break Rate, 8-hour Fix Rate, Abort Rate, Repeat and Recurrence Rate, the Flying Scheduling Effectiveness Rate, and the Cannibalization Rate. The data from LIMS-EV is 98 percent accurate and complete as of May 2011.[24]

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[24]Headquarters United States Air Force, A4IS, *LIMS-EV 101 Brief*, http://www.acq.osd.mil/log/mpp/cbm+/Briefings/LIMS-EV_OSD_CBMPlus_AG_Brief.pdf (accessed 7 April 2012).

Analysis Methodology

The method used to determine the exixstance of a correlation between these two sets of data was a simple scattergram, commonly used in statistics. Dictionary.com first defines correlation as: mutual relation of two or more things, parts, etc. The second definition is: the act of correlating or state of being correlated. In its third definition, it specifically defines correlation with respect to statistics as the degree to which two or more attributes or measurements on the same group of elements show a tendency to vary together.[25] It is important to note that correlation does not mean causation. The first comparison is between the aggregate maintenance data (entire F-16 fleet) and the aggregate mishap data. Each metric will then be broken down to compare each base's maintenance performance in the nine areas against its mishap performance rates by year and for the entire period. Data will be presented in graphs and tables followed by explanations by unit in line with the aggregate data.

Correlation determination

Scattergrams built from the LIMS-EV data and corresponding mishaps show trend lines and corresponding values using the Pearson correlation coefficient. The Pearson coefficient is a widely accepted basic correlation tool used in statistics and the most basic type.[26] While the computations involved in the manufacture of the trend line and the accompanying coefficient or R2 number were generated by the spreadsheet program, the results indicate how likely the metric is related to the number of mishaps

[25] Dictionary.com, http://dictionary.reference.com/ (accessed 17 May 2012).

[26] Creative Research Systems, "Correlation," http://www.surveysystem.com/ correlation.htm (accessed 17 May 2012).

experienced. The closer the coefficient approaches 1 or perfect correlation, the more likely the two sets of data correlate. The data for the scattergrams was arranged in ascending order, from lowest value for the metric to the highest value for the years measured and the number of mishaps experienced for that unit at that metric level for that respective FY. This ensured the data reflected the potential correlation the metric had on the mishap--or lack thereof. The resultant coefficients were compared across the entire USAF F-16 fleet for FYs 2001 through 2010 against all Class A mishaps. The comparison across each of the nine active duty bases for FYs 2000 through 2008, was accomplished by arranging the correlation coefficients generated by each unit, for each metric for the nine years studied, and taking the average of the coefficients in each category.

The statistical relevance of the correlation coefficients was determined by comparing each of the values derived to a critical value chart for Pearson's coefficient correlation. For the sample size of nine sets of data for each metric measured over the nine year study period, the degree of freedom used was seven, the normal N-2 figure where N=the sample size of the study, in this case the number of years being used as the sample for the sets of data used.[27]

Interpretation of Pearson correlation coefficients varies, but generally the following table demonstrates the potential correlation of factors for two sets of data:[28]

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[27]Del Siegle Ph.D., Neag School of Education-University of Connecticut, http://www.gifted.uconn.edu/siegle/research/Correlation/alphaleve.htm (accessed 7 April 2012).

[28]Acastat Software, Research Tools and Instructional Aids, http://www.acastat.com/Statbook/correlation.htm (accessed 7 April 2012).

Table 1. Characterizations of Pearson R	
Very high correlation	.9 to 1
High correlation	.7 to .9
Moderate correlation	.5 to .7
Low correlation	.3 to .5
Little if any correlation	0 to .3

Source: Created by author, data from Acastat Software. "Research Tools and Instructional Aids," http://www.acastat.com/Statbook/correlation.htm (accessed 7 April 2012).

The decision criteria for satisfying the null hypothesis that maintenance metrics correlate to mishaps experienced is comparing the final correlation coefficients to the Pearson critical values table for the sample size of 9 years (or N) at the .05 confidence interval, or stated alternately the results are expected to be accurate 95 percent of the time.[29]

[29]Del,Siegle, *Critical Values of the Pearson Product-Moment Correlation Coefficient*, http://www.gifted.uconn.edu/siegle/research/Correlation/corrchrt.htm (accessed 7 April 2012).

Table 2. Pearson Critical Values for Two-Tailed Probabilities

N	0.1	0.05	0.01
4	0.900	0.950	0.990
5	0.805	0.878	0.959
6	0.729	0.811	0.917
7	0.669	0.754	0.875
8	0.621	0.707	0.834
9	0.582	0.666	0.798
10	0.549	0.632	0.765

Source: Adapted by author, data from Del Siegle, *Critical Values of the Pearson Product-Moment Correlation Coefficient*, http://www.gifted.uconn.edu/siegle/research/Correlation/corrchrt.htm (accessed 7 April 2012).

Metrics data variation

No effort was made to interpret the meaning of variances in metrics data over a period of years or the number of mishaps (or lack thereof) over the same period for the units measured. Leadership, maintenance discipline, weather, organization operations tempo, unit mission, deployments, exercises, modification, fleet utilization and many other factors can affect a unit's performance with respect to its metrics. For the purpose of this study it is assumed that all units are affected by these factors equally.

CHAPTER 4

ANALYSIS

Understanding the Metrics

While the USAF tracks over thirty different aircraft maintenance related metrics, this paper will focus on the nine most commonly emphasized metrics in the F-16 community. The primary maintenance metrics tracked are: Mission Capable rate (MC), Total Non-Mission Capable rate Maintenance (TNMCM), Total Non-Mission Capable rate Supply (TNMCS), Break rate, Abort rate, 8-hour Fix rate, Cannibilization rate, Repeat/Recur rate, and Flying Scheduling Effectiveness (FSE) rate. The Mission Capable rate or MC is the percentage of the unit's possessed hours for aircraft that can fly at least one assigned mission.[30] Aircraft can often be on an installation and be possessed by another unit or entity while awaiting disposition instructions for repair from an engineering authority, official transfer of possession from one unit to another, or while being repaired or modified by another organization. While the aircraft experiences one of these (or other similar situations) events, this time does not factor into the unit's Mission Capable rate. The MC rate is the most basic of metrics as it lets leadership at all levels know the number of aircraft available to fly to meet everyday training sorties or potential contingency operations. MC rate is usually the first maintenance metric talked about in leadership meetings across the wing.[31]

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[30]Department of the Air Force, Air Force Instruction 21-103, *Equipment Inventory, Status And Utilization Reporting*, para A2.2 (Washington, DC: Government Printing Office, 2011), www.e-publishing.af.mil (accessed 15 May 2012).

[31]Author's personal experience in aircraft maintenance from 1989 to 2011.

The Total Non-Mission Capable Maintenance rate or TNMCM is the percentage of possessed hours for aircraft that cannot fly any assigned mission due to maintenance.[32] These are the aircraft actively being repaired, regardless of the length of time the repair takes to accomplish. This metric is almost exclusively controlled by the maintenance organization and is the normal cost of doing business in a maintenance organization as aircraft will inevitably break and must be repaired.

The Total Non-Mission Capable Supply rate or TNMCS is the percentage of possessed hours for aircraft that cannot fly any assigned mission due to lack of parts.[33] This metric is the organizational level grade for the entire supply chain. TNMCM time stops when parts are ordered against an aircraft and TNMCS time starts. This metric, combined with the MC and TNMCM numbers will account for the entire possessed time for the local aircraft fleet.

The Abort rate is the number of sorties aborted for whatever reason, which includes air aborts and ground aborts.[34] The Abort rate is computed by adding all air and ground or training aborts together and dividing by the total number of sorties attempted (flown and ground aborts), multiplied by 100. This rate is usually used when planning the number of aircraft to schedule for a successful number of sorties for a given period. For example, if the historical Abort rate is 5 percent, for every 20 aircraft scheduled to fly,

[32]Department of the Air Force, Air Force Instruction 21-103, *Equipment Inventory, Status And Utilization Reporting* para A2.5.2 (Washington, DC: Government Printing Office, 2011), www.e-publishing.af.mil (accessed 15 May 2012).

[33]Ibid., para A2.5.1.

[34]Air Force Logistics Management Agency, *Metrics Handbook for Maintenance Leaders,* http://www.aflma.hq.af.mil/shared/media/document/AFD-100107-055.pdf (accessed 15 May 2012), 26.

the unit expects at least one of those aircraft will not fly the scheduled sortie. Based on information, extra aircraft are provided for each scheduled period to mitigate this potential loss.

The Break rate is the number of aircraft landing with a grounding discrepancy (a discrepancy preventing the aircraft from flying) per total number of sorties and derived by dividing the number of sorties landing broken by the number of sorties flown for a given time period, multiplied by 100.[35] The Break rate allows leaders to anticipate the normal maintenance attrition for an organization. In line with the historic Break rate, the wing or squadron will usually schedule fewer sorties in the second and subsequent periods of the flying day, knowing that a certain percentage will break after a sortie.

The 8-hour Fix rate is the number of aircraft landing from flight with grounding discrepancies repaired versus the total number of aircraft with grounding discrepancies and is derived by dividing the number of discrepancy aircraft repaired by the number of discrepancy aircraft landing broken for a given time period multiplied by 100.[36] This is the metric used to measure a unit's ability to quickly repair aircraft for the next flying period. It is usually controlled by senior non-commissioned officers in charge of the unit's aircraft technicians at the organizational level of maintenance.

The Cannibalization rate is the number of cannibalizations (removal of an aircraft part from another aircraft instead of receiving the part from the supply system) that occur per sortie and is derived by adding all aircraft to aircraft cannibalization actions and all engine to aircraft cannibalization actions, then dividing by the number of sorties flown

[35]Ibid.

[36]Ibid.

for a given time period, multiplied by 100.[37] This metric shows the amount of work done by organizational level maintenance technicians to make up for shortages in the supply system. Cannibalization actions are particularly inefficient, as a serviceable part is removed from one aircraft, transported, and re-installed in another aircraft, instead of a part being issued from the supply system. This essentially doubles the amount of work required to fix a single discrepancy as the part is removed twice (original and donor aircraft) and re-installed twice (original immediately, donor when the part comes in from supply). It also can significantly extend the repair time on an aircraft.

The Repeat and Recur rate is the total number of repeat discrepancies added to the total number of recurring discrepancies, then divided by the total number of pilot reported discrepancies for a given period of time, and multiplied by 100.[38] This rate effectively measures how well a maintenance organization fixes discrepancies the first time. High repeat/recur rates are historically attributed to a lack of thorough trouble-shooting of discrepancies, pressure to quickly repair aircraft for subsequent sorties on the flying schedule, or a lack of experienced, qualified, or trained aircraft maintenance technicians.[39]

The Flying Scheduling Effectiveness rate or FSE is adjusted sorties scheduled minus the number of chargeable deviations, divided by the number of adjusted sorties

[37]Air Force Logistics Management Agency, *Metrics Handbook for Maintenance Leaders,* http://www.aflma.hq.af.mil/shared/media/document/AFD-100107-055.pdf (accessed 15 May 2012), 26.

[38]Ibid.

[39]Ibid.

scheduled, for a given time period, multiplied by 100.[40] This particular rate is very important as it shows the level of deviation from the planned operations and maintenance schedule. As the rate declines, the level of effort to provide aircraft to the flying schedule increases. Switching aircraft for a particular sortie may seem a benign event, but this requires that another aircraft be prepared for the flying schedule and may require additional personnel and time to achieve the sortie. The cascading effects of multiple aircraft swaps for broken aircraft or pilot training objectives can quickly overwhelm an organization.

Applying the Metrics to Daily Operations

A USAF F-16 will typically begin the day in Fully Mission Capable status. As the aircraft maintenance staff arrives for the day, the plane's status, as tracked for availability purposes, can change throughout the day.[41] If the aircraft is scheduled to fly on a given day, the normal process begins with a servicing crew checking important fluid levels, such as engine oil, aviation fuel levels, and hydraulic fluid levels of the aircraft. Additionally, gaseous pressure levels, including the pneumatic pressure of the aircraft's tires, and various bottles of nitrogen are checked as well. If any of these fail to meet standards, the proper aircraft forms are annotated appropriately and the status of the

[40]Air Force Logistics Management Agency, *Metrics Handbook for Maintenance Leaders*, http://www.aflma.hq.af.mil/shared/media/document/AFD-100107-055.pdf (accessed 15 May 2012), 27.

[41]This scenario throughout this section is based on the author's personal experience working with F-16s in three different maintenance organizations and 12 years of experience.

aircraft changes to Not Mission Capable Maintenance or NMCM. The aircraft remains in that status until the maintenance discrepancy is repaired or serviced.

Once the aircraft is ready for flight and the aircraft forms are in order, the maintenance crew will inform the operations squadron flight desk, the maintenance operations center, and finally, the pilot. Once the pilot arrives at the aircraft the sortie has officially started and the pilot assumes control of the aircraft for its sortie or flight.[42] The pilot will then accomplish his or her pre-flight inspection. If any grounding discrepancies are discovered, the aircraft sortie is considered aborted, and the pilot will most likely proceed to another aircraft. The current aircraft's forms will be annotated and its status reported as NMCM. Most often, however, the pilot climbs into the cockpit, starts the engine, proceeds with additional powered pre-flight operational checks, and taxis out to the end of runway for last chance checks prior to takeoff. If at any time in the process a discrepancy is found with the aircraft, the pilot will normally return to the aircraft parking spot to allow maintenance personnel the opportunity to fix the discrepancy and allow the pilot to make the sortie. If the discrepancy cannot be fixed in sufficient time to allow the pilot to make the sortie in the allotted time frame, the pilot will proceed to another aircraft or back to the squadron's building and the aircraft's forms will be annotated and its status reported as NMCM. For tracking purposes, as described above, an aircraft

[42]Normally each flight counts as one sortie, however, occaisionally more than one sortie can be accomplished on a given flight. One such example is the "Fight-Tank-Fight" scenario where a pilot may engage an adversary in a training scenario during the first sortie, rendezvous with an airborn fuel tanker to receive additional fuel, then engage in another sortie for a different training objective. In this instance, two sorties may be recorded for one flight.

failing to meet a scheduled sortie after the pilot has arrived at the aircraft is considered a ground abort.[43]

If the aircraft passes all checks, the pilot will proceed to takeoff and fly the planned sortie. Once airborne, if the aircraft develops an unsafe condition, the sortie is aborted and the pilot returns to base, which is known as an air abort for tracking purposes. Any aircraft discrepancy causing the pilot to fail to successfully fly a sortie once he or she arrives at the aircraft, is considered an abort, regardless of whether or not it flew.

Most sorties are successful, but may still have aircraft discrepancies of a non-emergency nature. These pilot reported discrepancies are annotated by the pilot in the aircraft forms and designated as one of three types by maintenance personnel:

> A grounding condition is annotated by a red X marking in the aircraft forms and means the aircraft is not fit to fly in its present condition. This aircraft's forms are annotated appropriately with the specific discrepancy and its status reported as NMCM until maintenance personnel repair the discrepancy.A non-grounding condition is annotated by a red diagonal mark in the aircraft forms and represents an unsatisfactory condition, but not an unsafe condition. This may or may not be repaired prior to the next scheduled flight but does not render the aircraft NMCM. An informational notation may also be made by the pilot to note a condition not normally encountered or one unfamiliar to the pilot. Maintenance technicians may or may not repair or research the note before the next scheduled flight and this note does not render the aircraft NMCM.[44]

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[43]Air Force Logistics Management Agency, *Metrics Handbook for Maintenance Leaders*, http://www.aflma.hq.af.mil/shared/media/document/AFD-100107-055.pdf (accessed 15 May 2012), 26.

[44]Department of the Air Force, Technical Order 00-20-1, *Aerospace Equipment Maintenance Inspection, Documentation, Policies, And Procedures*, http://www.tinker.af.mil/shared/media/document/AFD-061220-046.pdf (accessed 15 May 2012), para 4.1.2.

Aircraft discrepancies are also tracked for repeat or recurrence. A particular discrepancy, for example one involving radios, may have occurred on the prior flight of the aircraft. This is annotated in the aircraft forms as a repeat discrepancy. If the same discrepancy occurred in the last five aircraft sorties, the discrepancy is annotated as a “recur” or recurring discrepancy. This type of discrepancy is particularly important to the maintenance community. It may indicate numerous problems with an aircraft system, aircraft parts, maintenance repair issues, or even maintenance training shortcomings. The repeat and recur rates are one of the more important indicators for maintenance leaders.

Another important indicator is the 8-hour fix rate. Once the pilot annotates a grounding condition after a flight, the clock starts on an 8-hour window to measure if the maintenance organization can fix the aircraft within that time.[45] The purpose behind this metric is not only to maintain aircraft availability in a timely manner, but during a wartime mission when sorties are normally flown around the clock, rapid repair of aircraft becomes increasingly important. The downside to rapid repair of aircraft may come in failure to fully repair or temporarily fix an aircraft discrepancy. This can result in a repeat or recurring discrepancy, or worse, an aircraft mishap.

Upon successful completion of repairs to the aircraft, it is again returned to a fully mission capable status, annotated as such in the maintenance collection system and prepared for the next day's flying.

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[45] Air Force Logistics Management Agency, *Metrics Handbook for Maintenance Leaders*, http://www.aflma.hq.af.mil/shared/media/document/AFD-100107-055.pdf (accessed 15 May 2012), 26.

USAF Mishap Criteria

The reporting criteria that help the reader understand the information presented follows, to include the criteria for a Class A mishap and the minimum required investigation body.

> 1.10.1. Class A Mishap. A mishap resulting in one or more of the following:
>
> 1.10.1.1. Direct mishap cost totaling $1,000,000 or more.
>
> 1.10.1.2. A fatality or permanent total disability.
>
> 1.10.1.3. Destruction of a DoD aircraft (Attachment 1). NOTE: A destroyed UAV/UAS is not a Class A mishap unless the criteria in paragraphs 1.10.1.1. or 1.10.1.2. are met.[46]

Table 3. Investigation Membership Minimum Requirements.

1	Class A (Destroyed Aircraft, Fatality, or Permanent Total Disability) (Note 1)	Board President, Investigating Officer, AFSC Rep (Note 2), Maintenance Member, Medical Member Pilot Member, Recorder
2	Class A (Other)	Board President Investigating Officer 1 other Primary Member, Recorder
3	Class A or Class B (Engine-Confined) (Note 3)	Single Investigating Officer until failure mode is determined, then comply with Note 4
4	Class B (Other)	Board President Investigating Officer or Investigating Officer 1 other Primary Member

Source: Adapted by the author from USAF manual 91-223, *Aviation Safety Investigations and Reports* (Washington, DC: Government Printing Office, 2006), www.e.publishing. af.mil (accessed 15 May 2012).

[46]Department of the Air Force, Air Force Instruction 91-204, *Safety Investigations and Reports* (Washington, DC: Government Printing Office, 2011), www.e-publishing.af.mil (accessed 17 May 2012).

Analysis of the F-16 Fleet

Analysis begins with the MC rate for the entire F-16 fleet for the FYs 2001 through 2010 and the 66 Class A mishaps across those years, as shown in figure 1.

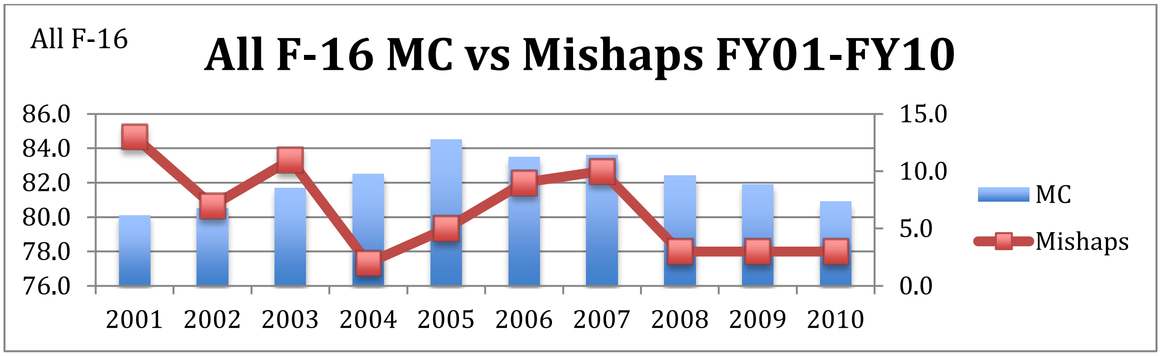

Figure 1. F-16 MC vc Mishaps FY01-FY10

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

Figure 1 shows a low of 80.1 percent in 2001 and a high of 84.5 percent in 2005, with the MC rate apparently having no discernible correlation with the number of mishaps experienced across the USAF, which ranged from a high of 13 mishaps in FY (FY) 2001 to a low of 2 in FY 2004. To further illustrate this, the MC rate was arranged in ascending order and the corresponding number of mishaps was plotted on a scattergram as shown in figure 2. Scattergrams are used throughout this chapter to provide a visual representation of the trend line generated by a mathematical formula known as Pearson's Coefficient, discussed in chapter 3. The most important part of the scattergram is the actual coefficient number in the upper right hand corner of each graph. The closer that number is to 1, the higher the correlation. Conversely, the closer the number is to zero, the lower the correlation. The distance of the data points away from the trend line also carries meaning, showing how much variance in the data was experienced and how reliable the data is with respect to the correlation being measured. The resultant trend line and coefficient of correlation for the MC rate was .02773, statistically insignificant.

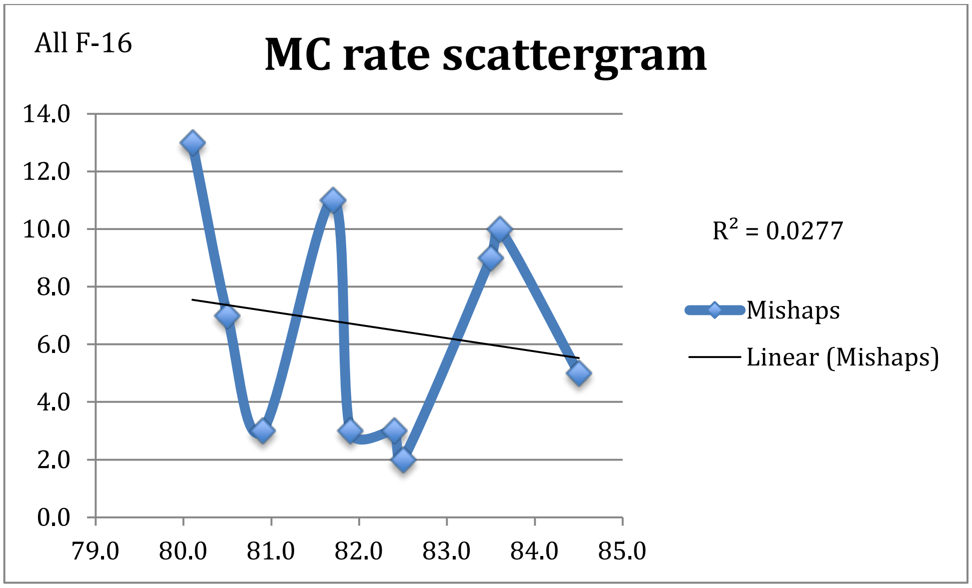

Figure 2. MC rate scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

Next, the Total Non-Mission Capable Maintenance Rate, or the amount of time aircraft were awaiting or being repaired and not capable of flying assigned missions is depicted in figure 3 showing the rate by year against the number of mishaps experienced.

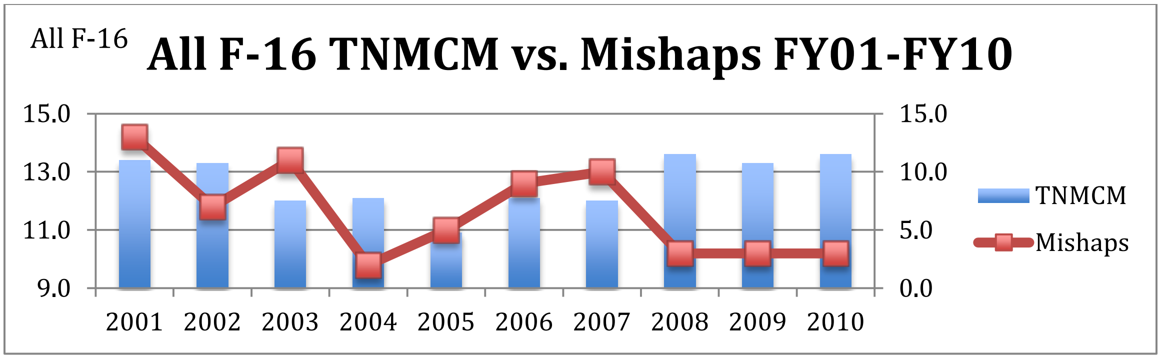

Figure 3. All F-16 TNMCM vs. Mishaps FY01-FY10

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

From a low of 10.9 percent in 2005 to a high of 13.6 percent in 2008 and 2010, the TNMCM rate also fails to exhibit any correlation with the number of mishaps experienced. The scattergram plot results as noted in figure 4 show a very insignificant correlation coefficient of .02475.

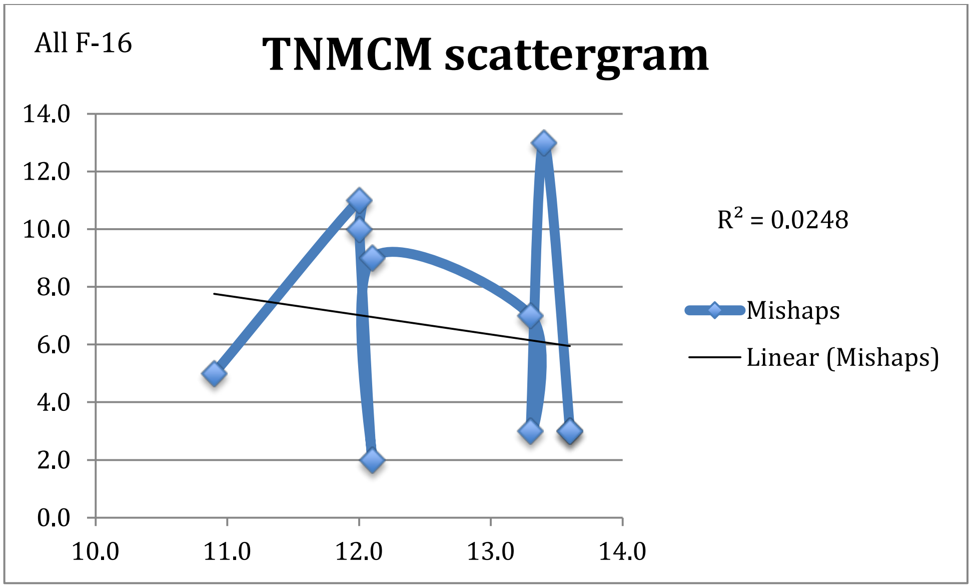

Figure 4. TNMCM rate scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

Next, the Total Non-Mission Capable Supply rates, or the amount of time aircraft were awaiting parts to be repaired as shown in figure 5 for the entire F-16 fleet for the FYs 2001 through 2010. The associated scattergram for the TNMCS rate shown in figure 6 also fails to show any significant correlation as exhibited by the coefficient of .17873.

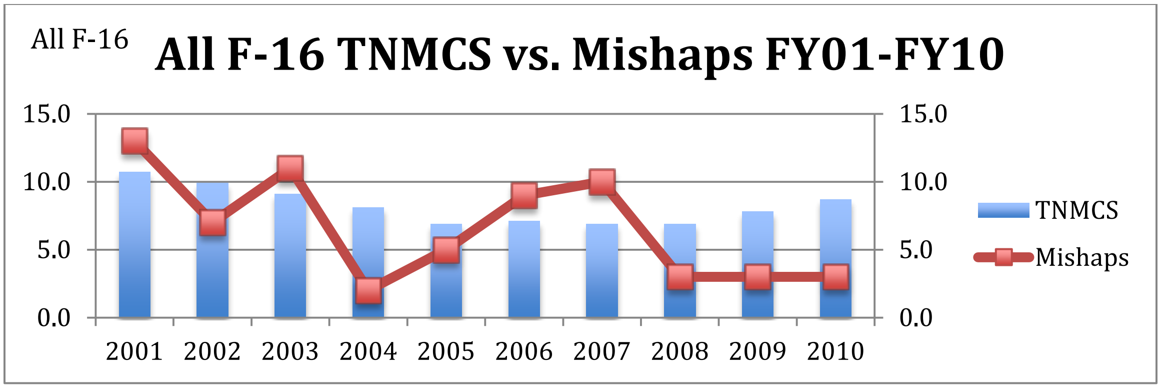

Figure 5. All F-16 TNMCS vs. Mishaps FY01-FY10

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

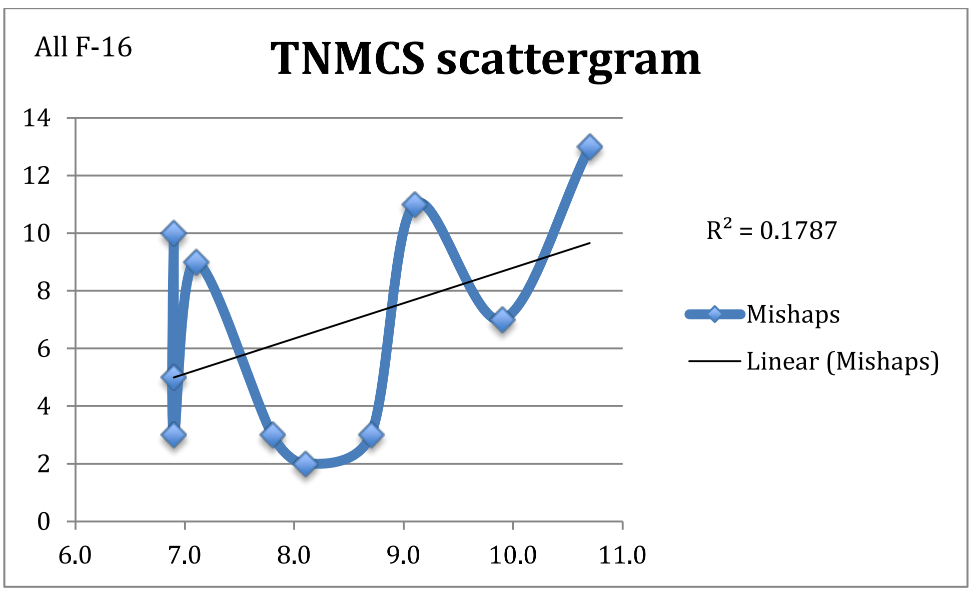

Figure 6. TNMCS scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Break rate graph, showing the percentage of the time that an aircraft would land with a grounding discrepancy, for all F-16 units from FY 2001 through 2010 is shown in figure 7. The scattergram for the Break rate shown in figure 8, depicts an extremely low correlation coefficient of .01958 and shows a particulary large variance in data from the trend lines center.

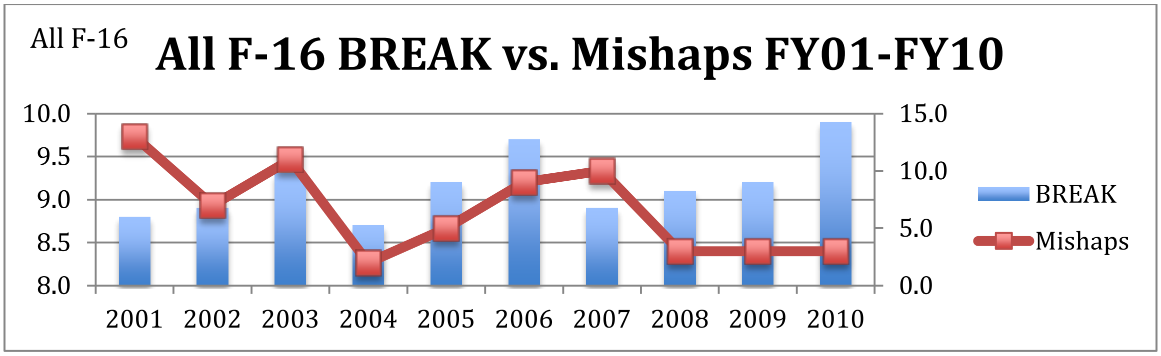

Figure 7. All F-16 Break rate vs. Mishaps FY01-FY10

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

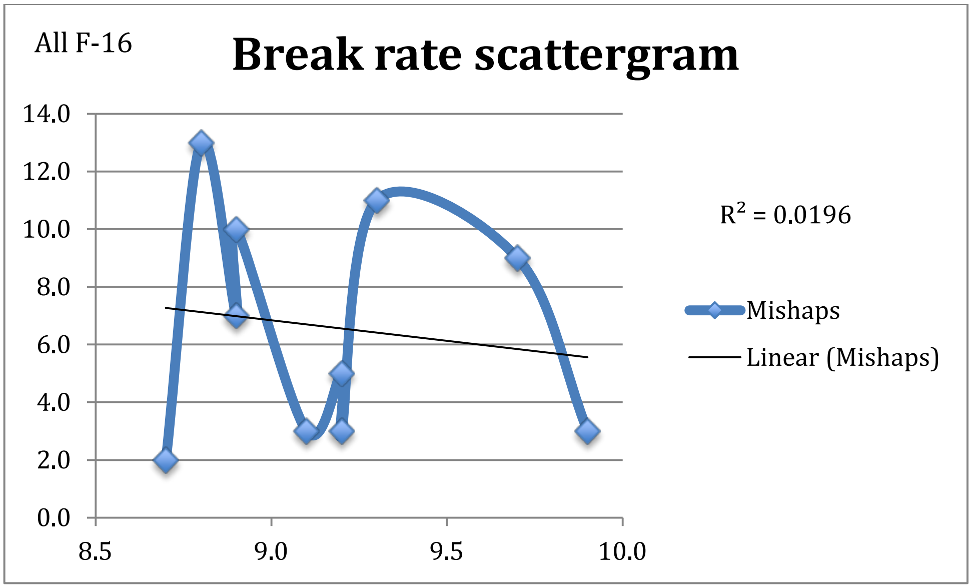

Figure 8. Break rate scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The 8-hour Fix rate graph, showing the percentage of the time aircraft with grounding conditions after flight were repaired within the eight hour standard, shows no apparent correlation with the number of mishaps experienced as shown in figure 9. The scattergram of the same 8-hour Fix rate data shows a very insignificant correlation coefficient of .04918 in figure 10.

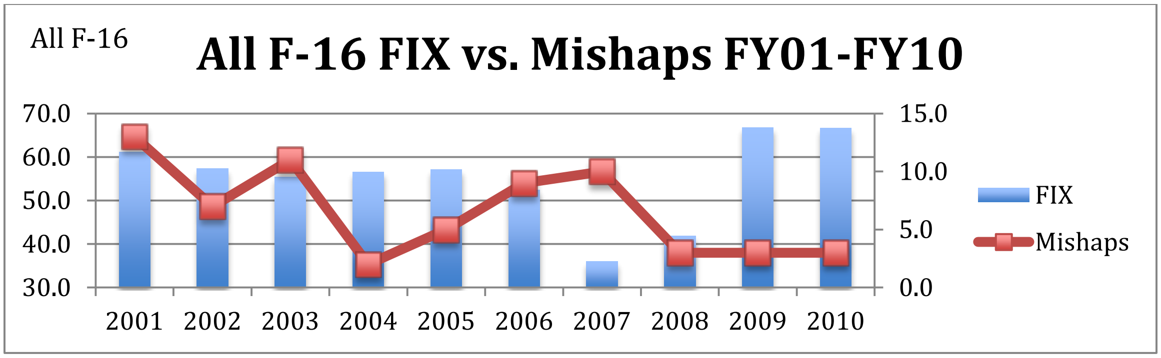

Figure 9. All F-16 Fix rate vs. Mishaps FY01-FY10

Source: Created by author, using data AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

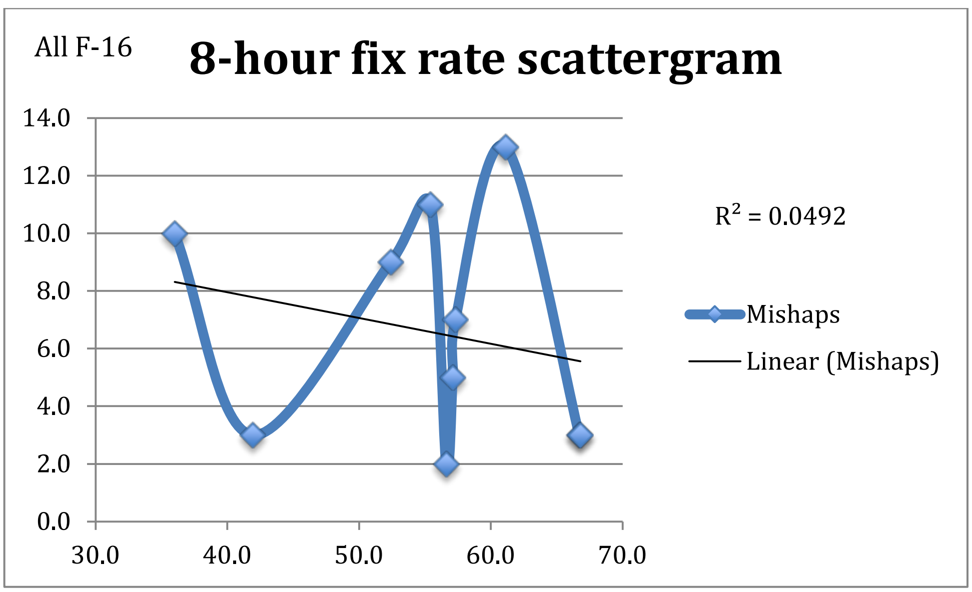

Figure 10. 8-hour Fix rate scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Abort rate, showing the percentage of sorties aborted for the entire F-16 community for FYs 2001 through 2010 is shown in figure 11.

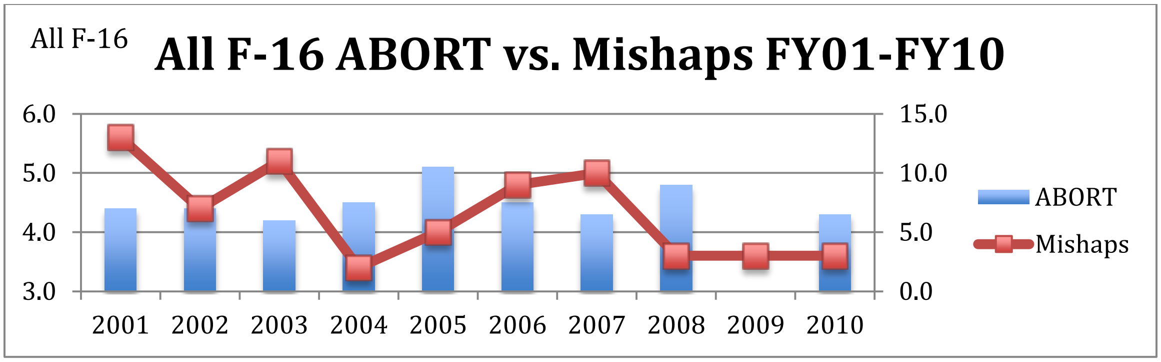

Figure 11. All F-16 Abort rate vs. Mishaps FY01-FY10

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

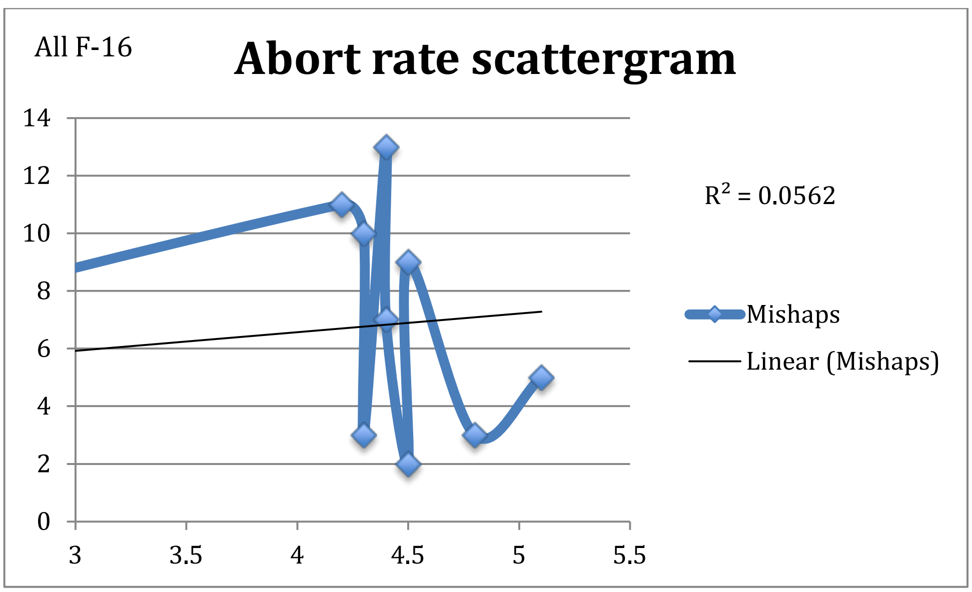

Figure 12. Abort rate scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The correlation coefficient for the Abort rate is an insignificant .05619 as shown in figure 12. The far left aberration was due to an absence of data available for this metric in FY 2009.

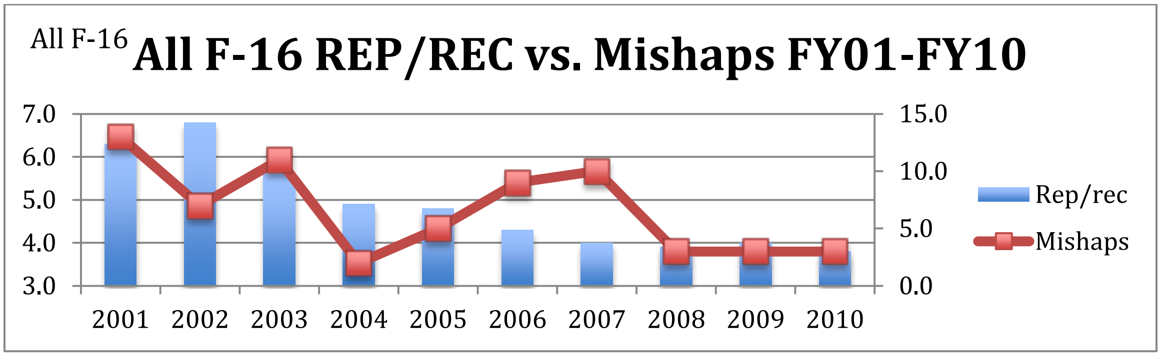

Figure 13. All F-16 Repeat and Recur rate vs. Mishaps FY01-FY10

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Repeat and Recur rate, or the number of times aircraft landed with the same discrepancy from the last flight (repeat) or the last five flights (recur) is shown in figure 13 for the entire F-16 fleet for FYs 2001 through 2010. This Repeat and Recur scattergram in figure 14 shows a correlation rate of .25842, the second highest in this study, although still not a significant correlation coefficient.

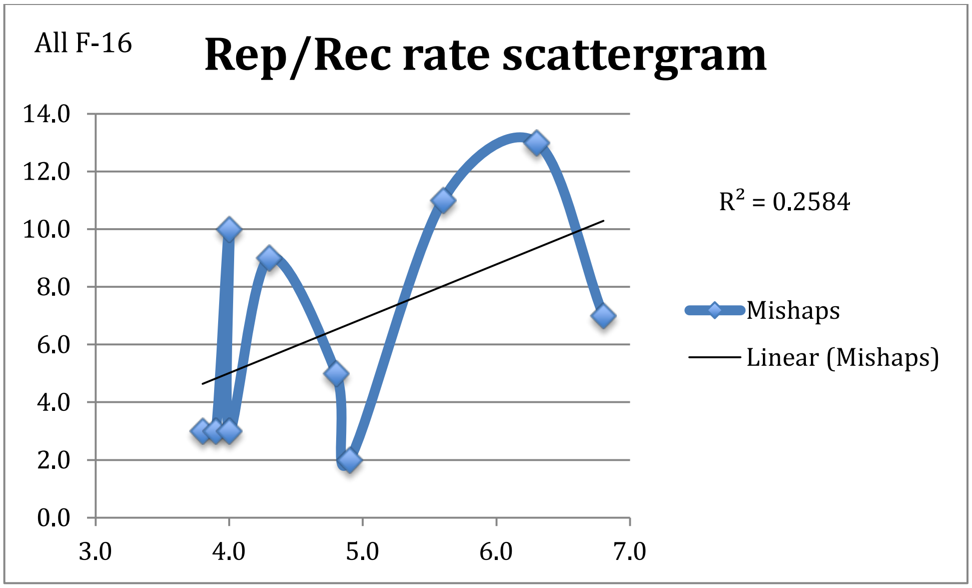

Figure 14. Repeat and Recur rate scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Cannibalization rate, or the number of times aircraft parts were removed from another aircraft instead of being issued from the supply system to repair a non-mission capable aircraft is shown in figure 15.

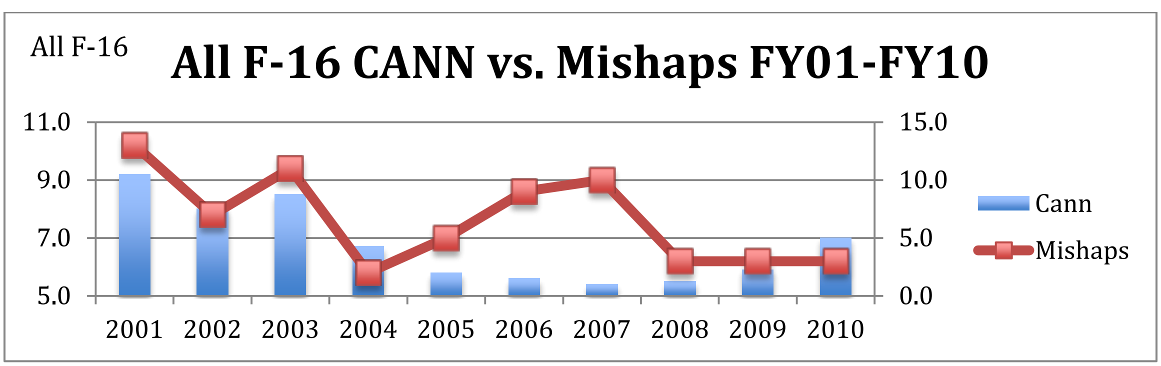

Figure 15. All F-16 Cannibalization rate vs. Mishaps FY01-FY10

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Cannibalization scattergram has the highest coefficient correlation at .26023 for the entire F-16 fleet metrics. While this number represents the highest correlation in this study, it is still far from being considered significant.

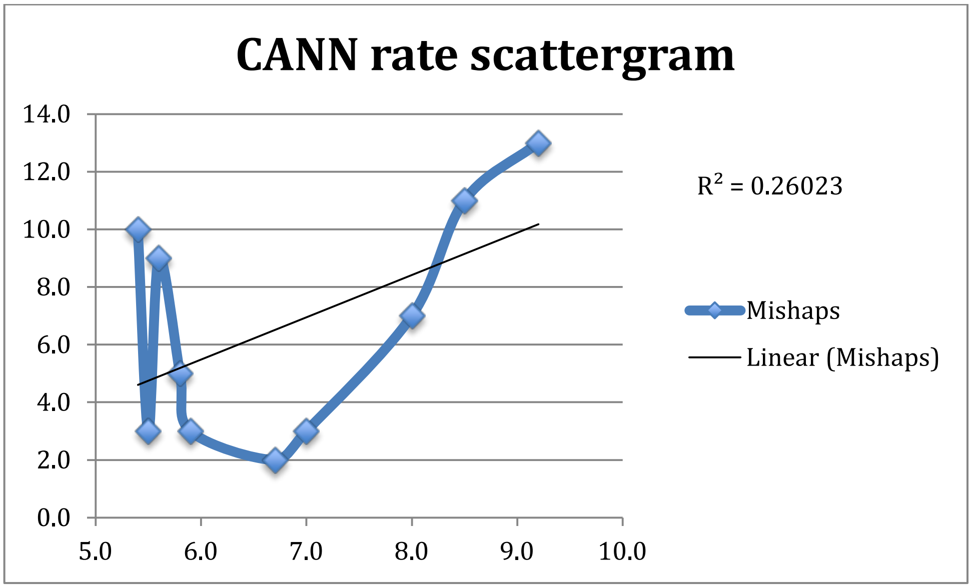

Figure 16. Cannibalization rate scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Flying Scheduling Effectiveness rate, or the degree to which the aircraft flying schedule was adhered to, is displayed in figure 17 for the 10 year period. The scattergram for the FSE, at a .11814 coefficient correlation, is not a significant number as shown in figure 18.

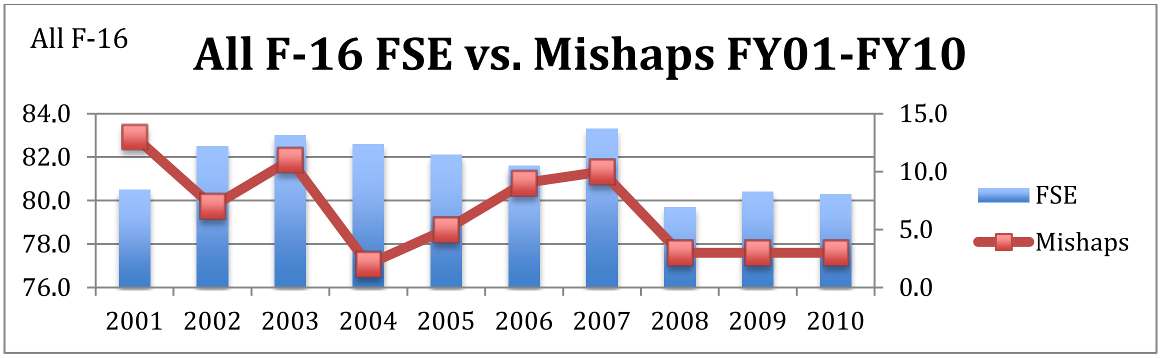

Figure 17. All F-16 FSE vs. Mishaps FY01-FY10

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

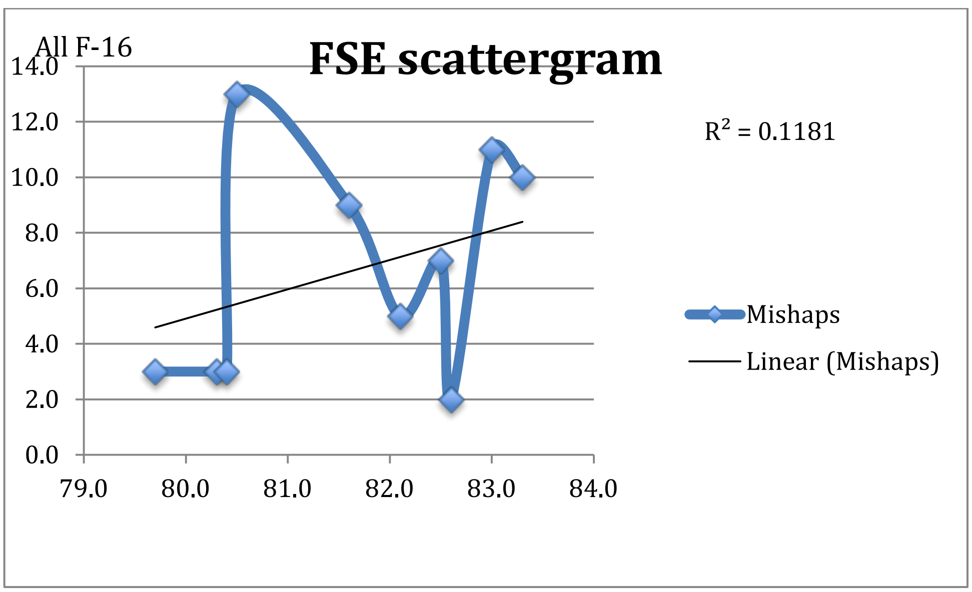

Figure 18. FSE rate scattergram

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

Analysis of the entire F-16 fleet from FY 2001 through 2010 shows no metric with a correlation coefficient higher than .26023, the correlation coefficient associated with the Cannibalization rate for the decade. Using table 1 from chapter 3, it is apparent this is in the “Little if any correlation” range.

Comparison of individual active-duty units

Nine active duty units were compared for the purposes of answering the research questions. All units were actively flying and maintaining F-16 for the period of FY 2000 through FY 2008. Comparison of the active duty units begins with this table of the units, with the mishaps plotted for the corresponding FYs:

Table 4. Active duty unit mishaps 2000-2008

FY	2000	2001	2002	2003	2004	2005	2006	2007	2008	Totals
Organization										
8 FW		1		1		1				3
20 FW	1	1				1	1			4
31 FW		1						1		2
35 FW		2	1							3
51 FW				1			1			2
52 FW			1				1			2
56 FW	2	1	1	2			1	2	2	11
57 FW				1		1		1		3
388 FW	1		1	4			1			7
Totals	4	6	4	9		3	5	4	2	37

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The total number of Class A mishaps for the period studied was 37. There were 69 across the entire USAF F-16 fleet during this period, with 11 of those coming from the 56th FW, the Air Education and Training Command base responsible for initial F-16 pilot training. Again, emphasizing the scope and limitations of the paper, no attempt to ascertain maintenance cultural effects, unit mission, or any other factors contributing to the metrics measured, will be made.

While each unit's metrics have been plotted and can be viewed in the attached tables, the only scattergrams and histograms displayed in this chapter will emphasize the high and low correlations, as measured by Pearson's correlation coefficient. Apparent visual correlations in the plots of the mishaps against the metrics as they occurred for each FY may or may not represent a mathematical correlation.

MC rate coefficients for the nine units studied presented no discernable correlation between the MC rate and mishaps experienced, as evidenced by table 5.

Table 5. Mission Capable rate correlation

Range	
0.0000033	Low
0.00128	
0.00668	
0.01043	
0.04513	
0.0953	
0.09692	
0.10196	
0.2486	High
0.067367033	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

Each coefficient number was derived from comparison of the unit's Mission Capable rate performance over the nine years with the number of mishaps experienced, from the lowest MC rate year through the highest. Even the highest value achieved by the 35 FW at .2486 is not halfway to achieving the .666 value required from the Pearson critical values table for the chosen confidence level of .95, the most commonly used confidence level in statistical studies.[47]

The next metric to be compared is the TNMCM metric, as displayed in table 6.

Table 6. Total Non-mission capable maintenance rate correlation

Range	
0.00018	Low
0.00041	
0.00119	
0.00939	
0.02681	
0.04851	
0.05926	
0.17351	
0.20098	High
0.057804444	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

[47]Del Siegle, *Confidence Interval*, http://www.gifted.uconn.edu/siegle/research/Samples/ConfidenceInterval.htm (accessed 7 April 2012)

The average coefficient for correlation for this metric was .057804444. This indicates an almost complete lack of correlation between the TNMCM metric and number of mishaps experienced in the sample group.

The TNMCS metric correlation average was .178087778 as shown in the table 7. Again, while a significantly higher number than the previous two coefficients and the highest of the active duty correlations, statistically this is a very low correlation represented by this average. Of note is the sample active-duty units TNMCS rate almost matches perfectly the correlation rate for the entire F-16 fleet in the study.

Table 7. Total Non-mission capable supply rate correlation

Range	
0.00018	Low
0.00187	
0.04556	
0.08988	
0.16788	
0.2025	
0.24863	
0.35953	
0.48676	High
0.178087778	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The next metric reviewed was the Break rate, as shown in the table 8. The Break rate represented an extremely low correlation rate from the sample group.

Table 8. Break rate correlation

Range	
0.00029	Low
0.00059	
0.00153	
0.01269	
0.01289	
0.03444	
0.04037	
0.04234	
0.06517	High
0.023367778	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The 8-hour fix rate correlation coefficient was.103825556. This is also in the very low correlation range.

Table 9. 8 hour fix rate correlation

Range	
0.00193	Low
0.00201	
0.00365	
0.01693	
0.0672	
0.08698	
0.17995	
0.19741	
0.37837	High
0.103825556	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Abort rate measured had a very low correlation coefficient of .053953111.

Table 10. Abort rate correlation

Range	
0.000028	Low
0.00915	
0.00919	
0.01254	
0.01258	
0.02777	
0.03536	
0.04788	
0.33108	High
0.053953111	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Flying Scheduling Effectiveness rate was a very low .079908067 as depicted in table 11.

Table 11. Flying Scheduling Effectiveness correlation

Range	
0.0000026	Low
0.00432	
0.00601	
0.00865	
0.01221	
0.08033	
0.0845	
0.14594	
0.37721	High
0.079908067	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Cannibalization rate's correlation coefficient was .1652, the second highest of the nine active-duty units sampled as shown in table 12.

Table 12. Cannibalization rate correlation

Range	
0.00074	Low
0.00235	
0.00345	
0.03483	
0.0382	
0.03887	
0.17025	
0.52409	
0.67402	High
0.1652	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The Repeat/Recur rate was .073091111 for the period sampled, in table 13 and a statistically insignificant correlation coefficient.

Table 13. Repeat and Recur correlation

Range	
0.00358	Low
0.01228	
0.01429	
0.03585	
0.05213	
0.0887	
0.1087	
0.15249	
0.1898	High
0.073091111	Average

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

The comparison of the nine active duty units produced a correlation coefficient no higher than the .178087 associated with the TNMCS rate. Most of the coefficients were significantly lower than that and show no indication of correlation to unit mishaps experienced.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

Answering the original research question, "Does a discernible, statistically relevant relationship exist between any one of nine specific active-duty F-16 maintenance performance indicators and active-duty F-16 mishaps experienced?" can only lead to a negative answer. Based upon the data presented, and using common statistical practices, the only possible conclusion is there is not a particular metric reviewed in this study that correlates to the Class A mishaps experienced by the unit. A quick summary table of the Pearson correlation coefficients:

Table 14. Summarization of correlation data

Metric	All F-16s FY 2001-2010	9 Active duty bases FY2000-FY2008
MC rate	.02773	.067367
TNMCM rate	.02475	.057804
TNMCS rate	.17873	.178087
Break rate	.01958	.023367
Fix rate	.04918	.103825
Abort rate	.05619	.053953
Rep/Rec rate	.25842	.073091
Cannibalization rate	.26023	.1652
FSE rate	.11814	.079908

Source: Created by author, using data from AFSAS, https://afsas.kirtland.af.mil, and LIMS-EV, https://www.my.af.mil/faswsv/faswsv/Main.html# (accessed 15 May 2012).

There are some metrics to note however. The Cannibalization rate and the Repeat and Recur rate for the entire F-16 fleet, while not meeting the criteria for consideration under the low correlation as specified in chapter three (.3 to .5 for low) had significantly higher coefficients than did any other metrics.

The significance of the Cannibalization metric is in the amount of extra work higher rates indicate for the average maintenance technician working on aircraft. As the TNMCS rate climbs, meaning more aircraft are not mission capable while awaiting parts from supply, the Cannibalization rate usually climbs as well as technicians remove parts from donor aircraft in order to meet the flying schedule requirements. Additional work across the same number of personnel may result in rushed technicians or less than stellar maintenance practices exhibited while trying to meet the flying schedule. It is also noteworthy that the active-duty sampled metrics had the Cannibalization rate a very close second for correlation coefficients at .1652.

The significance of the Repeat and Recur rate traditionally points to training or insufficient experience issues within the maintenance workforce. As aircraft discrepancies repeat or recur, the level of attention and work involved increases in an attempt to find the source of the discrepancy and to rectify the situation. Repeat and Recur discrepancies in and of themselves may not present a safety issue; however the tendency toward a higher rate usually indicates underlying problems in the organization. The higher correlation coefficient in this area could also point to the same issues.

Another issue of significance is the relative lack of congruity between the sampled active-duty bases and the entire F-16 fleet for the overlapping FYs of 2001-2008. While the TNMCS rate was nearly identical, and the Break and Abort rates were a

.03 and .04 difference, four of the nine rates studied had a greater than 50 percent difference from the entire F-16 fleet in both positive and negative correlation levels, however slight. This indicates the study's focus may have been too narrow in scope. Eliminating Air National Guard and Air Force Reserve units, while significantly reducing the number of units and metrics subjected to data manipulation and calculation, may have also removed the requisite sample size of mishaps for a statistically relevant study. The overall measurements for the entire F-16 fleet for the FYs 2001 through 2010 most likely provided a more accurate representation of the value of using metrics for predicting mishaps.

Overall however, the nine metrics studied, used extensively throughout the USAF and worthwhile for indicating various circumstances and illuminating potential problems, do not appear to have any particular value in predicting the chances of an F-16 unit experiencing a Class A mishap. This is the case regardless of consideration of the entire fleet or a smaller, more controlled sample of active duty units.

Recommendations

While this study failed to find the "silver bullet" of mishap prevention through maintenance metrics study, the positive correlation between the Cannibalization and Repeat and Recur rates may point to a slight value in a more far reaching study specifically focused on these two rates and perhaps across entire fleets using aggregate numbers from both active duty and reserve components. One potential method could utilize the summaries available from the USAF Safety Center combined with the annual metrics reports to accomplish a "quick-look" comparison and correlation determination in an effort toward increasing USAF aviation safety.

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Department of Military History
USACGSC
100 Stimson Avenue
Fort Leavenworth, KS 66027-2301

LtCol Daniel L. Longwell
Department of Joint and Multinational Operations
USACGSC
100 Stimson Avenue
Fort Leavenworth, KS 66027-2301

Major Julio Rodriguez
Department
USACGSC
100 Stimson Avenue
Fort Leavenworth, KS 66027-2301