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A Survey and Analysis of Aircraft Maintenance Metrics: A Balanced Scorecard Approach

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THESIS

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Abstract

Performance metrics have helped to sustain the Air Force, improve processes, and guided decisions makers through decades of challenges and change. The Air Force continues to change as it faces the challenges of an aging fleet coupled with the tightest budget constraints of modern times. The current metrics employed by the United States Air Force Aircraft Maintenance community have gone largely unchanged over decades despite a host of force altering events. The focus of this research is to evaluate current maintenance metrics and assess the utility of the Balanced Scorecard framework for use in a Maintenance Group. The researcher utilizes a mixed methodology to accomplish this evaluation, including survey research, statistical analysis, content analysis, and correlation analysis. The paper proposes a Maintenance Group Balanced Scorecard based on the analysis of survey responses from Maintenance Officers with Combat Air Forces (CAF) experience. The proposed Balanced Scorecard is comprised of existing, refined, and proposed metrics to measure each perspective category of the Balanced Scorecard, and is intended to help align maintenance metrics with organizational goals/objectives and the strategic goals of Maintenance Groups in CAF units.

To the DJOA:
Not just my classmates, but dear friends or worst enemies depending on the day, sounding boards, cheerleaders, cynics, aerobics/marathon/mudding partners, penguin killers, slackers, strivers, band members, etc…and of course, an extraordinary group of people who I'll miss dearly. Thank you for your friendship and making this educational experience bearable.

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Adrienne L. Stahl

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I. Introduction

General Issue

Successful organizations have long recognized performance metrics as a vital method of establishing easily understood and tangible goals for employees, understanding where processes are succeeding, or identifying areas in need of improvement. Performance metrics provide leaders and management personnel a means to manage by fact rather than by feel or anecdotal information. Well-developed metrics lend themselves to objective decision making and provide decision makers statistical proof to validate decisions already made or to guide them into the future. Additionally, the study of objective performance metrics solidifies constancy of purpose for every person vested in the success of the organization and propels the organization on the desired course. Since the goal of any manager is to extract the maximum potential of every resource in every process, effective measurement tools are necessary to increase efficiency and value, and minimize waste and error. In this manner, comprehensive performance measurement serves to focus attention and resources toward successful organizational behavior and minimizes the time and effort spent on identifying those behaviors that require modification to contribute more effectively to achieve

organizational goals. Quite simply, organizations develop strategy that is refined through goals, and progress towards meeting goals is measured using metrics.

Metrics are measurements that can be described as a simple count of actions or events over time, a ratio of one value to another, or a complex relationship among organizations, people, objects, processes or events. Performance measurements are specific types of metrics and are described as, "The tools we use to determine whether we are meeting our objectives and moving toward the successful implementation of our strategy. Specifically, we may describe measures as quantifiable standards used to evaluate and communicate performance against expected results" (Niven, 2002, p. 114). The terminology of metrics, maintenance metrics, and performance measurements are used interchangeably in the context of this thesis, as all are tools for leaders or managers to assess actions and processes in their organization, and to assist in decision-making. "Ultimately, the actions people take and the decisions they make determine the degree and nature of value that an operation creates. These actions and decisions can be greatly influenced by metrics" (Melnyk, et al., 2004, p. 211).

There are fewer organizations in the Air Force where decisions are more critical to safe and successful mission accomplishment than in combat aviation aircraft maintenance. Aircraft maintenance organizations exist in a highly dynamic environment with dwindling resources and priorities that shift almost daily. These factors and the importance of the mission necessitate effective performance metrics to maximize readiness and combat capability. Commanders and decision makers require fidelity in information presented in the most easily understood format to facilitate critical decisions in a time sensitive environment. It is paramount that performance metrics be easily

understood, timely, accurate, fact-based and immune to manipulation, and relevant to challenges of the changing environment.

Background

From the beginning of aviation--the establishment of the Aeronautical Division of the Army Signal Corps in August 1907 and the first flight of Wright Brother's flyer in September 1907--came the inception of the aircraft mechanic who was separate from the pilot who flew the aircraft. The specialized field of aircraft maintenance was formally established in 1911, with the publication of *Provisional Airplane Regulations for the Signal Corps, United States Army, 1911*. Even during the infancy of the Air Force, leaders and decision-makers recognized the necessity for reporting information for decision making and understanding of performance of aircraft--the primary formal metrics reported by flying units to higher command levels were in-commission or out-of-commission rates and accident rates (Townsend, 1978).

In September of 1956, the Air Force codified the need for formal performance measurement, reporting, and analysis when it published AFM 66-1, *Maintenance Management*, establishing the first set of standards, goals, and objectives for aircraft maintenance. "The established standards included aircraft in-commission rates, component repair standards, and aircraft scheduling objectives, among many others. This information told the maintenance man what he was expected to accomplish, and gave him the capability to measure his effectiveness in meeting these standards or goals" (Townsend, 1978).

From 1956 to current day, the Air Force has continued to use metrics in the Aircraft Maintenance community for "The measurement of the many logistics processes

that provide combat capability to the unit… [and] quick and accurate identification of areas for improvement, as well as identification of support problems beyond the scope of the unit" (Air Combat Command Instruction 21-118, 2012, p. 4). The list of specific sanctioned and reportable metrics evolved and expanded over time through multiple iterations of aircraft maintenance management policies and regulations such as Air Force Manual 66-1 (1972) and TAC Regulation 66-3; however, since the 2003 release of Air Force Policy Directive 21-1, *Maintenance, Air and Space Maintenance*, the list of sanctioned metrics has remained largely unchanged.

The mission of the United States Air Force is among the most complex in the world. With installations, aircraft of various mission design and purpose, equipment and people in every corner of the world engaged in a seemingly endless number of on-going missions, it is vitally important that leaders understand the state of their organization's operations to the furthest extent possible. This is of particular importance in the aircraft maintenance arena.

> The overarching objective of AF maintenance is to maintain aircraft and equipment in a safe, serviceable and ready condition to meet mission needs. Maintenance management metrics serve this overarching objective and are established and maintained by Headquarters Air Force (HAF), Major Commands (MAJCOMs), Wings and/or Squadrons to evaluate/improve equipment condition, personnel skills and long-term fleet health (Air Combat Command Instruction 21-118, 2012, p. 28)

Aircraft maintenance metrics are maintained and used to monitor and drive improved performance from HAF through MAJCOMs all the way down to the squadron level. Furthermore, unit performance metrics reach beyond the internal workings of the Air Force but also convey information about the Air Force to agencies, committees and people in positions of power outside of the Air Force that have significant influence.

Communication with policy makers at the Department of Defense and Congressional level undoubtedly has far-reaching and lasting impact. It is imperative the communication is fact-based and clearly articulates the successes, challenges, direction and needs of the Air Force. The Air Force uses metrics to produce statistical analysis for congressional committees, the Office of Management and Budget, and the Department of Defense. Lead MAJCOMs establish capability goals in coordination with the Air Staff. These goals enable HAF to assess resource allocation funding on a quarterly basis, and go into the yearly Readiness Reports to Congress. The Air Force uses metrics reports to develop and defend the US Air Force input to the Planning, Programming, Budgeting, and Execution (Department of the Air Force Instruction 21-103, 2012) for decisions on issues such as airframe retirements, airframe acquisition, manpower increases and reductions, budget increases or decreases, or suitability of units for participation in conflicts (Durand, 2008).

The Air Force has also used metrics to aid in major organizational restructuring decisions for aircraft maintenance and operations. The decision to transition from Production Oriented Maintenance Organization to the Combat Oriented Maintenance Organization in 1978 and the transition of the Objective Wing Organization to the Combat Wing Organization in 2002 were both made as an attempt to reverse declining maintenance performance metrics (Durand, 2008).

Useful and accurate performance measurement metrics have helped to sustain the Air Force, improve processes, and guided decisions makers through decades of challenges and change. An aging fleet, sequestration and subsequent budget constraints are the newest of the challenges the Air Forces faces. Maj. Gen. Edward L. Bolton Jr, the

Deputy Assistant Secretary for Budget, Office of the Assistant Secretary of the Air Force for Financial Management and Comptroller described these challenges:

> In terms of average aircraft age, Air Force "iron" is older than it has ever been. Additionally, high operations tempo has shortened service lives, increasing the cost to sustain and maintain our weapon systems. Faced with compounding fiscal challenges, we must make prudent choices to ensure the Air Force continues to preserve our Nation's airpower advantage. To this end, the Air Force is committed to avoiding a hollow force; one that looks good on paper, but has more units and equipment than it can support, lacks the resources to adequately man, train and maintain them, or keep up with advancing technologies.
>
> With these changes, the active duty Air Force will reduce to approximately 329,500 personnel in FY 2013, approaching the same size as when we were established as a separate service in 1947. At the same time, the FY 2013 NDAA permits the Air Force to proceed with selected aircraft retirements and transfers necessary to meet budget targets while protecting readiness and modernization.
>
> With the onset of Sequestration, we have begun implementing immediate actions to mitigate an approximate $10B reduction to Air Force Total Obligation Authority. We've taken steps to minimize impacts to readiness and our people; however, the results of these cuts will be felt across all Air Force Core Missions and challenge the goals of our FY 2014 Budget Submission which does not reflect Sequestration reductions. Given today's fiscally constrained environment, the Air Force must pursue the best combination of choices available to balance force reductions and manage war-fighting risks, resources and the bow-wave of impacts from FY 2013. Taking these actions allows us to keep faith with our 687,634 total force Airmen and continue to excel in our role to fly, fight, and win in air, space and cyberspace (Bolton, 2013, p. 4).

Clearly, Air Force resources will require more attention and more critical decisions than ever before. Couple the challenge of the aging fleet, the effort to recapitalize, with the a reduced force structure during the tightest budget constraints of modern times and one can easily see how maintenance management metrics will play an increasingly important role. The importance of a sound aircraft maintenance metrics set is more critical than ever before, and the evaluation of the current metrics set is

imperative to ensure aircraft maintenance metrics are meeting the needs of Air Force decision makers at every level.

Problem

Air Policy Directive 21-1, *Maintenance, Air and Space Maintenance* provides direction from the departmental level down to the wings for reporting performance measurements but hasn't been reviewed or changed since February 2003; however, the Air Force's, and the Maintenance Group's situation has changed vastly since that time. A review of the maintenance metrics is needed to ensure it is relevant, and that it is meeting the needs of the maintainers that use it. "There is a pressing need for companies to reevaluate their performance measurement systems. This reevaluation should be conducted for both the individual metrics and the performance measurement system as a whole" (Caplice & Sheffi, 1994, p. 11). No MAJCOM-wide study has been accomplished to determine whether the current set of sanctioned metrics is useful for the leaders and decision-makers that use them, or if metrics are in need of revision, addition or deletion.

Additionally, metrics traditionally tracked in a Maintenance Group are not mandated to be studied in an integrated fashion. Some metrics are mandated to be studied and discussed in a group setting, while others are only required to be reported to Higher Headquarters (Air Combat Command Instruction 21-118, 2012). Many separate meetings take place where a limited number and type of metrics are discussed, such as Maintenance Status of Training and Maintenance Standardization and Evaluation Program, but no meeting is mandated which integrates all metrics for a consolidated view of the performance of all facets of successful performance. The limited scope of these individual meetings provides a relatively myopic view of the entire wing and limits the

ability of leaders and managers to see the interrelation between the various processes that contribute to the end goal of the organization. Studying different types of metrics at different times makes it difficult to, "see whether improvement in one area may have been achieved at the expense of another" (Kaplan & Norton, 1992, p. 73). Lack of standardization further limits the effectiveness of these compartmentalized meetings. The frequency and interval of meetings to study and analyze metrics is not standardized, and neither are the required attendees at these established meetings.

Research Objectives

The objective of this research was to evaluate individual maintenance metrics and the sanctioned maintenance metrics set currently employed by the Aircraft Maintenance community. The researcher sought to assess the relevance of current metrics to the leaders and decision makers that use them, as well as the optimal frequency for their review. In an effort to evaluate the efficacy of individual metrics for inclusion into selected framework, the researcher sought to evaluate the metrics against an objective evaluation criteria summarized from previous research. Lastly, to better align maintenance metrics with organizational goals/objectives and the strategic goals of the Air Force, the researcher sought to adapt, propose and evaluate a balanced scorecard metrics framework for use by Maintenance Group leaders and decision makers.

Research Question

1. What metrics should be used in the Maintenance Group Balanced Scorecard framework to meet the needs of the CAF Maintenance Community?

II. Literature Review

The general intent of this literature review was to study a broad spectrum of publications across different contexts in order to understand the importance of metrics as a critical managerial challenge, and to gain insights into various approaches to, and perspectives of, metrics and their requirements to support the decision making process. Specifically, the researcher's objectives during this literature review were to determine effective criteria for evaluating individual metrics, and gain a thorough understanding of the balanced scorecard framework to apply to USAF Combat Air Force (CAF) maintenance operations. In order to achieve these objectives, the researcher classified and analyzed the literature in several different ways (Appendix A).

The first way the researcher classified publications was by the origin of publication, from either the DoD or USAF sector or the private industry or academic sector. The purpose of researching literature from both origins was first, to establish an understanding of metrics-related research accomplished supporting functions unique to the DoD or USAF; second, to collect the current metrics used to measure performance in the field; and third, to understand themes and perspectives of both sectors related to performance measurement identification, design, and characteristics.

The researcher further classified the literature by identifying general focus areas of each publication, which examined or addressed metrics concepts from broad conceptual models or frameworks, to more refined metrics systems or sets, to a very focused few or individual metrics.

The third classification the researcher explored was the focus of the topic categories each article addressed. The researcher sought to include literature across six topic categories to facilitate a well-developed knowledge base to support this research. The topic categories included literature that addressed:

1. The purpose, importance, or characteristics of its respective focus area
2. Proposals of specific metrics, metrics sets/systems, or frameworks
3. The design, development, or selection of one of more of the focus areas
4. The implementation of individual metrics, systems or frameworks
5. The management of metrics, metrics sets, or conceptual frameworks
6. The evaluation of one of more of the focus areas

Lastly, the researcher sought to classify the publications by the methodology used to conduct the research. The publications were assembled into:

1. Literature Review/Content Analysis
2. Case Study-based
3. Survey/interview-based
4. Conceptual Model/Framework-based
5. Expert opinion
6. Mathematical/statistical analysis

Of particular interest to the researcher were three Air Force publications related to metrics in the Maintenance Group, which served as foundations for the researcher's methodology. The first was Capt Brian Waller's thesis *Evaluation of Air Force Aircraft Maintenance Metrics for Integration into the Expeditionary Combat Support System*. In his thesis, Capt Waller recommended expanding his case study of suitable and useful metrics to be incorporated into the Expeditionary Combat Support System into a statistical survey by a larger population of maintenance experts. He states, "Further revelations may be developed by expanding the expert pool to include maintenance managers from other organizations, such as fighter or special operations units as well as evaluations from managers at higher-level headquarters" (Waller, 2009, p. 115). Additionally, he determined, "The results of this study have found a number of metrics that need re-evaluation, if not re-engineering. Further exploration should be undertaken in order to determine how to best change these metrics to align better with the strategic goals of the Air Force as well as the goals for effective metrics" (Waller, 2009, p. 115).

The second study was a report written by Capt Emily Harris titled *Development of Aerospace Ground Equipment (AGE) Metrics*, which addressed the lack of standardized metrics to measure the performance of AGE maintenance, and proposed a set of metrics to be used at the Maintenance Group level (Harris, 2011).

Lastly, the Air Force Research Laboratory and the University of Arkansas published a report called *The Use of Decision Models in the Development of a Collaborative Integrated Solutions System* which identified a need to have a strategically aligned performance measurement system for flightline maintenance activities, and used

the Kaplan and Norton's Balanced Scorecard approach to develop a proposed metrics set for use by an Aircraft Maintenance Unit (Nachtmann, et al., 2003).

Appendix A shows the researcher's breakdown of all reviewed literature and the determined categorizations.

Officially Sanctioned Metrics

The next objective of the literature review was to determine the officially sanctioned metrics in aircraft maintenance through a literature review of regulations and Air Force Instructions (AFI). The researcher found that metrics were scattered across many different aircraft maintenance and training regulations, supplements, and Tactics, Techniques and Procedures, and identified over a hundred metrics currently in use. The researcher called this list of unfiltered and unconsolidated metrics "Exhaustive List of Metrics" which is listed in Appendix B. For the ease of surveying the maintenance officer population, the researcher consolidated metrics that she deemed similar in intent to make a "Consolidated List of Metrics", which can be found in Appendix C.

Current Frequency and Levels of Metrics Study

After researching and determining the officially sanctioned metrics, the researcher sought to determine the mandated frequency and management level of study of the officially sanctioned metrics through a literature review of regulations and AFIs. The researcher noted that the set of "traditional" aircraft maintenance metrics actually had no AFI mandated meeting at the Wing or Maintenance Group level, while other metrics had AFI mandated meetings for their study by leaders and managers. The researcher outlined the frequency and level of management in which the officially sanctioned metrics are reviewed in Appendix D.

Evaluation Criteria for Individual Metrics

To aid in determining the efficacy of the individual metrics, the literature review included research to establish a viable set of objective criteria for evaluating individual metrics. After carefully considering various methods of evaluating individual metrics discovered in her exploration, the researcher determined the Caplice and Sheffi criteria was the most comprehensive and complete set of criteria to use in her study. In the literature review performed by Caplice and Sheffi, they evaluated past publications on metrics evaluation, and found several common general characteristics in good performance metrics (Caplice & Sheffi, 1994). They produced a set of eight evaluation criteria based on this review, which are described below and outlined in Figure 1.

Validity

"A metric is valid if it reflects the actual activity being performed and controls for any exogenous factors that are out of the process manager's control" (Caplice & Sheffi, 1994, p. 15). For example, Deviation Rate may be considered valid because it accurately measures departures from the printed flying schedule, takes into account external factors such as weather.

Robustness

"A metric is robust if it is widely accepted, is interpreted similarly by different users, and can be used for comparisons across time, locations, and organizations" (Caplice & Sheffi, 1994, p. 15). For example, Fully Mission Capable rate may be considered robust because it is interpreted the same by all that use it, is measured the same way at any time or at any location by all organizations and is easily repeatable.

Usefulness

"A metric is useful if it is readily understood by the decision maker and suggests a course of action or direction to be taken" (Caplice & Sheffi, 1994, p. 15). For example, Aircraft Availability may be considered useful because the decision maker can immediately understand the limitation imposed by a low number of available aircraft. He may take action to reduce the number of aircraft employed for non-mission priority purposes such as trainers.

Integration

"A metric is integrative if it incorporates all of the major components and aspects of the process being measured and promotes coordination across functions, divisions, or firms in the supply chain. The primary thrust of this criterion is to promote coordination between the players involved in the process" (Caplice & Sheffi, 1994, p. 15). For example, Total Not Mission Capable rate may be considered integrated because it includes both maintenance and supply functions and encourages coordination between maintenance and supply agencies to reduce the number of Not Mission Capable aircraft (Caplice & Sheffi, 1994).

Economy

"A metric is economical if the benefit of tracking it outweighs the cost to collect, process, and report it. This is more of a judgment call than a strict cost-benefit comparison so that the economy criterion should be used to select between potential metrics rather than for the decision of whether to use any metric at all" (Caplice & Sheffi, 1994, p. 15). For example, Mission Impaired Capability Awaiting Parts may be

considered economical because it is relatively easy to collect the data and the benefit of putting higher priority on parts returns aircraft to service faster.

Compatibility

"A metric is compatible with the existing data collection, information systems, and information flows of the firm if no significant additional work is required to install and use it. While compatibility has some overlap with the economy criterion, in that any system can be made to be compatible to a proposed metric given the needed time and money, they are not the same. A metric which is economical in terms of collecting and reporting data might not always be compatible with the existing flow of information" (Caplice & Sheffi, 1994, pp. 15-16). For example, Average Sortie Duration may be considered compatible because the information is collected during an existing process (Pilot debrief) and captured in an already existing database.

Level of Detail

"A metric has the correct level of detail if it captures and reports the data in a level of aggregation or granularity to be useful to the decision maker" (Caplice & Sheffi, 1994, p. 16) . For example, UTE rate may be considered to have the proper level of detail because it is measured monthly (daily or weekly is too often) and gives the decision maker an idea of how often aircraft are being flown during a 30 day period.

Behavioral Soundness

"A metric that is behaviorally sound discourages any counter-productive actions or game-playing by those process owners or organizations being measured. While it is always hoped that a measure will align peoples' actions with the organization's overall objectives, in many cases it can provide incentives for doing the opposite" (Caplice &

Sheffi, 1994, p. 16). For example, Abort rate may be considered behaviorally sound because it is simply a report of an event and there are no counterproductive actions or means to "game the system" to improve the metric, but it is a top indicator of how well maintenance executes the flying mission.

Criterion	Description
Validity	The metric accurately captures the events and activities being measured and controls for any exogenous factors
Robustness	The metric is interpreted similarly by the users, is comparable across time, location, and organizations. Metric is repeatable.
Usefulness	The metric is readily understandable by the decision maker and provides a guide for action to be taken
Integration	The metric includes all relevant aspects of the process and promotes coordination across function and divisions.
Economy	The benefits of using the metric outweigh the cost of data collection, analysis, and reporting
Compatibility	The metric is compatible with the existing information, material, and cash flows and systems in the organization
Level of Detail	The metric provides a sufficient degree of granularity or aggregation for the user
Behavioral Soundness	The metrics minimized incentive for counterproductive acts or game playing and is presented in a useful form

Figure 1: Metric Evaluation Criteria (Caplice & Sheffi, 1994, p. 14)

Metrics Set Theory/Framework

The researcher included an examination of established theory and frameworks on how metrics sets are constructed in the literature review. The purpose of this examination was to solidify understanding of the various theories and approaches to metrics set construction and to select a theory to build the Maintenance Group's metric set against. The researcher chose to scope this research around the balanced scorecard

framework from the many available because of the credibility of the source and because of its enduring success in corporate applications.

Balanced Scorecard overview

The balanced scorecard approach to constructing effective metrics sets was introduced in an attempt to reconcile performance measurement problems in traditional management strategies. The creators of the balanced scorecard framework, Kaplan and Norton, realized the vital importance of having an easily understood, yet comprehensive method of providing top managers sufficient details on operational measures regarding financial measures, results of decisions, customer satisfaction, internal processes and innovation and improvement activities. According to authors Kaplan and Norton, the balanced scorecard was developed as a set of measures used to give managers an all-inclusive view of their organization's performance:

> The balanced scorecard includes financial measures that tell the results of actions already taken, and compliments the financial measures with operational measures on customer satisfaction, internal process, and the organization's innovation and improvement activities—operational measures that are the drivers of future financial performance (Kaplan & Norton, 1992, p. 71).

During the development of the balanced scorecard theory, Kaplan and Norton recognized that for an organization to successfully achieve its objectives, a clear strategy is necessary to ensure there is a balanced approach to avoid compromising one goal for another and thus jeopardizing the entire endeavor. One of the most prevalent failures in management strategy is failing to identify the interrelation of the various processes and aspects in the organization. As stated in the Balanced Scorecard Institute's website:

> Traditional management strategies overemphasized financial measures at the expense of progress and growth. This overemphasis brought about short-term gains to the detriment of long-term success. The balanced scorecard is a

> performance management system that allows organizations to clarify their strategy and assure that every aspect of operations is directed toward the success of these goals" (Balanced Scorecard Institute, 1998-2013).

Successful strategists also understand that less traditional, non-financial performance measures add value to a successful organizational strategy. In addition to the traditional financial performance measures, the balanced scorecard incorporates non-financial measures that create value for an organization such as customer relationships, skills and knowledge of the workforce, and technology.

In order for an organization to achieve its goals, its performance measurement system must align with the overall mission of the organization. The four perspectives of the balanced scorecard focus on the mission or strategic objectives of an organization and include the Customer Perspective, the Internal Process Perspective, the Financial Perspective and the Learning and Growth Perspective. Kaplan and Norton explain the purpose of the four different perspectives: "[Perspectives] allow managers to…answer four basic questions: How do customers see us? What must we excel at? Can we continue to improve and create value? How do we look to shareholders?" (Kaplan & Norton, 1992, p. 72) Purposeful and valid answers to these questions provide focus for the time, effort and money invested into every activity in every process. To enhance understanding of the four perspectives, refer to Figure 2.

Figure 2: Graphical Representation of Balanced Scorecard (Kaplan and Norton, 1996)

The balanced scorecard provides a multi-faceted view of the organization from multiple angles from the inside out and from the outside in. The report is a composite view of customer focus, internal process focus, financial focus and improvement/growth focus. It reaches beyond being a snapshot of top-level information and brings a critical evaluation of essential components of an organization's strategy.

> The scorecard brings together, in a single management report, many of the seemingly disparate elements of a company's competitive agenda: becoming customer oriented, shortening response time, improving quality, emphasizing teamwork, reducing new product launch times, and managing for the long term. The scorecard also guards against sub-optimization. By forcing senior managers to consider all the important operational measures together, the balanced scorecard lets them see whether improvement in one area may have been achieved at the expense of another (Kaplan & Norton, 1992, p. 73).

The balanced scorecard can serve as an effective organizational tool providing executives and top-level managers a comprehensive view of the business and a means to map out a successful strategy, but the balanced scorecard approach will be ineffective if the performance measures are not aligned with the organizational strategy. Therefore, aligning performance measures with organizational strategy is of utmost importance to executives and top-level managers. According to Nachtman, et al.,

> Organizational Strategy is the guiding factor behind the balanced scorecard. Organizational strategy is defined as a set of long-term goals that, if successfully achieved, will revolutionize the way a unit operates. Without strategic alignment or the integration of this organizational strategy into the balanced scorecard, a balanced scorecard is merely collection of performance measures. Strategic planning and alignment to a given strategy should be the top priority in any balanced scorecard venture (Nachtmann, et al., 2003, pp. 16-17).

The balanced scorecard was introduced as a valuable method for private businesses to develop successful strategy and measure performance. The researcher studied the balanced scorecard and sought to apply the principles to the benefit of the mission of the Air Force, and more specifically, the Maintenance Groups in Combat Air Forces (CAF). To explore its potential for use, the researcher reviewed the perspectives proposed by Kaplan and Norton, and then considered how these perspectives could translate and apply to a Maintenance Group.

Customer Perspective

The customer perspective, the first proposed by Kaplan and Norton, helps to establish the fundamental purpose and existence of an organization. "When choosing measures for the Customer perspective of the Scorecard, organizations must answer two critical questions: Who are our target customers? What is our value proposition in serving them? Sounds simple enough, but both of these questions offer many challenges to organizations" (Niven, 2002, p. 15).

In the corporate world where gaining market share to garner a profit is the ultimate goal, the customer is normally well defined and the concept seems obvious; if the needs of customer are being met and are satisfied, the end goal of gaining market share and collecting a profit is achieved. If their needs are not met and the customer is not satisfied, market share shifts to another company and revenue is lost. When applying

these concepts to a military organization such as the Maintenance Group within a flying wing, the concept of who the customer is not driven by market share and garnering a profit, but by an essential and required combat support capability.

Oxford Dictionary defines customer as "a person or thing of a specified kind that one has to deal with" (Oxford University Press, 2014). Considering this definition, the customer of the Maintenance Group could be one, or all, of the entities in a flying wing that the members of the Maintenance Group deal with--the Aircrew from the Operations Group, the maintainers within the Maintenance Group, assigned aircraft, or assigned equipment. From the perspective of the Maintenance Group, the most readily identifiable customers are the aircrews. However, the Maintenance Group is typically the largest, most complex organization in any flying wing and is comprised of multiple squadrons and flights, many of which endeavor to benefit others within the Maintenance Group itself. For instance, an avionics backshop is focused primarily on repairing parts to benefit the Aircraft Maintenance Squadron that strives to generate airplanes. A backshop's direct measure of success is repair cycle time in support of the Aircraft Maintenance Squadron. Another example would be the Military Training Flight (MTF), whose mission it is to train maintainers from other squadrons. An MTF instructor does not directly benefit aircrews; he or she provides training and education to other maintainers and squadrons within the group and measures success by the quality and quantity of training accomplished. These are just a very few examples of how organizations within the Maintenance Group benefit each other and can measure success without considering aircrews at all. The intertwining of the various squadrons and flights

is complex and meeting the demands of "internal customers" consumes time and effort, but is an absolute necessity.

One might not normally think of aircraft and equipment as a "customer" as they are objects in a process, but aircraft and equipment have service requirements of their own, whether or not they are flown by aircrew or used by maintainers. Additionally, the needs of aircraft and equipment are often diametrically opposed with the needs of aircrews and consume an enormous amount of Maintenance Group resources. Aircrews need to fly to train and be proficient, but aircraft and equipment require out of commission time for maintenance and health. The pilot requires an airplane to serve his purpose and an airplane is of no use without a pilot. The Maintenance Group's success comes from finding the critical balance to ensure the best interest of both is served. Ultimately, mission success is dependent on this balance and the needs of one should not consistently be given preference over the other.

Aircrews need continuous training to maintain proficiency and to prepare for combat. Providing the aircraft for Aircrews often comes at the expense to aircraft combat-readiness when systems degrade or fail in flight or on the ground. Equally important is the need to train and educate the maintenance force, who must maintain a perfect balance of qualifications and certifications to safely, efficiently, and effectively provide aircraft to pilots in combat scenarios. Equipment must be available and functional to allow any of this to happen, but is subject to wear and tear just like aircraft. In the context of a Maintenance Group, it could be argued that success comes from effectively serving not one, but four customers. Each of these entities competes against the other for the use of resources, but cannot succeed if any one of the others is failing.

Internal Process Perspective

From the Internal Process Perspective, the organization must answer the question, "What must we excel at?" Focusing on the answers to that question helps to identify critical processes to assist in prioritization, and add focus, direction and thrust for that organization. Kaplan and Norton state:

> Customer-based measures are important, but they must be translated into measures of what the company must do internally to meet its customer's expectations. After all, excellent customer performance derives from processes, decisions, and actions occurring throughout an organization. Managers need to focus on those critical internal operations that enable them to satisfy customer needs. The internal measures for the balanced scorecard should stem from processes that have the greatest impact on customer satisfaction--factors that affect cycle time, quality, employee skills, and productivity, for example. (Kaplan & Norton, 1992, p. 74).

In the context of a flying wing and Maintenance Group's potential customers--be it aircrew of the Operations Group, maintainers, aircraft or equipment--the needs of each of these customers is to be combat-ready to meet the expectations of the stakeholder, the combatant commander. The internal processes of a flying wing, specifically the maintenance complex, are diverse and many. Each one of these processes must relate to the strategic objective of the Maintenance Group, and ultimately serve the needs of the customers and the primary stakeholder. Air Force Policy Directive 21-1, *Maintenance,* outlines general processes the AF must excel at by stating, "The AF shall support readiness objectives by maintaining equipment in optimum condition, assign skilled personnel necessary to support expeditionary air forces, and manage fleet health to ensure long-term capability of air and space equipment" (Department of the Air Force Policy Directive 21-1, 2003, pp. 1-2). To specify and narrow the scope, this paper discusses ten

vital internal processes in the flying wing that are cornerstone to the general processes outlined in AFPD 21-1:

1. Aircrew Mission/Training Scheduling
2. Aircrew Mission/Training Execution
3. Aircraft Flying Scheduling
4. Aircraft Flying Execution
5. Maintenance Training Scheduling
6. Maintenance Training Execution
7. Aircraft Maintenance Scheduling
8. Aircraft Maintenance Execution
9. Equipment Maintenance Scheduling
10. Equipment Maintenance Execution

Aircrew Mission/Training Scheduling and Execution Process and Flying Scheduling and Execution Process

Air Force Aircrew training is not only paramount to the success of the mission, it is crucial to his or her survival and the survival of his or her aircraft in a combat scenario. Aircrews in the CAF are among the most comprehensively trained in the world as is necessary to operate effectively in nearly any environment, in any theater, against any adversary on earth. Aircrews develop skills through several years of intense training before ever entering the cockpit of a combat-coded aircraft. According to AFI 11-202 volume 1, *Aircrew Training*,

> The USAF Aircrew Training Program (ATP) ensures all aircrew members obtain and maintain the certification/qualification and proficiency needed to effectively perform their unit's mission. The objective of the ATP is to develop and maintain

> a high state of mission readiness for immediate and effective employment across the range of military operations" (Department of the Air Force Instruction 11-202, Volume 1, 2010, p. 3).

Accumulated skill necessary to operate tactical aircraft is developed from the fundamentals of taking off and maintaining straight and level flight and culminates in combat mission ready status where he or she is proficient in basic combat maneuvers. After fundamentals for basic aircrew duties in the assigned aircraft are mastered during Initial Qualification Training, the aircrew continues to hone skills in advanced aerial combat tactics during Continuation Training (CT) and Upgrade Training (UGT). The CT program provides aircrew members with the volume, frequency, and mix of training necessary to maintain proficiency in the assigned certification/qualification level. Aircrews in a combat-coded unit may be trained to the proficiency levels of Combat Mission Ready (CMR) or the Basic Mission Capable (BMC). Aircrew who maintain qualification and proficiency in the command or unit combat mission are considered CMR, while aircrews who are qualified in some aspect of the unit mission, but do not maintain CMR status are considered BMC.

The Ready Aircrew Program (RAP) is a training program developed by local commanders to align their units' CT with the skills and qualifications required to meet their units' Designed Operations Capability (DOC) statement primary and secondary mission sets. The RAP Tasking Message, sent to flying wings annually by their MAJCOM, "defines the *minimum* required mix of annual sorties, simulator missions and training events aircrew must accomplish to sustain combat mission readiness" (HQ ACC/A3T, 2013). RAP lists training and proficiency requirements for each level according to the crew's position in the unit and qualifications and experience with the

weapons system. For example, a typical inexperienced Air Force pilot requires nine sorties in a single month just to stay proficient in take-off and landing. Beyond the fundamental take-off and landing is a myriad of other proficiencies that must be maintained such as night flying, aerial refueling, air-to-ground, air-to-air, or firing guns for close air support. Flying squadrons first develop long-term annual and quarterly RAP training plans, and continually refresh and refine these plans into more short term monthly and weekly training schedules. This process will be referred to as the Aircrew Mission/Training Scheduling process. Maintenance and Operations leaders then begin the Flying Scheduling Process by collaborating to develop each of these plans into a Flying Schedule by communicating requirements, understanding and considering limitations, and establishing a final, signed agreement between both agencies. The Aircrew Mission/Training Execution Process begins with the development of the mission plan. A pilot or Aircrew can spend days planning for an upcoming mission culminating in the mission pre-brief which occurs immediately before entering the daily flying cycle as outlined in Figure 3.

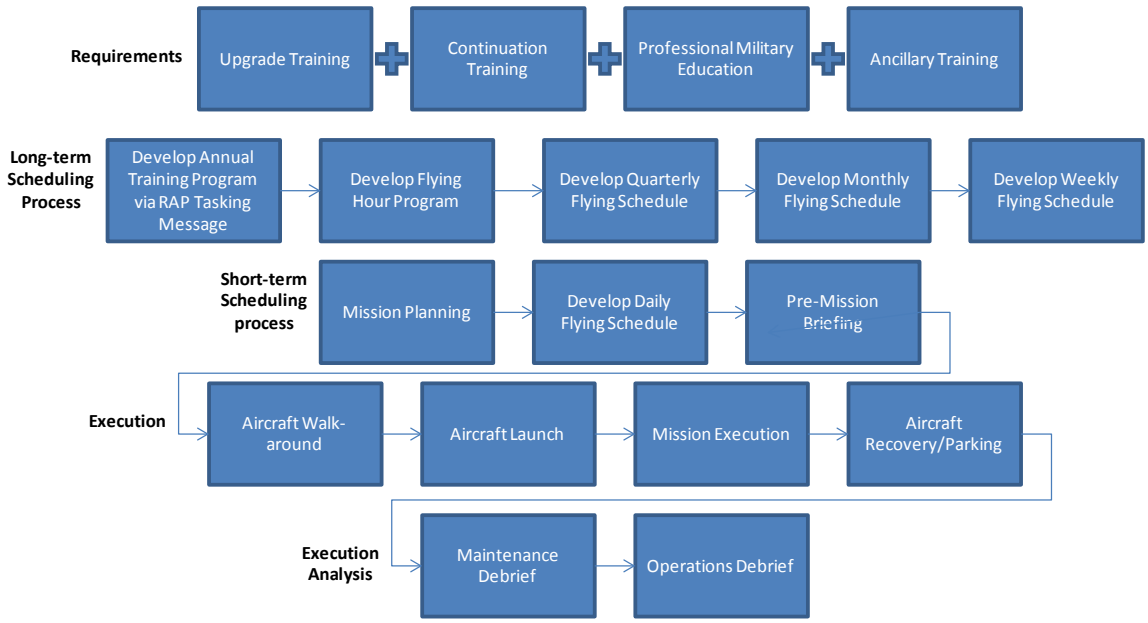


Figure 3. Aircrew Mission/Training Scheduling and Execution Processes

Scheduling aircrew training and mission planning are arduous processes for operators. A single deviation during the short term planning process can disrupt multiple aircrew training events and cause significant scrap and schedule rework for both operators and maintenance. Maintenance processes, specifically the delivery of mission-capable airplanes on-time for scheduled events, are clearly the most critical component to the execution of the schedule. The short term scheduling process is very closely tied to success of the Maintenance Scheduling and Execution Processes, which will be described in detail. Maintenance failure to meet the schedule for execution of planned missions can turn a well thought out plan into a toppling house of cards.

The Flying Execution Process begins with the aircrew's arrival at the aircraft, and is another process where aircraft maintenance processes intersect with the flying process. These intersections of processes continues to the aircrew's walk-around inspection,

through engine start-up and launch procedures and finally ends when the aircraft is marshaled out of the end-of-runway (EOR) inspection area.

Once an aircraft takes-off and a sortie begins, the Aircrew Mission/Training Execution Process continues--the Aircrew is required to accomplish a certain number of flight events for the sortie to be considered effective. A non-effective sortie is one in which no RAP mission/sortie can be logged, and can be caused by factors such as aircraft system failures, air aborts, range weather, or in the case of an UGT sortie the pilot's failure to progress. Any one of these factors causing a sortie to be non-effective is costly as it drives the need for an additional sortie to be scheduled to complete the desired training.

Aircraft Maintenance Scheduling and Execution Process

The return on the investment of training professional maintainers is realized when the skills gained are applied in the Aircraft Maintenance Scheduling and Execution processes. Most combat-coded squadrons have a fleet of between 18 and 25 aircraft assigned and ensuring the long-term health of the fleet demands the continuous attention of maintenance personnel.

> Aircraft and equipment readiness is the maintenance mission. The maintenance function ensures assigned aircraft and equipment are safe, serviceable, and properly configured to meet mission needs. Maintenance actions include, but are not limited to, inspection, repair, overhaul, modification, preservation, refurbishment, troubleshooting, testing, and analyzing condition and performance (Department of the Air Force Instruction 21-101, 2010, p. 14) .

Each fleet of aircraft requires preventative and unscheduled maintenance actions in order to be safe for flight and capable of performing any mission for which the aircraft is designed. Scheduled maintenance actions are performed based on prescribed intervals

(hourly-based, sortie-based, or calendar-based) must be accomplished without interfering with the primary flying mission. The scheduling of preventative maintenance events requires a detailed plan for proper execution and to ensure an adequate number of aircraft are available for execution of the flying schedule. Unscheduled maintenance occurs either as a result of pilot-reported discrepancies after flight, or as ground-found discrepancies discovered during inspections or scheduled maintenance. Both preventative and unscheduled maintenance can be grounding write-ups, or flyable write-ups (Department of the Air Force TO 00-20-1, 2010). The severity of the write-ups not only effects airworthiness, but also determines the status of the aircraft as compared to the Mission Essential Subsystem List published by lead commands. The focus of professional maintenance leaders and managers is one of knowing exactly what the status of each aircraft is, assessing and setting priority, and allocating the proper resources (manpower and equipment) to restoring each aircraft to fully mission capable status in the shortest amount of time possible. Figure 4 depicts the Aircraft Maintenance and Scheduling Process.

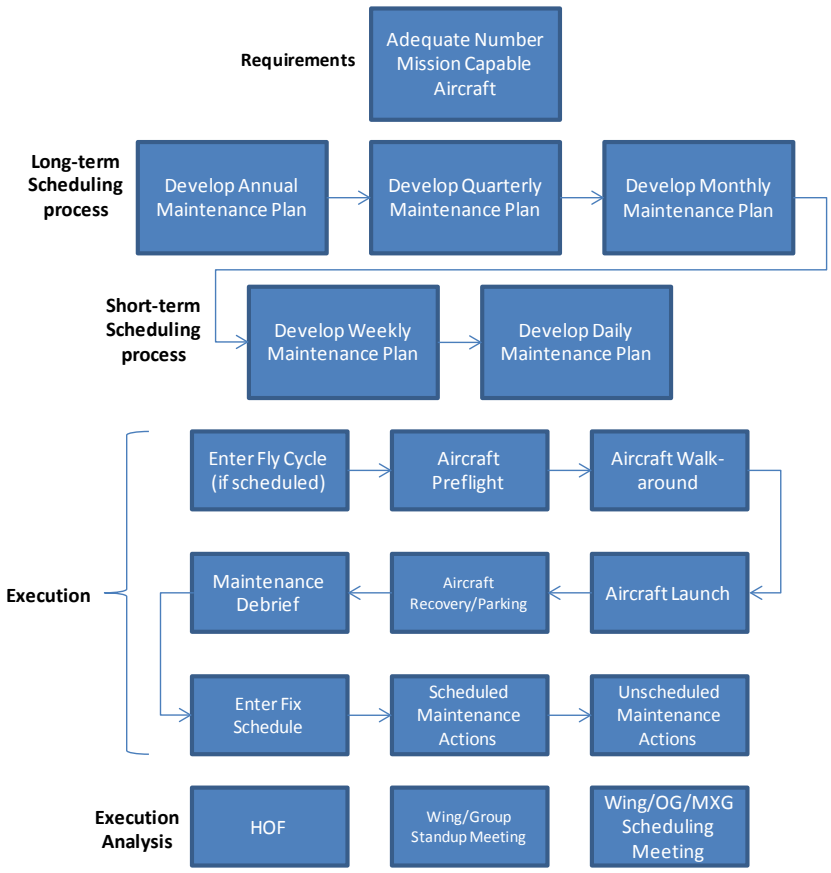


Figure 4: Aircraft Maintenance Scheduling and Execution Process

Equipment Maintenance Scheduling and Execution Process

The success of the flying wing's critical processes of maintaining aircraft and training combat-ready pilots relies on the availability of equipment. The combat-ready equipment process is necessary to ensure the correct assortment of equipment is available to support all scheduled and unscheduled maintenance events. Often, the equipment is so complex or so costly that MAJCOM level management is required. Most every suborganization within the maintenance group has a hand in Equipment Maintenance, but the most visible Equipment Maintenance processes include:

1. Aerospace Ground Equipment (AGE)

2. Munitions Material Handling Equipment (MMHE)
3. Alternate Mission Equipment (AME)
4. Test, Measurement and Diagnostic Equipment (TMDE)
5. General tools and toolkits

With such a diverse and extensive list of equipment to manage in a typical Maintenance Group, one could correctly ascertain that the requirements to keep equipment combat-ready are quite complex. Each different type of equipment has its own requirements for scheduled maintenance and inspections to ensure it is combat-ready. Quite simply, however, the Equipment Maintenance Scheduling and Execution Process (Figure 5) looks similar to the Aircraft Maintenance Scheduling and Execution Process.

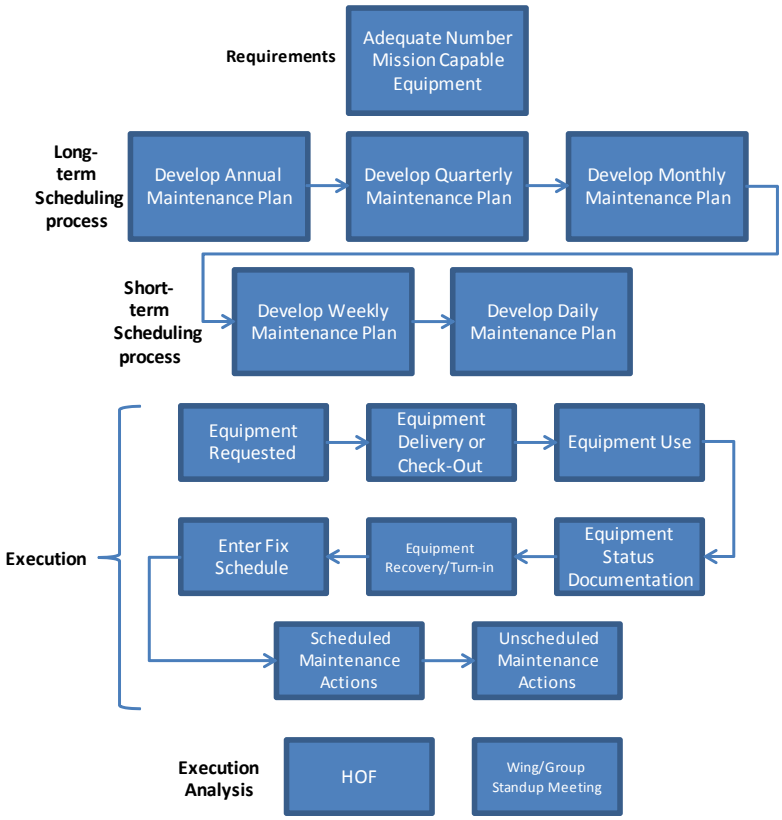


Figure 5: Equipment Maintenance Scheduling and Execution

Maintenance Training Scheduling and Execution Process

The success of any flying unit depends on the availability of the right number of maintainers with the right skill sets and experience to meet mission requirements. Skills and experience are a result of training, and just as in pilot training, the cumulative knowledge that our most valuable and technically advanced maintainers require comes at significant expense over time. Without trained and skillful maintainers to generate aircraft, airpower is unsustainable, pilot training is impossible, and mission objectives are unachievable. AFI 21-101 states:

> Maintenance training is an essential element of improving and sustaining unit capability; it must receive priority treatment by SQ/CC and MOO/MX SUPT. When balancing resources (e.g., aircraft, support equipment, facilities, tools, funding, personnel), maintenance training carries an equal priority with the operational training mission. Accomplish maintenance training away from the production/test environment (whenever possible) to eliminate/minimize distractions (Department of the Air Force Instruction 21-101, 2010, p. 128)

Undoubtedly, the investment the Maintenance Group makes to develop combat-ready maintainers is worthy and comes with another set of processes that ultimately add value and affect customer satisfaction. According to AFP 36-2241, *Professional Development Guide,* the strategy of the Air Force's Education and Training (E&T) program is, "Develop, manage, and execute realistic and flexible training programs to produce a highly skilled, motivated force capable of carrying out all tasks and functions in support of the Air Force mission. These programs should provide the foundation for Air Force readiness" (Department of the Air Force Pamphlet 36-2241, 2013, p. 275)

The components of the Maintenance Group's Maintenance Training Scheduling and Execution include on-the-job training (OJT), Upgrade Training (UGT), and

Certification Training. The OJT program includes job knowledge, job proficiency and job experience. For maintainers, the job knowledge component is satisfied by successfully completing a career development course (CDC) that provides career knowledge, general task, and deployment/unit type code (UTC) task knowledge. The Job Proficiency component is the initial training an Airman receives at his first work center and is achieved through hands-on training on tasks in the work center (work center requirements). The job experience component is gained during and after UGT. UGT is how an Airman progresses through the skill levels (3-, 7-, and 9-skill level) and is considered the most vital piece to an Airman's total training program (Department of the Air Force Instruction 36-2201, 2010).

To achieve his 3-skill level and become an Apprentice, an Airman must complete an initial skills course (technical school). To be a 5-skill level, or Journeyman, an Airman must complete the CDC for his Air Force Specialty Code (AFSC) and the mandatory core tasks outlined in the Career Field Education and Training Program (CFETP). Additionally, the 5-skill level requires a minimum of 12 months of UGT and meet the mandatory requirements listed in the Air Force Enlisted Classification Directory (AFECD), be recommended by his supervisor and approved by his commander (Department of the Air Force Instruction 36-2101, 2013).

An Airman becomes a Craftsman when he is awarded his 7-skill level. To achieve his 7-skill level the Airman must complete a second CDC (7-level craftsman course), meet the mandatory requirements listed in the AFECD, complete an additional 12 months of UGT, be recommended by his supervisor and approved by the commander (Department of the Air Force Instruction 36-2101, 2013).

The top three percent of the enlisted force achieve the 9-skill level, or Superintendent. To be awarded the 9-skill level the member must be a Senior Master Sergeant or Chief Master Sergeant, be recommended by his supervisor and approved by the commander (Department of the Air Force Instruction 36-2101, 2013).

Developing a skillful maintainer takes a comprehensive plan and requires a tremendous amount of time and effort. In addition to the skill level progression outlined above, a maintainer attends courses at Field Training Detachments (FTD) throughout the Air Force to gain formal training on specific systems such as hydraulics, engines, or advanced avionics. Furthering the training regimen is recurring training, computer based training and Professional Military Education.

The maintainer's bottom-line mission is to deliver safe and reliable airplanes to keep the war-fighter in the cockpit as safe as possible in an inherently dangerous environment, and the Maintenance Training Scheduling and Execution Processes (Figure 6) are vital in ensuring that mission succeeds.

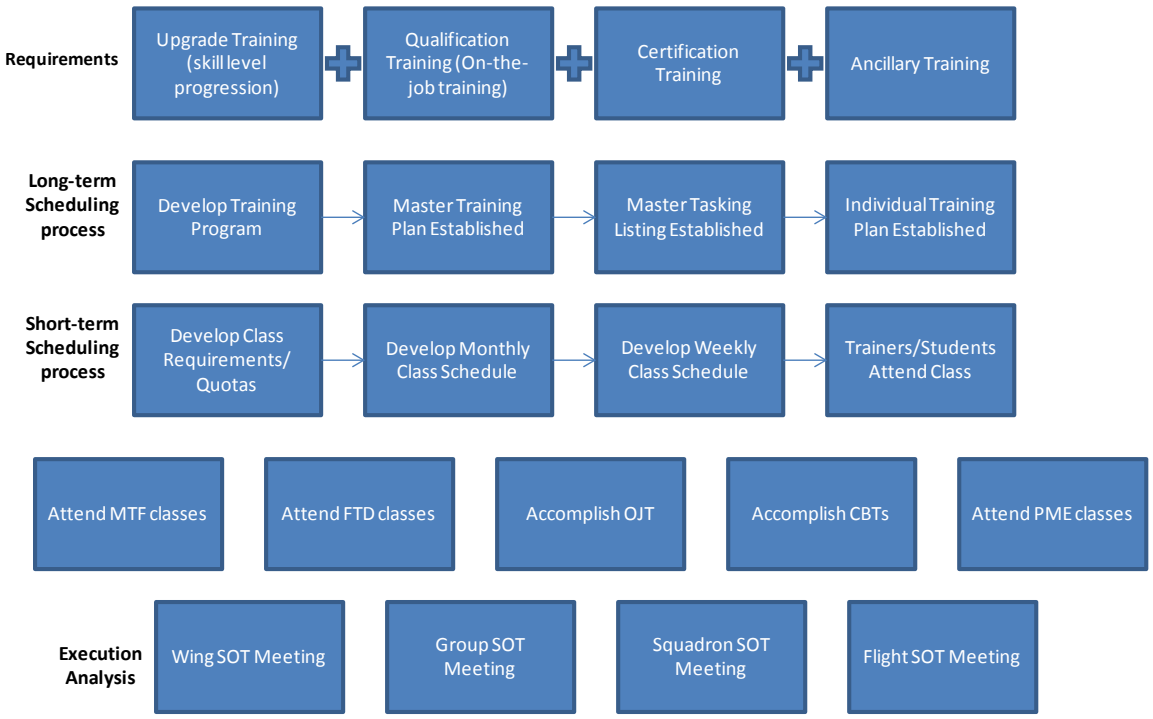


Figure 6: Maintenance Training Scheduling and Execution Process

Monitoring and improving critical processes ultimately leads to achieving objectives and customer satisfaction. Responding to the necessity of improving processes takes careful consideration if resources are to be used effectively and process operations are to be optimized to the benefit of the customer. Meaningful thought and action to improve not only add to customer satisfaction, but also ensure that processes stay ahead of increasing challenges and the declining curve of resources.

Financial Perspective

The Financial Perspective of the balanced scorecard contains the big-picture metrics that gives the manager a holistic view of whether the execution of stated strategy is leading to acceptable end results. The "how" of how an organization arrived at these big picture metrics is detailed through measures chosen in the other perspectives.

> We could focus all of our energy and capabilities on improving customer satisfaction, quality, on-time delivery, or any number of things, but without an indication of their effect on the organization's financial returns they are of limited value. Classic lagging indicators are normally encountered in the financial perspective (Niven, 2002, p. 17).

In the corporate world, the shareholders' perspective is of paramount importance to business leaders. Shareholders are driven by and demand a return on their investment dollars. For the Air Force, the shareholders are the Combatant Commanders who are responsible for the prosecution of contingency operations in their area of responsibility. It is vitally important for Maintenance Group leaders to consider, "How do the shareholders view us?" The Aircraft Maintenance community must develop and maintain performance measures that accurately convey to the Combatant Commander the bottom-line readiness of the units that are preparing to support them. Air Force Personnel Directive 21-1, *Maintenance,* defines readiness as "The ability of US military forces to fight and meet the demands of the national military strategy. Unit readiness is the ability to provide capabilities required by the combatant commanders to execute their assigned missions" (Department of the Air Force Policy Directive 21-1, 2003, p. 6). From the Maintenance Group standpoint, one must consider the critical assets under the group's control--aircraft, maintenance personnel, and equipment--and how the culmination of the previously described processes affects their bottom-line readiness.

Learning and Growth Perspective

> Once you identify measures and related initiatives in your Customer and Internal Process perspectives, you can be certain of discovering some gaps between your current organizational infrastructure of employee skills and information systems, and the level necessary to achieve your results. The measures you design in this perspective will help you close that gap and ensure sustainable performance for the future. (Niven, 2002, p. 16).

The Learning and Growth Perspective applies to the less tangible internal elements that sustain value added processes. Elements typically found in the Learning and Growth Perspective are “enablers” of all the other perspectives. One might consider technology, training or communications in the Learning and Growth Perspective, but for the purpose of clarity, the researcher chose the maintenance workforce because the maintainers are the foremost and most important enablers of all other processes and perspectives. For the Maintenance Group, the number one internal element that sustains the primary value added processes is trained and skilled personnel. From the perspective of the Maintenance Group's employees, the maintainers, a more fitting description of the "gaps" between infrastructure of skills and the level necessary to achieve results would be the workforce quality. Workforce quality could take into account skill level and experience level, quality of maintenance, safety of maintenance, maintenance discipline, and retention rates.

Maintenance Group's Balanced Scorecard

While Kaplan and Norton formulated the four perspectives outlined in Figure 2, they also, “recognize these four perspectives should be considered a template, not a straight jacket. These perspectives are intended to portray the essential elements that can lead to success in a typical organization” (Kaplan & Norton, 1996). In other words, the

creator of the balanced scorecard for any organization must use some latitude to tailor the framework to best fit organizational requirements/structure and the needs of leaders and managers that will use the balanced scorecard to develop strategy.

To meet the unique requirements of a typical CAF Maintenance Group, the researcher made adjustments to Kaplan and Norton's balanced scorecard to develop the Proposed Maintenance Group Balanced Scorecard (Figure 7). The first perspective remains as the Customer perspective. Since a Maintenance Group's value is not measured in financial terms, the second perspective was renamed "Readiness" which better reflects what is expected by the customer and stakeholders (the combatant commander). The measures that fall under "Readiness"--aircraft, maintenance personnel, and equipment--tell us whether our strategy execution, which is detailed through measures chosen in the other perspectives, is leading to improved bottom-line results. The third perspective remains as the Processes Perspective as suggested by Kaplan and Norton, while the last perspective has been retitled "Workforce Quality" Perspective. Figure 7 depicts the Proposed Maintenance Group Balanced Scorecard Perspectives and the Perspective Categories that fall under them. This proposed Balanced Scorecard framework was used as the model to be evaluated as described in Chapter III, Methodology.

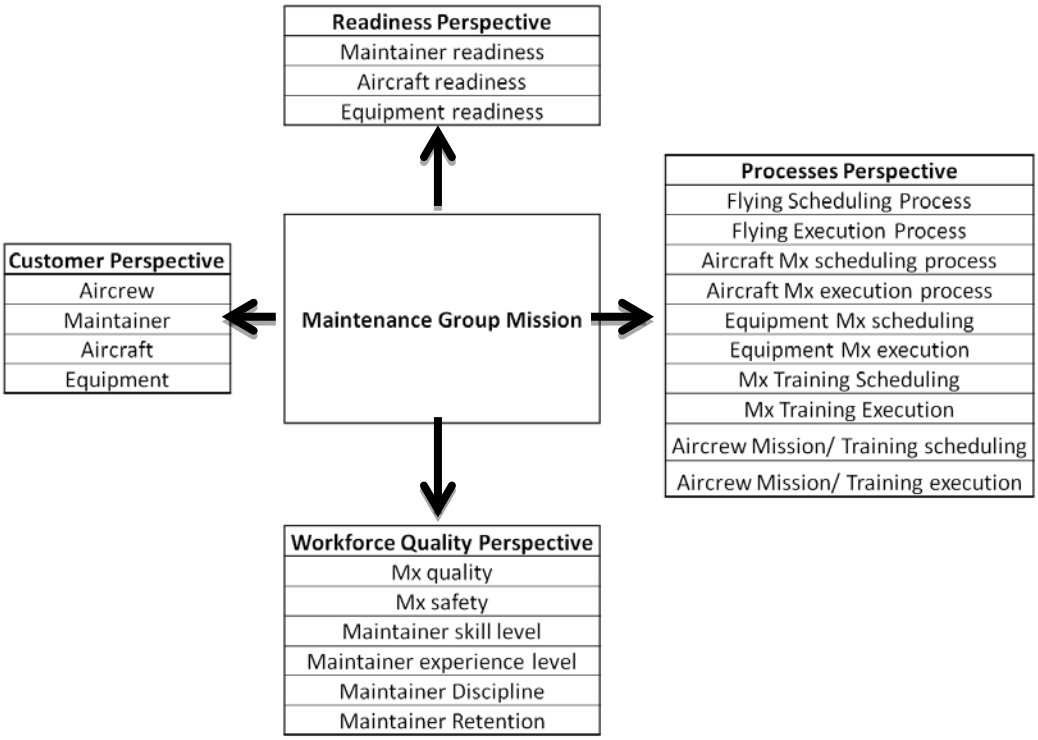


Figure 7: Proposed Maintenance Group Balanced Scorecard Perspectives and Perspective Categories

III. Methodology

Overview

The purpose of this chapter is to outline the methods used in this study. First, a background for survey method of research and why they were chosen will be given, followed by a detailed description of the survey tool that was administered. The researcher will discuss measures of reliability and error addressed in the study, then address data preparation and the data analysis methodology, including statistical analysis, content analysis, and correlation analysis.

Method

The researcher chose to utilize a survey as the method of data collection. "Surveys are systems for collecting information from people to describe, compare, and predict attitudes, opinions, values and behavior based on what people say or see and what is contained in records about them and their activities" (Fink, 2003). The researcher chose to apply this research method for two reasons:

1) "Provides standardized measurement that is consistent across all respondents and ensures that comparable information is obtained about everyone who is described." (Fowler, 2014)
2) Probability sampling enables one to have confidence that the sample is not a biased one and to estimate how precise the data are likely to be. Data from a properly chosen sample are a great improvement over data from a sample who attend meetings, speak loudest, write letters, or happen to be convenient to poll. (Fowler, 2014)

Survey Formulation Methodology

The researcher used the results of the literature review to formulate a survey to be sent to aircraft maintenance officers with CAF maintenance experience. The purpose of this survey was to query the maintenance experts who actually use the sanctioned metrics in the management of their organizations to:

1. Explore the utility of the balanced scorecard framework for use in a Maintenance Group
2. Explore the optimal frequency of metrics analysis at each maintenance management level
3. Evaluate the "goodness" of individual maintenance metrics

The survey was a cross-sectional design that gathered descriptive data at one fixed point in time, and asked 38 questions. These questions included demographic questions, closed-ended questions, multiple and single-response questions, Likert-scale questions, and Multiple-rating matrices, dynamic probing as well as open-ended questions.

Demographics

The first section of the survey asked for the survey respondent's rank, type of experience and level of experience to establish demographics of the respondents. This demographic data was used as background information and to differentiate, analyze, trend and map data survey responses in different ways.

Strategic Objective

The purpose of the second section of the survey was to determine the over-arching strategic objective of a typical Maintenance Group.

Maintenance Group Balanced Scorecard Perspectives

The survey then began to explore the structure of the Maintenance Group Balanced Scorecard.

Customer Perspective

To establish the structure for the Customer Perspective, the survey asked respondents whom the customers are the Maintenance Groups serve to achieve their strategic objective, in terms of providing support, training or services. The potential customers of the Maintenance Group outlined in Chapter II--Aircrew, maintainers, aircraft and equipment--were all offered as options, and the respondent could choose as many as they thought were appropriate.

Processes Perspective

Next, the survey explored the Processes Perspective of the Maintenance Group Balanced Scorecard. The researcher listed the 10 processes outlined previously, and asked the respondents to rate the relative importance of each process in providing for the customer that the respondent had previously identified. The survey continued on to ask the respondent which of those same processes they believe the Maintenance Group has an impact on. At this point, the researcher asked respondents to assign metrics from the cumulative sanctioned metrics list in Appendix C to each of the 10 processes. The researcher also asked respondents if they felt the set of metrics they assigned to each process were adequate, and if not, to list and suggest metrics that may be more adequate to communicate the desired information.

Readiness Perspective

The next section examined the Readiness Perspective of the Maintenance Group Balanced Scorecard. The purpose of this section was to identify the metrics that best depict the readiness of Maintenance Group entities. The survey outlined the three entities of the Maintenance Group--aircraft, maintenance personnel, and equipment--and asked the respondents to choose from the existing set of metrics which best depict the readiness of each entity. The researcher also asked respondents if they felt the set of metrics offered and chosen were adequate, and if not, to suggest more adequate metrics to portray readiness.

Workforce Quality Perspective

The last portion of the Maintenance Group Balanced Scorecard part of the survey addressed the Workforce Quality Perspective. The purpose of this section of the survey was to identify the metrics that best depict the quality and skills of maintainers. The researcher outlined six indicators of Workforce Quality for the respondents, and asked the respondents to identify appropriate metrics to portray each of those indicators from the existing set of metrics.

Balanced Scorecard utility and frequency

The purpose of the next section was to determine the utility of the Maintenance Group Balanced Scorecard, and the optimal frequency of analysis of the metrics in each perspective. The survey asked respondents to assess the benefit of examining metrics representing each perspective in the same setting, in order for the researcher to determine field support or opposition of the concept. The researcher also asked respondents what

they felt the optimal frequency of analysis would be for the Maintenance Group Balanced Scorecard approach.

Efficacy of individual metrics

The last section of the survey asked respondents to evaluate 28 individual maintenance metrics based on their experience utilizing and analyzing metrics. The survey asked respondents to select every metric they believe is not "good" for any reason, and then asked them to explain their reason for each metric selected.

Institutional and Air Force Approval

The researcher applied for Institutional Review Board exemption from human experimentation requirements, since the survey did not collect sensitive data, which could reasonably damage the subjects' financial standing, employability, or reputation. The demographic data collected also could not map a given response to a specific subject. This exemption was received through Air Force Institute of Technology review board on 18 December 2014.

The researcher applied for a survey control number, which is required by Air Force Instruction 38-501, *Air Force Survey Program*, and received control number AF14-123AFIT on 5 February 2014.

Population and Sample

As this research was focused on Maintenance Metrics for use in a CAF Maintenance Group, the population for this research are all members of a CAF Maintenance Group who use maintenance metrics to aid in decision making and assess the performance of their organization, equipment, aircraft or personnel. This population includes officers, enlisted, contract or government civilians who are involved in

Maintenance Group operations, including members of the Maintenance Group, Operations Group, and support agencies.

The researcher elected to use Maintenance Officers in the grade of O-1 through O-6 as the sample frame of the population. These ranks typically serve at the Maintenance Group level, and most directly apply the knowledge gleaned from maintenance metrics analysis. Maintenance Officers in a Maintenance Group serve in leadership roles that regularly interact with other decision-makers that comprise the population described above, therefore, have a solid understanding of how metrics are used by and affect the entire population. Maintenance Officers are charged with understanding the big picture of Maintenance Group operations, and typically study, analyze and brief maintenance metrics in detail on a regular basis.

In order to collect data from this sample, manpower data was collected from Headquarters Air Force Force Development Branch that listed 1,406 Air Force Aircraft Maintenance Officers in the grade of O-1 through O-6; however, the target population was actually a sub-category of maintenance officers who had experience in CAF flying wings.

Testing and Administration

Pre-Test

The survey was pre-tested by nine participants over six rounds of pre-testing. A pre-test process was conducted to ensure item specificity, readability, representativeness and face validity. In each round, nine individuals participated to complete the survey and provide feedback about any procedural or production problems (Dillman, 2007). All nine

participants were Maintenance Officers with CAF experience, which made them potential respondents as well, and included two PhDs, two graduate students, and five Maintenance Officers currently assigned to CAF flying wings. All nine that were asked to take the survey participated, for a response rate of 100%. Throughout the pre-test process, the survey was edited for grammar, content, and structure and resubmitted to participants until the survey was deemed satisfactory.

Pilot Test

The survey was sent to 51 individuals during the pilot test, who were all part of the sample frame described above. Out of the 51 asked to complete the survey 27 responded, for a response rate of 53%. All pilot test responses were complete and therefore added to the data gathered from live survey implementation.

Survey Administration

The Maintenance Metrics survey, administered online from 10-20 February 2014, targeted Aircraft Maintenance Officers with experience in the CAF at the flying wing and Maintenance Group level. The purpose of and directions for the survey, authority for the survey, as well as a guarantee of confidentiality and voluntary participation statement accompanied the invitation for survey completion sent by E-mail to each potential participant.

Survey Reliability and Error

Reliability

To test the reliability of the survey, the researcher used the test-retest method, which asks respondents to complete the survey at two different points in order to measure how stable the responses are. The researcher sent a pared-down version of the final

survey, which consisted of 16 questions, to eight survey respondents who had taken the original survey one week prior. The researcher then calculated the correlation coefficient between the responses on the two tests using the Gamma statistic. The researcher chose the Gamma statistic to measure reliability because of the ranked ordinal nature of the survey response data, with a small number of response categories. An obtained value of +1 for gamma indicates the presence of a perfect correlation between two variables, and an obtained value of -1 for gamma indicates the presence of a perfect negative correlation (Harding University, 2014). The following equation depicts the calculation for the Gamma statistic:

Equation 1: Gamma Statistic formula

$$G = \frac{N_a - N_i}{N_a + N_i}$$

N_a = Number of Agreements

N_i = Number of Inversions

To determine the significance of the Gamma statistic, a z-score is calculated based upon formula in Equation 2. The obtained value for the z-score will then be compared to the critical values of z to determine if the correlation is statistically significant. The critical value for z at the .05 significance level is +1.96.

Equation 2: Gamma Statistic z-score formula

$$z = G\sqrt{\frac{N_a - N_i}{N(1-G^2)}}$$

N_a = Number of Agreements

N_i = Number of Inversions

N = Number of Cases

The calculation for the Gamma statistic was based on 1527 agreements and 79 inversions between the variables (Variable 1=test responses, Variable 2=retest responses), and was calculated at .902, indicating a high correlation between variables, as see in Equation 3:

Equation 3: Gamma Statistic result

$$G = \frac{N_a - N_i}{N_a + N_i} = \frac{1527 - 79}{1527 + 79} = \frac{1,448}{1,606} = .902 = G$$

N_a = Number of Agreements = 1527

N_i = Number of Inversions = 79

The researcher calculated the z-score to be 1.979, as shown in Equation 4, which fell within the .05 significance level critical value of +/- 1.96. This means the results between the two tests were found to be statistically significant, and therefore found the survey to be reliable.

Equation 4: Gamma statistic z-score results

$$z = .902\sqrt{\frac{1448}{300.45}} = .902 * 2.195 = 1.979 = z$$

N_a = Number of Agreements =1527

N_i = Number of Inversions=79

N = Number of Cases=1606

Sampling Error

The first type of error the researcher addressed was sampling error. "Sampling error is the degree to which the results from the sample deviate from those that would be obtained from the entire population, because of random error in the selection of respondent and the corresponding reduction in reliability" (Alreck & Settle, 2004).

Given the population size of Maintenance Officers, the researcher determined that to minimize sampling error and maximize reliability in the respondent results, she would strive to achieve a 95% confidence level, with a confidence interval of plus or minus 5%. Based on these sampling error goals, the desired sample size, or the number of maintenance officer responses needed, was 302. Since it was impossible to discern from the manpower data collected which of the 1,406 maintenance officers met the eligibility criteria of CAF experience, the survey was sent to a sample frame of the population (O-1 to O-6), and used demographic data from the respondents to determine who met the criteria for the subpopulation. The researcher considered only the responses of officers with CAF experience during data analysis.

Non Sampling Error

Non-Response Bias

"Non-response bias refers to the mistake one expects to make in estimating a population characteristic based on a sample of survey data in which, due to non-response, certain types of survey respondents are under-represented" (Berg, 2005). Since the sample frame of the survey was limited to Maintenance Officers in the grades of O-1 through O-6, it is possible that results were affected by non-response bias, or bias incurred because other members of the population were not surveyed. Members of the population who were not surveyed include enlisted, contract or government personnel, and members of the Operations Group and support agencies who may utilize maintenance metrics. Maintenance Officers in grades higher than O-6 also have experience in Maintenance Groups, but were not surveyed.

Response Bias

Another threat to validity of the survey responses was respondent fatigue. Respondent fatigue occurs when people taking the survey are affected by boredom or lack of motivation to accurately answer the questions (Lavrakas, 2008). The researcher observed that only half of respondents who began the survey actually completed it, which could have been the result of respondent fatigue. Incomplete surveys were not considered valid for data analysis and those responses discarded, but there is a possibility that the remaining valid survey responses were not a representative sample o the population. There is also a possibility that answers that were considered valid were actually affected by respondent fatigue; however, these cases were not as easy to identify. When constructing the survey, the researcher made length of the survey as short as possible without losing the integrity of data being gathered; however, the survey was 38 questions long and could have still introduced respondent fatigue despite the researchers attempt to avoid it.

Response rate

The researcher calculated the response rate by dividing the number of people who submitted a completed survey (80% or more of questions answered) by the number of people she contacted or attempted to contact to complete the survey. As previously addressed in Chapter III, the researcher used the manpower data collected from Headquarters Air Force Development Branch to determine a sample frame size of 1,406 Air Force Aircraft Maintenance Officers in the grade of O-1 through O-6; however, the target population was actually a sub-category of Maintenance Officers who had experience in CAF flying wings. The researcher first sent the survey to the population

sample frame of 1,406 officers on 11 February 2014 and followed up with a subsequent invitation on 18 February 2014. The survey invitation failed to reach nine members, so the population sample frame was adjusted to a 1,397 "solicited population" as depicted in the "solicited population" column shown below. Of the 1,397 Maintenance Officers in the solicited population, 675 initiated the survey, with 361 completing it for a 54% completion rate, and a 26% total response rate. Of the 352 completed surveys, 309 of the officers indicated they had CAF experience for a subcategory response rate of 22%. These 309 responses from the target sub-category were used in the researcher's data analysis. The completion rate, response rate and CAF experience rate by respondents is depicted in Table 1.

Table 1: Survey Response Rates

Rank	Sample Frame Population	Solicited Population	Total Started Survey	Total Completed Survey	Completion rate	Response Rate	CAF Experience	% of Resp
2Lt	118	118	43	23	53.5%	19.5%	11	9.3%
1Lt	175	174	70	35	50.0%	20.1%	23	13.2%
Capt	397	396	188	105	55.9%	26.5%	89	22.5%
Maj	306	306	167	81	48.5%	26.5%	78	25.5%
LtCol	291	286	144	83	57.6%	29.0%	75	26.2%
Col	119	117	63	34	54.0%	29.1%	33	28.2%
Total	1406	1397	675	361	53.5%	25.8%	309	22.1%

Demographics

The first section of the survey asked for the survey respondent's rank, type of experience and level of experience to establish demographics of the respondents. This demographic data, as shown in Table 2, is used as background information and to differentiate, analyze, trend and map data survey responses in different ways. The demographic data reveals that the majority of the survey respondents were in the ranks of

O-3 through O-5. Almost 50% of the respondents held positions in the Maintenance Group (AMU OIC, AMXS Operations, Squadron Commander, Deputy or Group Commander) that actually have direct ownership/authority over aircraft maintenance and aircraft maintainers. Over 50% of the respondents have great than 6 years in a CAF flying wing. Over 60% have between 6 and 20 plus years analyzing/reporting maintenance metrics and 75% had between 6 and 20 plus years experience in the aircraft maintenance arena. The demographic data lends credibility to the information and opinions captured because the largest proportion of respondents operate or have operated in aircraft maintenance for a sufficient amount of time to be considered experts in positions most relevant to the aircraft maintenance profession.

Table 2: Demographics

1. What is your rank?		
Answer Options	Response %	Response Count
2Lt (O-1)	3.6%	11
1Lt (O-2)	7.5%	23
Captain (O-3)	28.9%	89
Major (O-4)	25.0%	77
LtCol (O-5)	24.4%	75
Colonel (O-6)	10.7%	33
2. Which most closely describes your current MAJCOM (or equivalent)?		
Answer Options	Response %	Response Count
ACC	24.0%	74
AETC	11.7%	36
AFGSC	5.2%	16
AFMC	13.3%	41
AFR	0.6%	2
AFSC	0.0%	0
AFSOC	3.9%	12
AMC	12.7%	39
ANG	0.3%	1
Direct Reporting Unit (DRU)	1.9%	6
DLA	0.3%	1

Table 3: Demographics

Forward Operating Agency (FOA)	0.0%	0
HAF	3.9%	12
PACAF	9.4%	29
USAFCENT	3.2%	10
USAFE	4.9%	15
Other (please specify)	4.5%	14
3. What is the management level of your current position?		
Answer Options	Response %	Response Count
Flight Commander	3.9%	12
AMU OIC	12.8%	39
EMS/CMS/MXS/Muns/MOS Operations Officer	5.3%	16
AMXS Operations Officer	8.9%	27
Squadron Commander	14.5%	44
Deputy or Group Commander	14.8%	45
MAJCOM	7.9%	24
Depot	2.3%	7
Other (please specify)	29.6%	90
4. How many years of experience do you have in Aircraft Maintenance?		
Answer Options	**Response %**	**Response Count**
Less than 1 year	1.0%	3
1-3 years	8.8%	27
4-6 years	11.4%	35
6-10 years	15.9%	49
10-15 years	15.6%	48
15-20 years	19.8%	61
20+ years	27.6%	85
5. How many years of experience do you have in a Combat Air Forces (CAF) flying wing?		
Answer Options	**Response %**	**Response Count**
None	0.0%	0
Less than 1 year	4.2%	13
1-3 years	25.3%	78
4-6 years	19.5%	60
6-10 years	22.7%	70
10-15 years	15.9%	49
15-20 years	6.8%	21
20+ years	5.5%	17
6. What levels of maintenance have you managed? Please select all that apply.		
Answer Options	**Response %**	**Response Count**
Flight Commander	96.1%	296
AMU OIC	89.9%	277

Table 4: Demographics

EMS/CMS/MXS/Muns/MOS Operations Officer	62.0%	191
AMXS Operations Officer/Squadron Maintenance Officer (SMO)	59.4%	183
Squadron Commander	48.7%	150
Deputy or Group Commander	23.1%	71
MAJCOM	26.0%	80
Depot	24.0%	74
Other (please specify)	14.3%	44
7. How much experience do you have analyzing or reporting maintenance metrics?		
Answer Options	**Response %**	**Response Count**
Less than 1 year	3.6%	11
1-3 years	12.4%	38
4-6 years	19.5%	60
6-10 years	20.8%	64
10-15 years	21.5%	66
15-20 years	13.7%	42
20+ years	8.5%	26

Data Preparation

Data Inspection

The researcher inspected the data for errors that could have occurred during data entry or errors resulting from respondents' inconsistent answers. The most conspicuous errors the researcher searched for were incomplete survey responses, which were not considered in the analysis.

Closed-ended survey responses

The researcher imported closed-ended survey responses into Excel to perform descriptive statistical analyses, response rates, and frequencies. Close-ended survey responses were coded using pre-weighted Likert scales (1=Strongly Disagree to 5=Strongly Agree), or used binary yes/no responses.

Open-ended Survey Responses

The researcher used a coding mechanism to organize content and reveal trends or patterns in open-ended survey responses. The coding mechanism entailed categorizing responses and assigning a numerical code to each category, then entering into excel for further statistical analysis such as frequency distribution, central tendency, and variability.

Survey Analysis Methodology

Statistical Analysis

The researcher used a three-part process to analyze the metrics that respondents assigned to perspective categories,

First, the researcher applied an initial filter of metrics to consider under each Balanced Scorecard. The mean and standard deviation of metric selections under each perspective category were calculated to perform this filter. Chebyshev's Rule in statistics states that no useful information is provided on the fraction of measurements that fall within one standard deviation of the mean (McClave, et al., 2011). Therefore, any metrics that garnered enough selections to fall above one standard deviation from the mean number of responses were considered for inclusion in the Maintenance Group Balanced Scorecard, while any metrics that fell below the one standard deviation standard were excluded.

Next, the researcher determined that a 50% selection rate for a metric assignment to a perspective category was the minimum threshold for consideration--if a metric had less than 50% of respondents who assigned it to the process under review, it was

eliminated from consideration for inclusion to the scorecard (Warr, 2014). This filter eliminated most illogical and unrelated metric and perspective category combinations, such as Abort Rate assignment to the Equipment Maintenance Scheduling Process. This filter also prevented metrics from being selected that met the one standard deviation from the mean criteria described above, but were part of a data set with too low an average and standard deviation to be meaningful for this study.

Finally, the researcher analyzed the data that indicated the respondents' feelings on whether the available metrics adequately measured the efficiency and effectiveness of the perspective categories under consideration. Four data permutations were possible when comparing respondents' feelings regarding metric adequacy data, and the actual metrics assignment data:

1. Respondents felt the metrics presented were adequate, and at least one metric fell above one standard deviation from the mean
2. Respondents felt measures were adequate, but no measures fell above one standard deviation from the mean
3. Respondents felt measures were inadequate, but at least one measure fell above one standard deviation from the mean
4. Respondents felt measures were inadequate, and no measures fell above one standard deviation from the mean.

If the results fell into any of these categories with the exception of first, the researcher would perform additional Content Analysis using respondents' comments relating to these metrics and processes.

Content Analysis and Qualitative Validity

The researcher opted to use an open-ended question to let respondents state, in their own words, what problems they had with individual metrics, providing them "freedom in framing the answers" (Weisberg & Bowen, 1977, p. 49). Providing this type of freedom required coding to organize content and properly analyze and trend the responses. The researcher used manifest coding to evaluate the substance of the respondent's answer to a question when responses did not meet one of both criteria listed above. To develop the manifest codes for the open-ended questions, the researcher used a mix of the theoretical approach and the contextual approach.

The theoretical method develops codes based on expected answers, which the researcher used in the analysis of efficacy of individual metrics (Weisberg & Bowen, 1977). The researcher used the Caplice and Sheffi metrics evaluation criteria discussed in Chapter II as the theoretical method to code these open-ended responses into one of the eight criterion categories.

For perspective category coding, the researcher used the contextual method. This approach codes answers based on responses received, which was of utility to the researcher since there were no preconceptions about the answers she would receive to open-ended questions through the majority of the survey. (Weisberg & Bowen, 1977). The researcher first sought to classify and trend respondents' issues with available metrics; based on respondents' answers, the researcher developed the following categories:

1. Not classifiable
2. Don't need to track

3. No metrics available but should be
4. Metrics available and looked at MXG level but not listed as choices
5. Metrics Available from external sources but not visible to MXG
6. Metrics available from internal sources but not looked at MXG level
7. Metrics available but are inadequate

The researcher then sought to classify and trend proposed metrics by respondents. The classifications for proposed metrics were unique to the perspective category in question.

To ensure validity of the coding process, the researcher first independently analyzed comments for the perspective categories that required additional analysis, and then utilized an external auditor to review the qualitative study and provide an objective assessment of the coding (Lincoln & Guba, 1985). The researcher and external auditor reviewed and discussed respective individual coding results. A comparison of the individually coded items by the researcher and the external auditor resulted in a confirmation rate of 92%.

Correlation Analysis

The researcher performed a correlation analysis to examine the relationship between perspective categories and the selection of metrics used to represent each category. Correlation analysis is to measure the linear relationship or association between defined variables; the resulting correlation coefficient (r or rho) indicates how closely the data fit a linear pattern. A positive correlation coefficient indicates that an increase in one variable corresponds to an increase in the other variable, implying a relationship between the two. A negative correlation indicates the opposite; when one variable increases, the other decreases (Taylor, 1990). Correlation coefficient values fall

between -1 and 1. Values falling under 0.35 are generally considered to represent low or weak correlations, and values falling from 0.36 to 0.67 are considered modest or moderate correlations. Values falling between 0.68 and 1.0 can be considered strong or high correlations and values greater than 0.90 can be considered very high correlations (Taylor, 1990).

A correlation coefficient (r) was used to examine the relationship between perspective categories with regard to selection of metrics used to represent each category. A high correlation coefficient when comparing two perspective categories indicates strong agreement of same metrics selected to measure those categories, while a low correlation coefficient indicates weak agreement among the choice of metrics selected. This information can assist in determining if perspective categories selected are redundant in nature and should be eliminated from the Maintenance Group Balanced Scorecard, or if available metrics should be tailored to better measure the unique purposes of each perspective category in question.

JMP 10.0 provided the correlation analysis. The data was normalized by converting raw number of responses into percentages of total respondents per perspective category, since the total number of respondents differed from category to category. Each pair of perspective category entries were placed in a scatterplot, and a best fit regression line used to indicate the degree of correlation between the two perspective categories under consideration. For example, the regression line of the plot of perspective categories A and B in Figure 8 (y = -.1397, x + .4302) shows two perspective categories with a relatively low slope angle (m = -.13), or correlation.

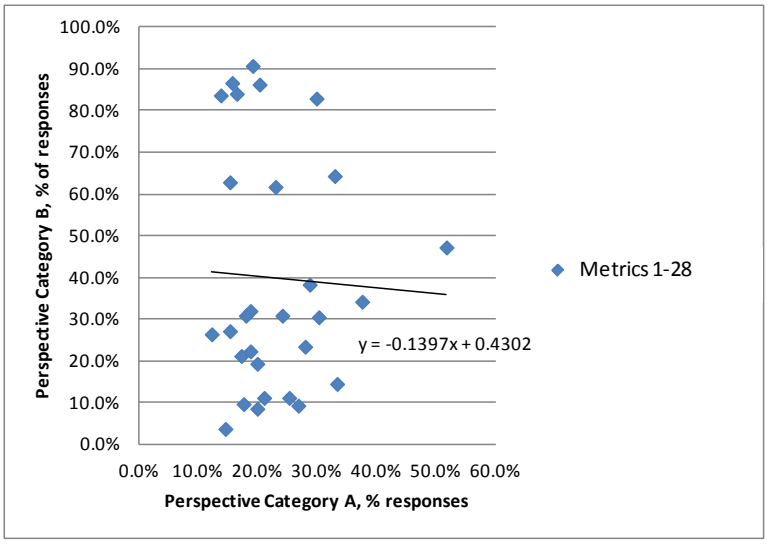


Figure 8: Example Perspective Category Regression Plot

A high correlation coefficient between two perspective categories indicates a high agreement of votes for the metrics selected to measure those categories. A low correlation coefficient indicates a low agreement of votes for the metrics selected to measure them. As outlined in Figure 7, the 19 perspective categories were:

1. Flying Scheduling Process
2. Flying Execution Process
3. Aircraft Maintenance scheduling process
4. Aircraft Maintenance execution process
5. Equipment Maintenance scheduling
6. Equipment Maintenance execution
7. Maintenance Training Scheduling
8. Maintenance Training Execution
9. Aircrew Mission/ Training scheduling
10. Aircrew Mission/ Training execution

11. Maintainer readiness

12. Aircraft readiness

13. Equipment readiness

14. Maintenance quality

15. Maintenance safety

16. Maintainer skill level

17. Maintainer experience level

18. Maintainer Discipline

19. Maintainer Retention

For the 171 combination pairs of 19 perspective categories, the researcher determined that any r-value that fell above .68 would be further analyzed, as values in that range are generally considered high correlations.

While it is true that metrics are designed to intertwine and can be used to corroborate concerns rising from other metrics and therefore should be correlated, the researcher sought to identify high correlations where they shouldn't logically exist. For example, an extremely high correlation--or nearly exact selections of metrics and magnitude of those selections--indicates either the right mix of metrics is not available to portray the desired information, or the suggested perspective categories under consideration are redundant. This information can substantiate the previously performed statistical and Content Analysis, and assist in determining if a perspective category should be eliminated from the Maintenance Group Balanced Scorecard, or if available

metrics should be tailored or added to better measure the unique purposes of each perspective category in question.

IV. Results and Analysis

Overview

In this chapter, the researcher will first present the findings from the survey research relating to the Maintenance Group Balanced Scorecard, and the Perspectives and metrics contained therein. The researcher will present the results of the statistical analysis, content analysis and correlation Analysis, as well findings on the efficacy of individual metrics to refine the proposed Maintenance Group Balanced Scorecard presented in Chapter III.

Statistical Analysis

Strategic Objective

The first survey question sought to answer the researcher's first research question, what is the general strategic objective of a Maintenance Group? When asked what their assessment of the statement, "The primary strategic objective of a CAF Maintenance Group is to maintain air and space equipment in a safe, serviceable and ready condition to facilitate mission-readiness of the flying wing", 97% of the respondents indicated that they agreed or strongly agreed with this statement. The comments following this question established the foundation for the Balanced Scorecard, and helped to clearly define which customers must be served to achieve the strategic objective, and the critical processes required to serve those customers. Over 25% of respondents added that while the definition was mostly correct, CAF units do not work with space assets, and noted the lack of mention of personnel. For this reason, the researcher refined the general strategic objective of the Maintenance Group to read, "Maintain aircraft, equipment and personnel

in a safe, serviceable and ready condition to facilitate the mission-readiness of the flying wing."

Maintenance Group Balanced Scorecard perspectives

With the strategic objective clearly identified by the respondents, the survey then began to further explore the structure of the Maintenance Group Balanced Scorecard that includes the Customer Perspective, Process Perspective, Readiness Perspective and the Workforce Quality Perspective. As previously discussed, these perspectives provide specific answers to simple questions that keep an organization on task to excel at specific processes to benefit a clearly defined customer.

Customer Perspective

To clarify and solidify the structure for the Customer Perspective, the survey asked respondents whom the customers are the Maintenance Groups serve to achieve their strategic objective, in terms of providing support, training or services. With maintainers, Aircrew, aircraft and equipment as their options, 88% of the respondents stated that the Maintenance Group should view the Aircrew as customers, and 50% of the respondents stated that the Maintenance Group should view maintainers as customers. Although a little more than half the population considered maintainers as customers, the number of positive responses did not fall above one standard deviation from the mean number of responses for all processes, and therefore was deemed insignificant. Figure 9 shows the breakdown of responses on who the customer is the Maintenance Group provides for. As there was a clear preference indicated by respondents, and that preference met the filter and standard deviation criteria, no Content Analysis was required to substantiate these findings.

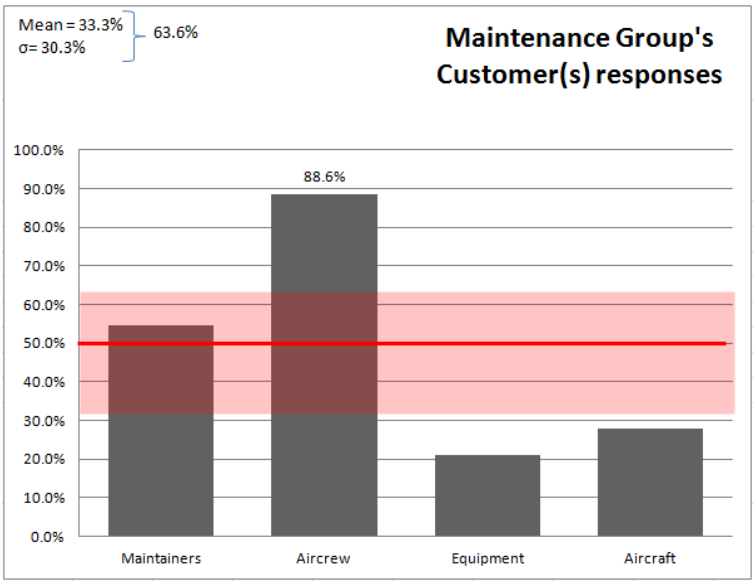


Figure 9: MXG's Customer(s) Responses

Process Perspective

The identification of the Aircrew as the Customer was used as the point of reference when identifying the Maintenance Group's critical processes in providing for customers. In the survey, the researcher listed the 10 processes outlined in Chapter II and asked the respondents to rate the relative importance of each process in providing for the Aircrew as the customer. Figure 10 depicts that nearly 80% of respondents of the 272 respondents felt that Aircraft Flying Scheduling and Execution were critical processes in providing for the Aircrew as the customer. Aircrew Mission/Training Scheduling and Execution also fell above one standard deviation of the average number of responses for all processes and were included as critical processes for serving Aircrew as the customer as well. These processes will be classified under the Customer Perspective of the Maintenance Group Balanced Scorecard as they most critically affect the customer.

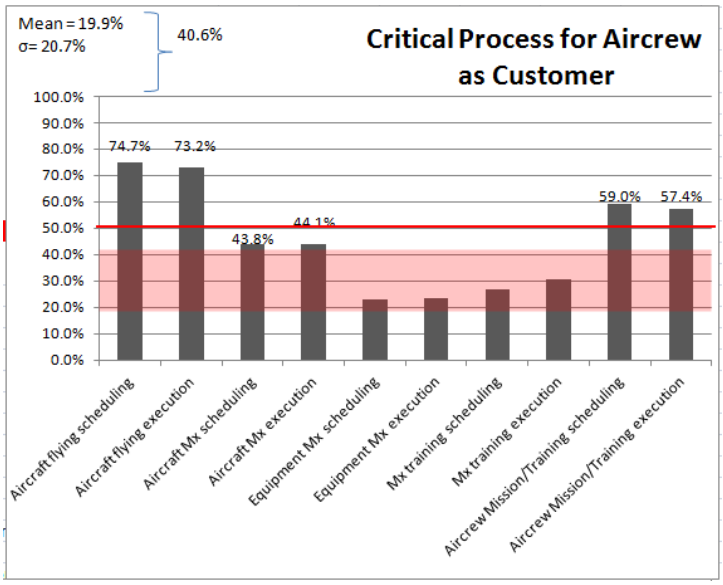


Figure 10: Critical Processes for Aircrew as Customer

Aircraft Maintenance Scheduling and Execution, Equipment Maintenance Scheduling and Execution, and Maintenance Training Scheduling and Execution will therefore be considered Internal processes; although these processes do not directly impact the Aircrew as the customer according to respondents, these processes indirectly provide for the Customer; about 60% of respondents classified these processes as "important or moderately important" (Figure 11).

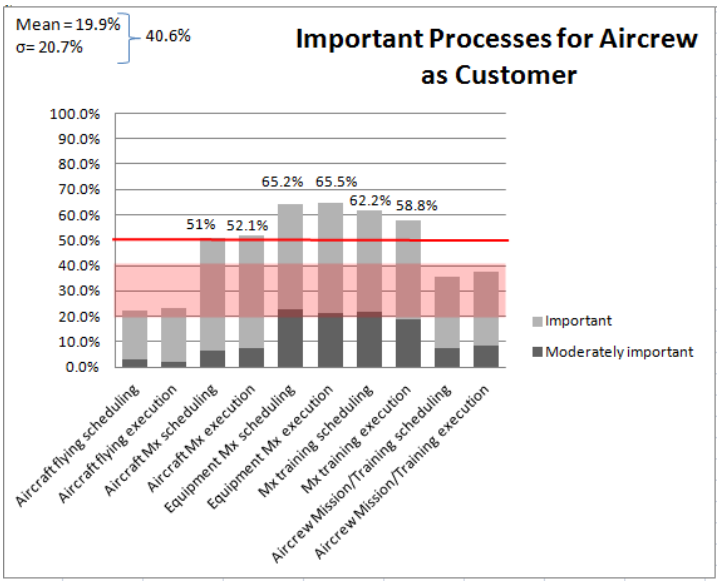


Figure 11: Important Processes for Aircrew as Customer

Since the Customer of the Maintenance Group (Figure 9), the Critical Processes for that customer (Figure 10) and Important Internal Processes (Figure 11) have been established, the next step was to assign metrics that best portray the efficiency and effectiveness of those processes.

The survey asked respondents to assign metrics (listed in Appendix C) to each of the ten processes, selecting as many metrics for each process that they deemed appropriate. Appendix H depicts the percentage of respondents who selected each metric for each process.

The next portion will describe the results of this three-part analysis for each of the Process categories as described in the Chapter III. First, the filtering process was applied for metric selection, followed by analysis of respondents' perception of the adequacy of the metrics set for each process. Finally, a content analysis was performed when the

filtering and metric adequacy analysis did not paint a clear picture of what metrics were appropriate to use.

Aircrew Mission/Training Scheduling and Execution

Filtering Process: In the Aircrew Mission/Training Scheduling Process category, only two metrics met the 50% selection rate and fell above one standard deviation from the mean: Flying Scheduling Effectiveness and Average Sortie Duration (Figure 12). The Execution category had four metrics that met the inclusion criteria: Abort rate, Average Sortie Duration, Deviation rate, and Flying Scheduling Effectiveness (Figure 13). Respondents perceived these metrics the most relevant to the Aircrew Mission/Training Scheduling processes and should be considered as part of the Maintenance Group's Balanced Scorecard.

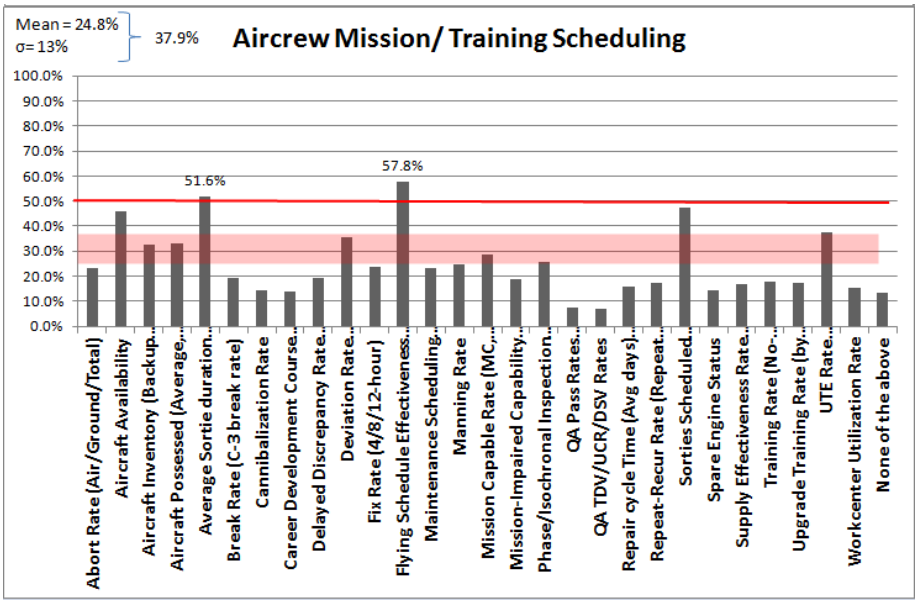


Figure 12: Metric Assignment to Aircrew Mission/Training Scheduling Process

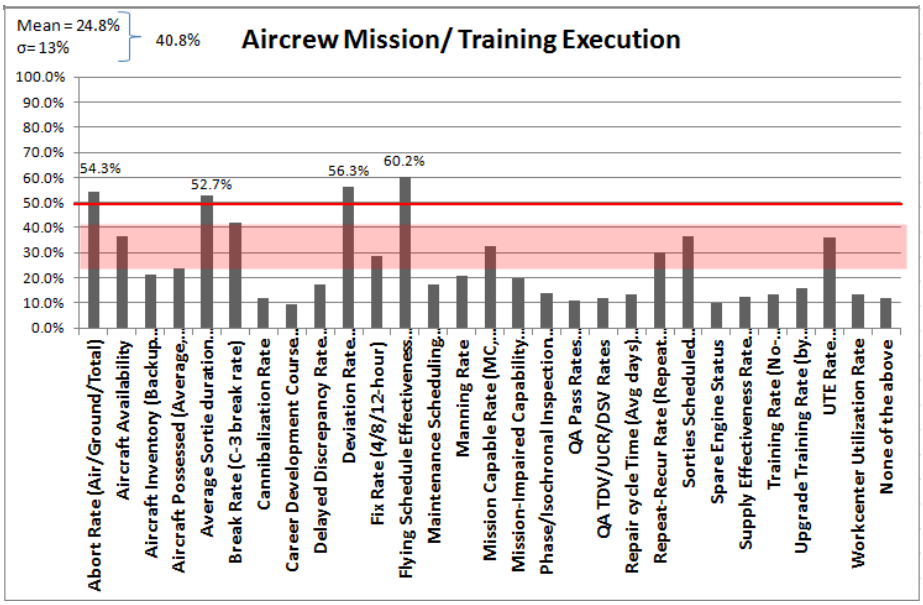


Figure 13: Metric Assignment to Aircrew Mission/Training Execution Process

Respondent analysis of adequacy: Less than 50% of the respondents felt there was adequate measure of the Aircrew Mission/Training Scheduling and Execution processes. (Figure 14).

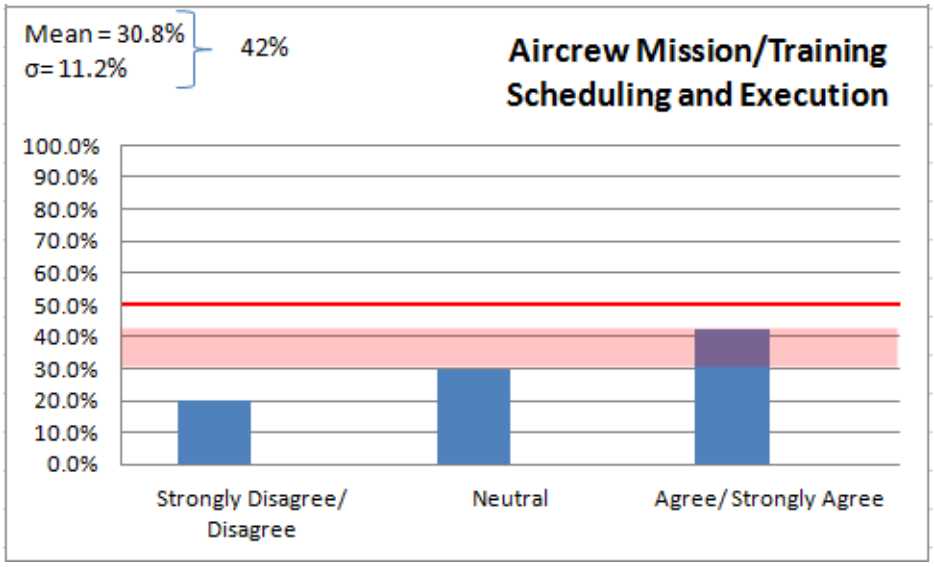


Figure 14: Adequacy of Available Metrics for Aircrew Mission/Training Scheduling Process

Although at least one measure fell above one standard deviation from the mean inclusion requirement, respondents felt measures were inadequate; therefore, content analysis was required to reveal reasons for the perceived inadequacy.

Trend issues with available metrics: Content analysis of comments offered by respondents regarding issues they had with metrics representing the Aircrew Mission/Training Scheduling and Execution Processes overwhelmingly pointed to a lack of visibility of metrics that are studied by the Operations Group that could be of significant value to the Maintenance Group. Comments indicate the need for plainly visible measures for progress toward specific goals for Operations that are discussed in an open forum with Maintenance, so Maintenance is able to see how their processes truly impact Operations schedules. Current metrics do not clearly articulate if there were deviations to scheduled missions, only if there were deviations to the scheduled launch of the sortie. Comments also suggest there is a lack of metrics to understand if Operations is being judicious with the aircraft provided to them, as well as a lack of metrics to be able to substantiate the need for such things as adding sorties or making last minute changes to the schedule. Decisions appear to be assertions based on anecdote and often put Maintenance in a reactive posture. Bottom line, the comments indicate a lack of transparency and understanding in Operation's requirements and exactly how Maintenance impacts them (Figure 15).

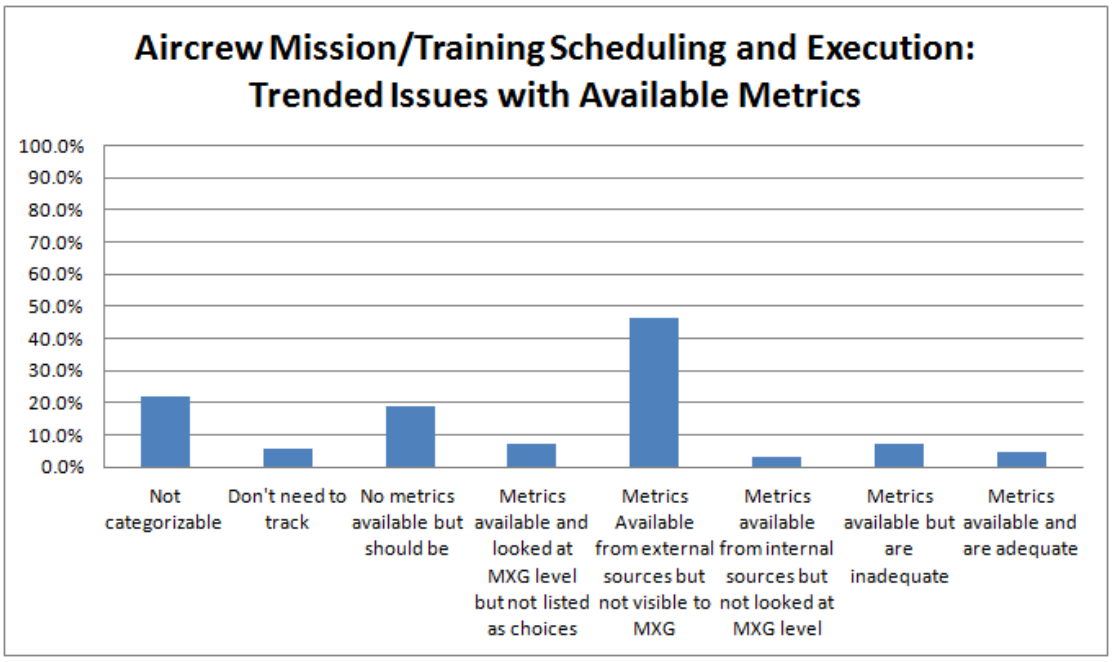


Figure 15: Aircrew Mission/Training Scheduling and Execution Process Metrics Issues

Trend suggested metrics: The majority of respondents pointed to an effectiveness metric as a useful tool in knowing how the Maintenance Group is serving the customer. A Mission Effectiveness Rate yielded the most suggestions by far, to help maintainers to understand with more fidelity if Aircrew accomplished the mission as planned and scheduled. Additional suggestions further refined the Mission Effectiveness Rate; some respondents suggested metrics that articulate thrash in the Aircrew Scheduling Process. For example, a rate that shows deviations between scheduled missions and planned missions, a rate that shows deviations between planned missions and briefed missions, and a rate that shows deviations between briefed missions and flown missions. Deviations to any parts of the Scheduling/Planning/Execution process would be attributed to the responsible agency--similar to traditional Flying Scheduling Effectiveness rate--to understand what is causing thrash to the schedule and why (Figure 16).

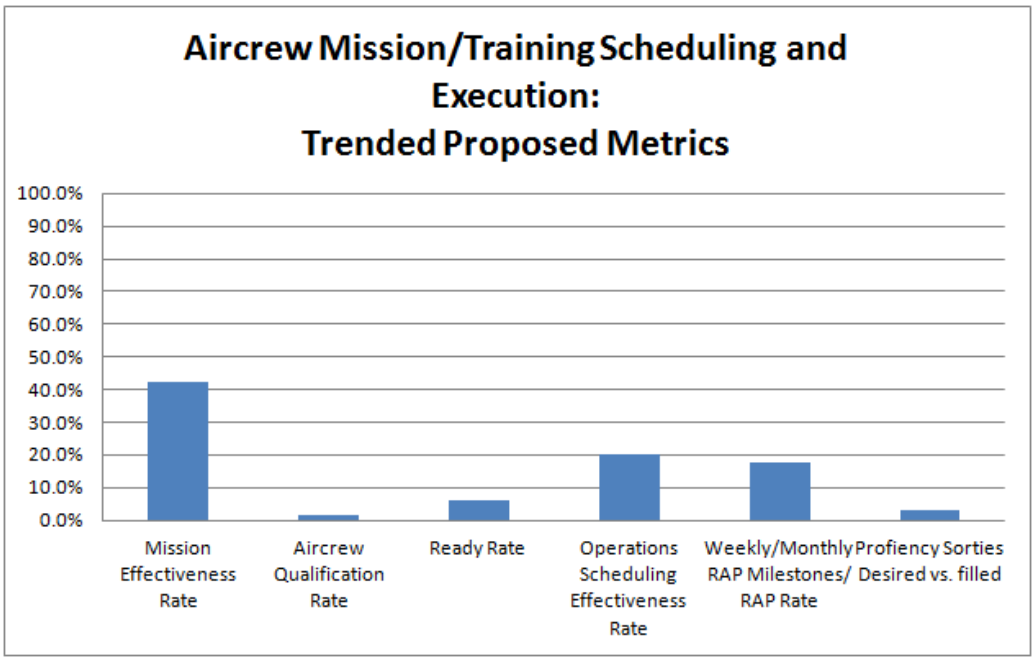


Figure 16: Aircrew Mission/Training Scheduling Process Suggested Metrics

Flying Scheduling and Execution

Filtering Process: Six metrics met the inclusion criteria for the Flying Scheduling Process. These included Aircraft Availability, Flying Scheduling Effectiveness, Maintenance Scheduling Effectiveness, Phase/Isochronal Inspection, Sorties Scheduled and UTE Rate (Figure 17). Five metrics met the 50% selection rate for the Flying Execution Process: Abort Rate, Average Sortie Duration, Break Rate, Deviation Rate and Flying Scheduling Effectiveness (Figure 18). Respondents perceived these metrics as the most relevant to the Aircraft Flying Scheduling and Execution Processes and should be considered as part of the Maintenance Group's Balanced Scorecard.

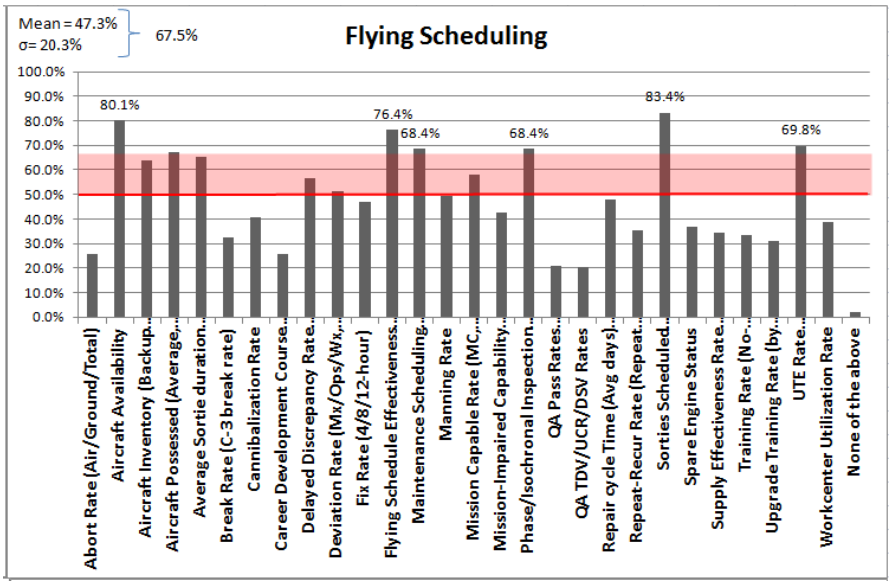


Figure 17: Metric Assignment to Flying Scheduling Process

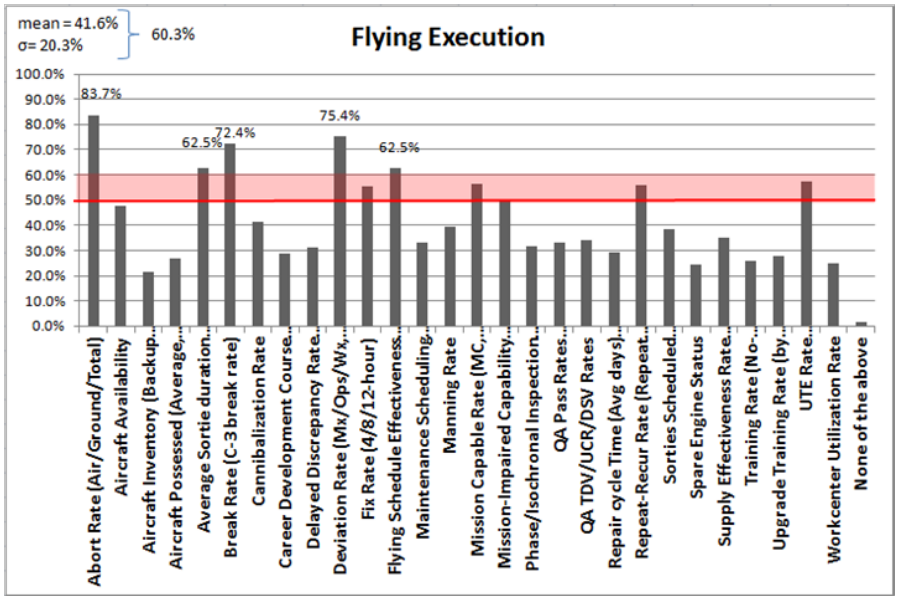


Figure 18: Metric Assignment to Flying Execution Process

Respondent analysis of adequacy: The response rate met both the 50% agreement rate, and exceeded one standard deviation from the mean responses. Approximately 78% of survey respondents indicated the metrics currently available for the Flying Scheduling Process are adequate (Figure 19).

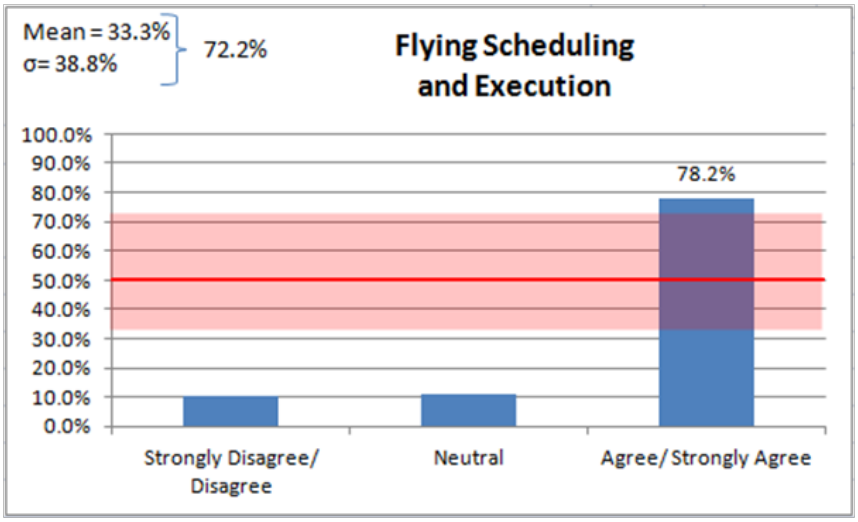


Figure 19: Adequacy of Available Metrics for Flying Scheduling Process

Respondents felt measures were adequate, and at least one measure fell above one standard deviation from the mean--content analysis was not required.

Maintenance Training Scheduling and Execution

Filtering Process: Three metrics for the Maintenance Training Scheduling Process met the inclusion criteria: CDC Pass Rate, Training Rate and the Upgrade Training Rate (Figure 20). Three metrics for the Maintenance Training Execution Process met the inclusion criteria: CDC pass rate, Training Rate and the Upgrade Training Rate (Figure 21). Respondents perceived these metrics the most relevant to the Maintenance Training Scheduling and Execution Processes and should be considered as part of the Maintenance Group's Balanced Scorecard.

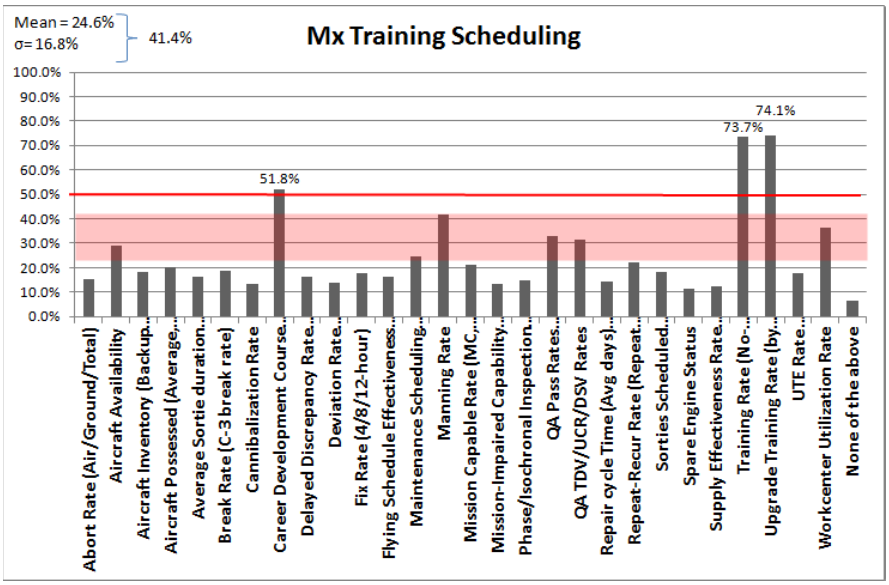


Figure 20: Metric Assignment to Maintenance Training Scheduling Process

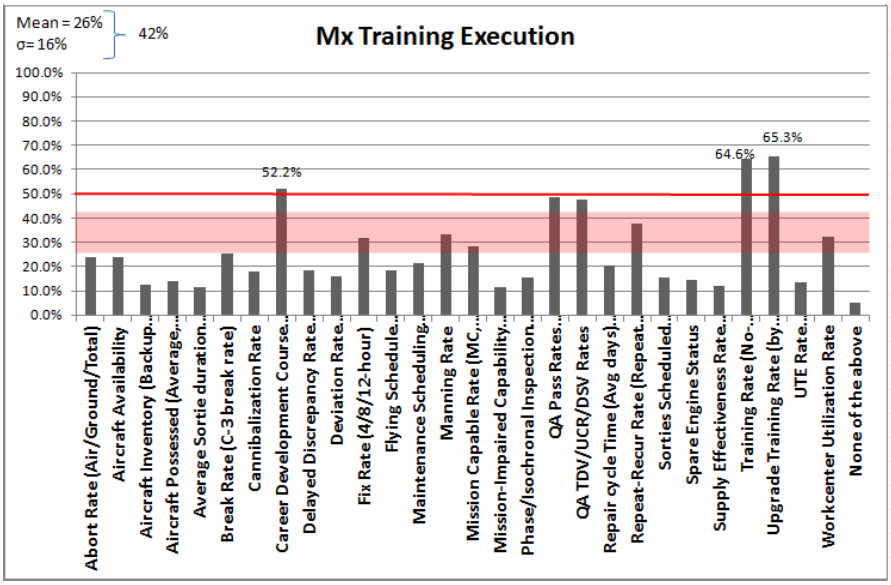


Figure 21: Metric Assignment to Maintenance Training Execution Process

Respondent analysis of adequacy: The response rate met both the 50% agreement rate, and exceeded one standard deviation from the mean responses (Figure 22).

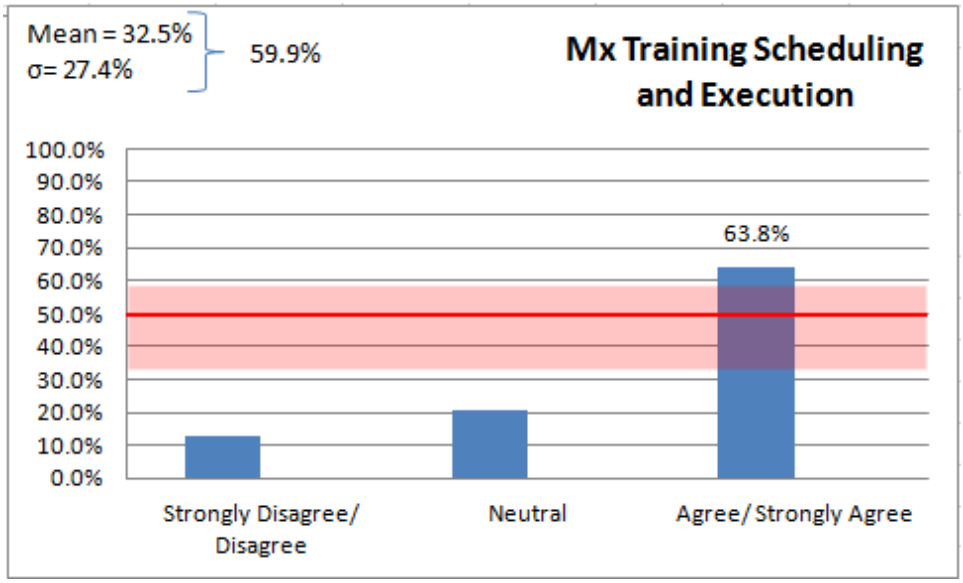


Figure 22: Adequacy of Available Metrics for Maintenance Training Scheduling Process

Respondents felt measures were adequate, and at least one measure fell above one standard deviation from the mean—content analysis not required.

Aircraft Maintenance Scheduling and Execution

Filtering Process: Four metrics met the inclusion criteria for the Aircraft Maintenance Scheduling Process: Aircraft Availability, Delayed Discrepancy Rate, Maintenance Scheduling Effectiveness, and Phase/Isochronal Inspection (Figure 23). Six metrics met the inclusion criteria for the Aircraft Maintenance Execution Process: Abort Rate, Break Rate, Fix Rate, Maintenance Scheduling Effectiveness, Mission Capable Rate, and Repeat/Recur Rate (Figure 24). Respondents perceived these metrics the most relevant to the Aircraft Maintenance Scheduling and Execution Processes and should be considered as part of the Maintenance Group's Balanced Scorecard.

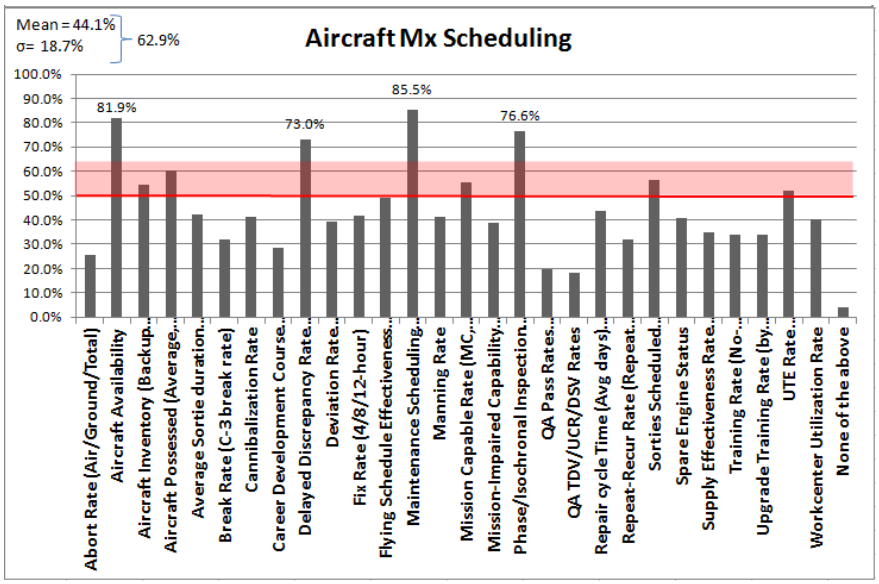


Figure 23: Metric Assignment to Aircraft Maintenance Scheduling Process

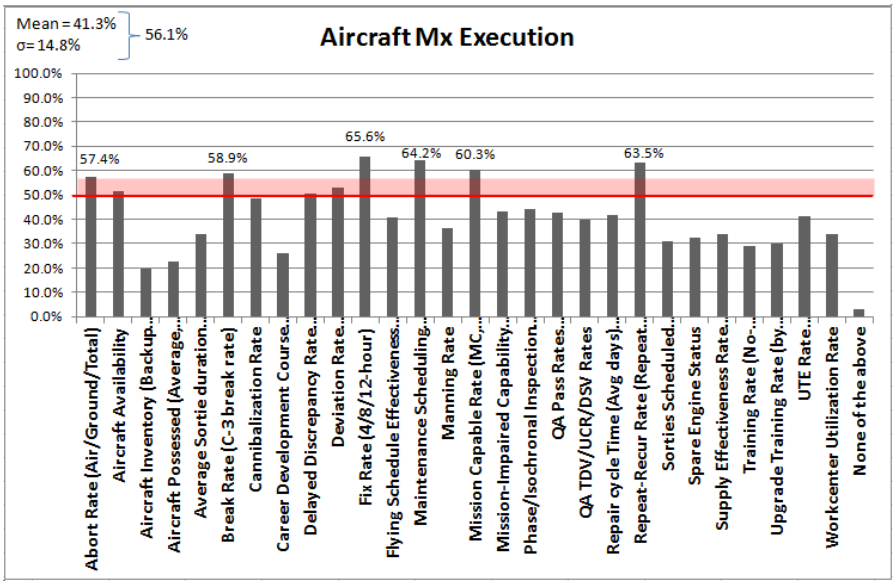


Figure 24: Metric Assignment to Aircraft Maintenance Execution Process

Respondent analysis of adequacy: The response rate met both the 50% agreement rate, and exceeded one standard deviation from the mean responses and indicated 79% of respondents agreed there were adequate metrics for Aircraft Maintenance and Execution (Figure 25).

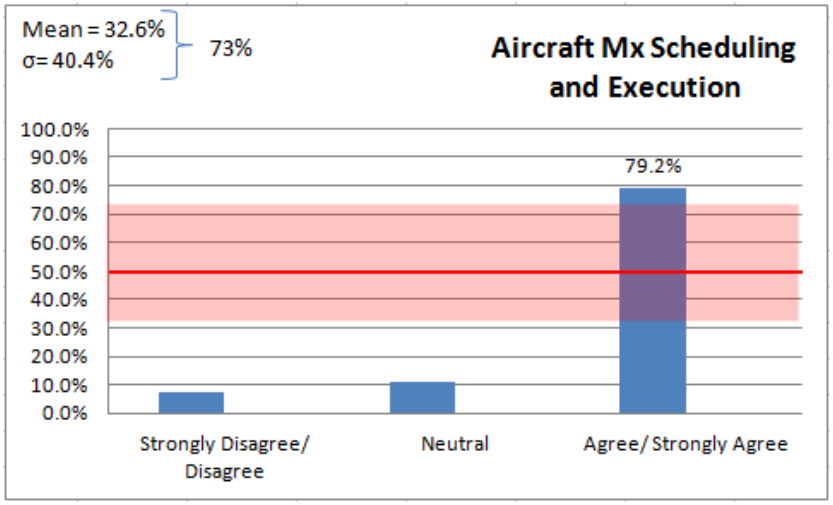


Figure 25: Adequacy of Available Metrics for Aircraft Maintenance Scheduling Process

Respondents felt measures were adequate, and at least one measure fell above one standard deviation from the mean—content analysis not required.

Equipment Maintenance Scheduling and Execution

Filtering Process: Only one metric, Maintenance Scheduling Effectiveness, met the inclusion criteria for the Equipment Maintenance Scheduling Process (Figure 26). The filtering process for the Equipment Maintenance Scheduling and Execution indicates that, although equipment maintenance may be important, the relevance of the metrics is insufficient to be included on a balanced scorecard (Figure 27).

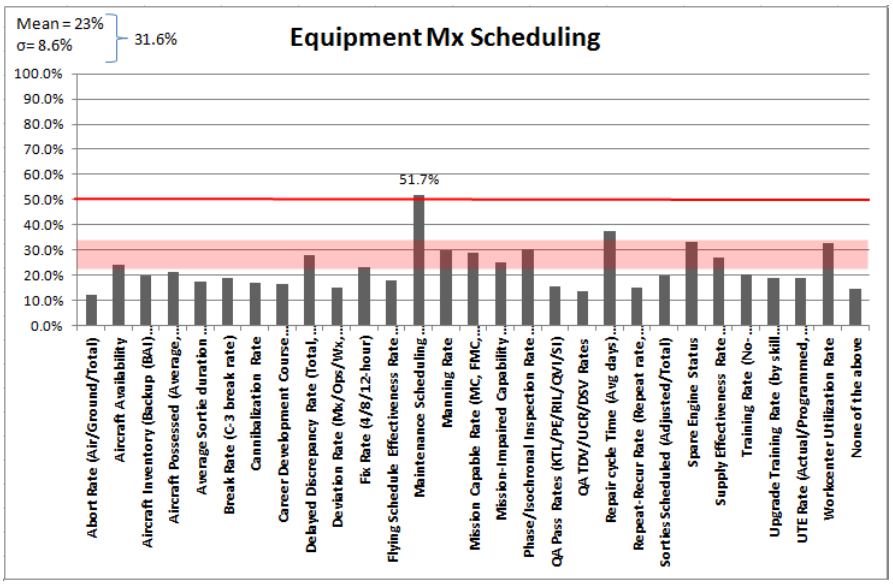


Figure 26: Metric Assignment to Equipment Maintenance Scheduling Process

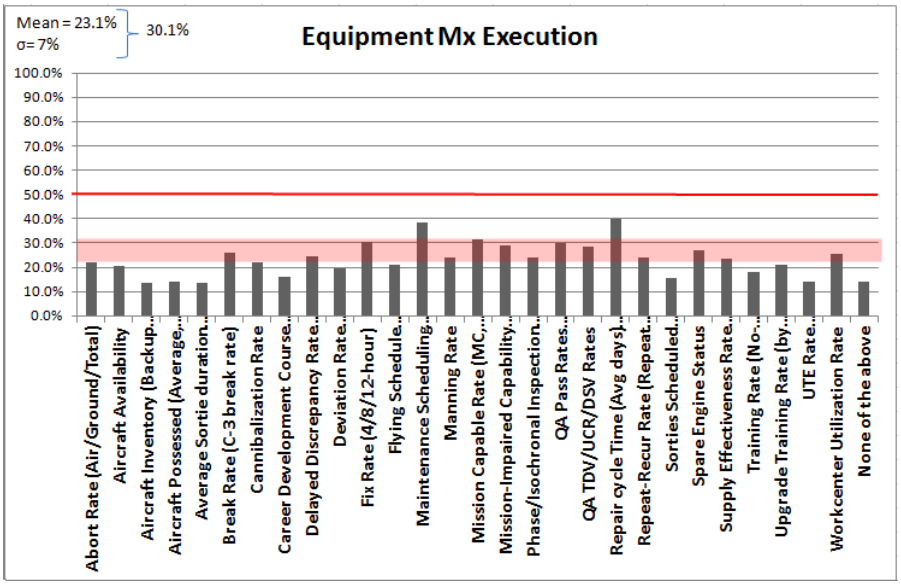


Figure 27: Metric Assignment to Equipment Maintenance Execution Process

Respondent analysis of adequacy: The response rate did not meet the 50% agreement rate for either process (Figure 28).

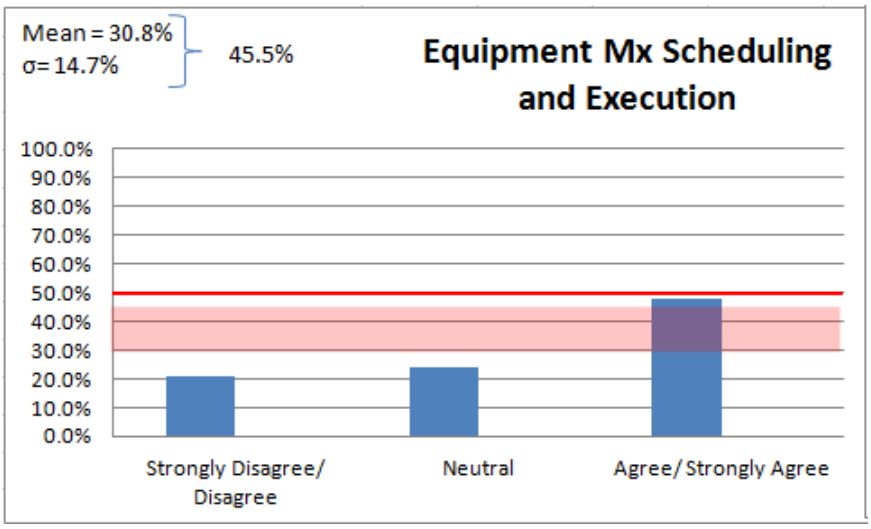


Figure 28: Adequacy of Available Metrics for Equipment Maintenance Scheduling Process

Respondents felt measures were inadequate, and at least one measure fell above one standard deviation from the mean--content analysis was required.

Trend issues with available metrics: Content analysis of issues respondents had with metrics representing this process indicated that metrics available for measuring efficiency and effectiveness of equipment maintenance were generally inadequate, or didn't exist at all, with many suggestions for improvement (Figure 29)

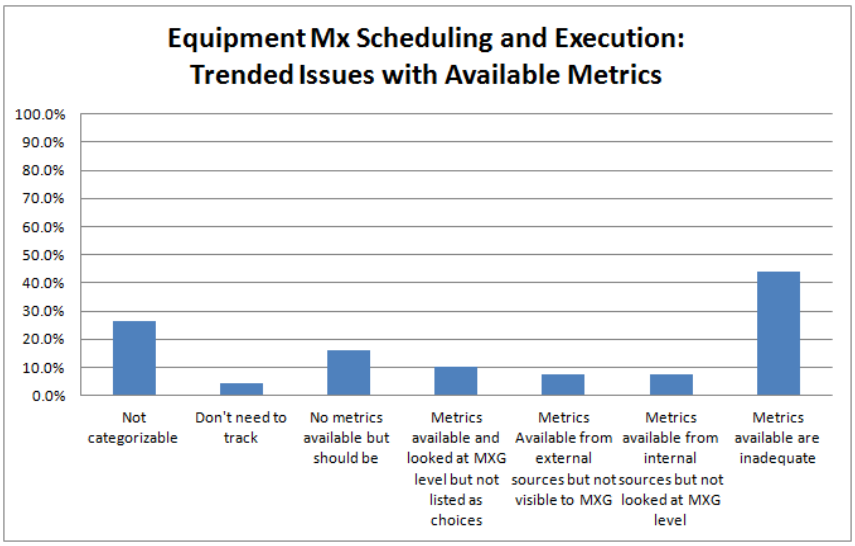


Figure 29: Equipment Maintenance Scheduling and Execution Process Metrics Issues

Trend suggested metrics: Upon studying open-ended responses that further develop respondents' opinions that the existing metrics for Equipment Maintenance Scheduling and Execution are inadequate, several metrics suggestions were found to be a trend. Many respondents felt equipment maintenance metrics that paralleled many metrics already used in Aircraft Maintenance Scheduling and Execution would be helpful in studying whether the processes are efficient and effective. Equipment Maintenance Scheduling Effectiveness Rate, Break Rates, and Fix Rates were among metrics suggested by Maintenance Officers. Additionally, comments suggested that it may be helpful to highlight metrics that are mandated to be studied at the flight level and provide visibility of these processes at the Group level. Respondents expressed the most interest in highlighting Equipment Mission Capable Rate (or In-Commission Rate) and Equipment Availability Rate (Figure 30).

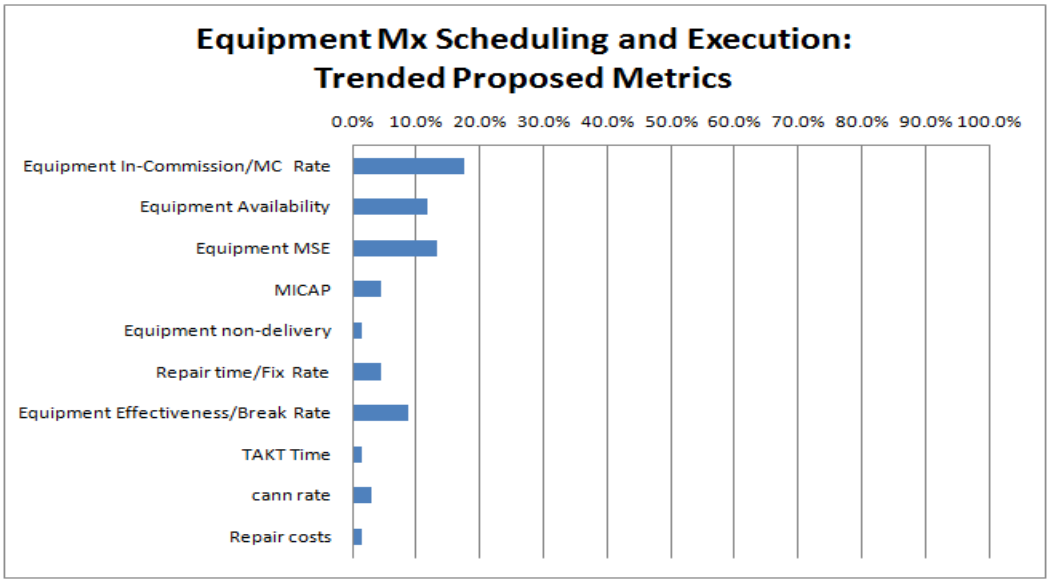


Figure 30: Equipment Maintenance Scheduling and Execution Process Suggested Metrics

Readiness Perspective

Aircraft, Maintainer and Equipment Readiness

Filtering Process: Five metrics met the inclusion criteria for the Aircraft Readiness Category: Abort Rate, Aircraft Availability, Break Rate, Delayed Discrepancy Rate, and Mission Capable Rate (Figure 31). For Maintainer Readiness, six metrics met the inclusion criteria: CDC Pass Rate, Manning Rate, QA Pass Rates, QA TDV/DSV/UCR Rates, Training Rate, and Upgrade Training Rate (Figure 32). For Equipment Readiness, one metric met the inclusion criteria: Spare Engine Status (Figure 33). Respondents perceived these metrics the most relevant to Aircraft, Maintainer, and Equipment Readiness categories and should be considered as part of the Maintenance Group's Balanced Scorecard.

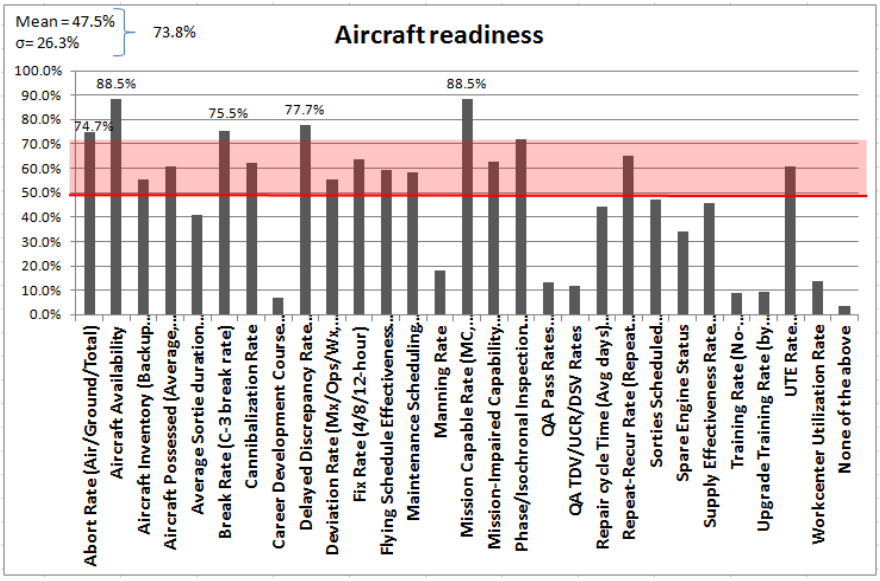


Figure 31: Metric Assignment to Aircraft Readiness

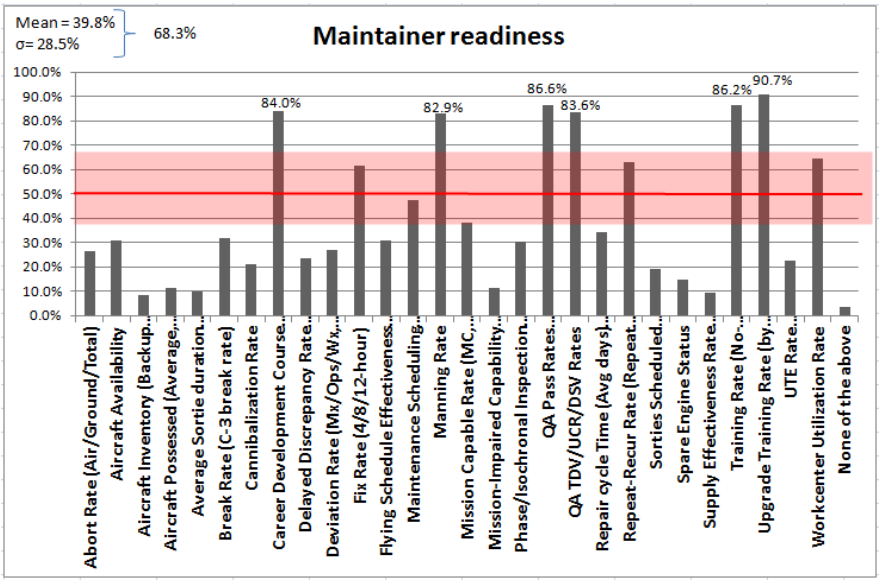


Figure 32: Metric Assignment to Maintainer Readiness

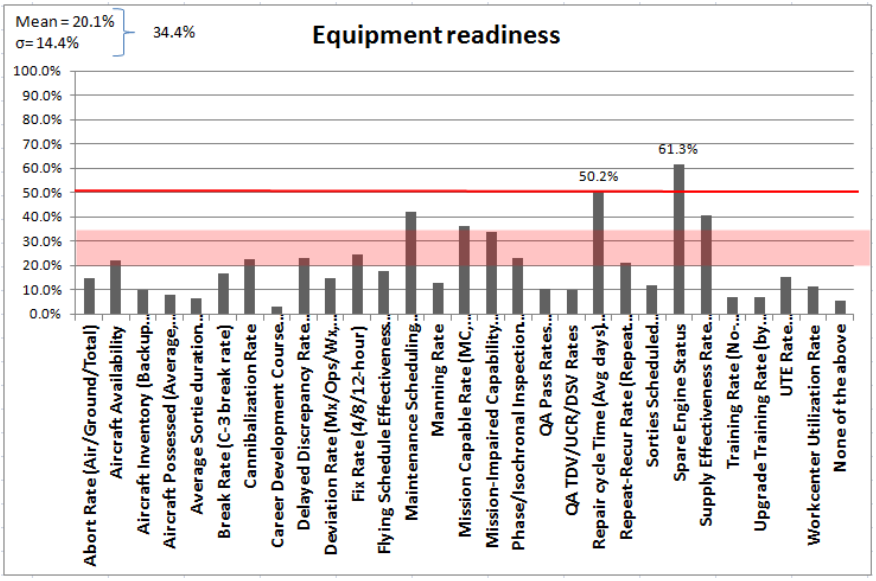


Figure 33: Metric Assignment to Equipment Readiness

Respondent analysis of adequacy: Enough respondents felt selected measures were adequate to meet the 50% minimum threshold and the 1 standard deviation from the mean threshold for Aircraft, Maintainer and Equipment Readiness (Figure 34).

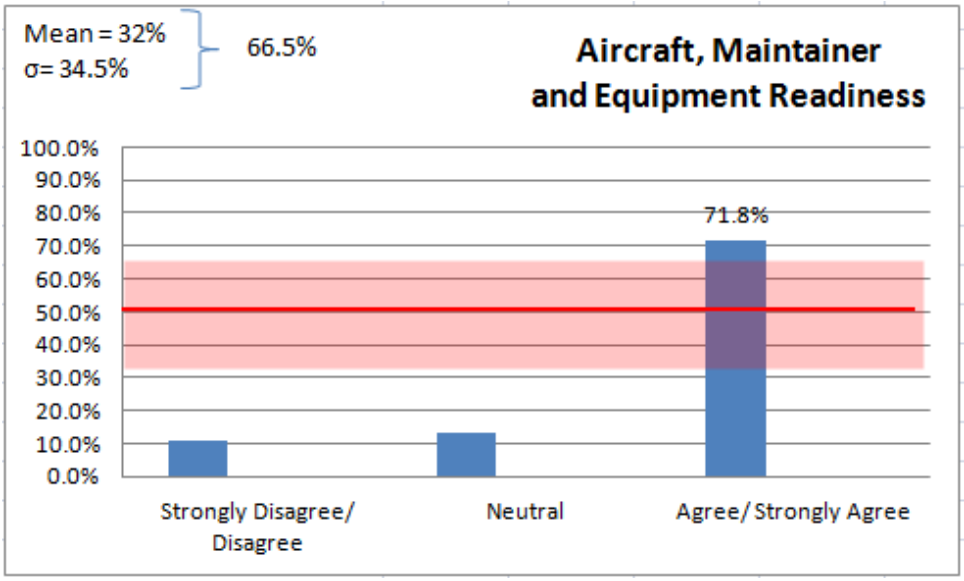


Figure 34: Adequacy of Available Metrics for Equipment Readiness

Respondents felt measures were adequate, and two measures fell above one standard deviation from the mean—content analysis was not required.

Workforce Quality Perspective

Maintenance Quality and Safety

Filtering Process: For Maintenance Quality, seven metrics met the inclusion criteria of 50% selection rate and were above one standard deviation from the mean, including Abort Rate, Break Rate, Delayed Discrepancy Rate, Fix Rate, QA Pass Rates, QA TDV/UCR/DSV Rates, and Repeat/Recur Rate (Figure 35). Maintenance Safety had two metrics meet the inclusion criteria: QA Pass Rate and QA TDV/UCR/DSV Rate (Figure 36). Respondents perceived these metrics the most relevant to Maintenance Quality and Safety and should be considered as part of the Maintenance Group's Balanced Scorecard.

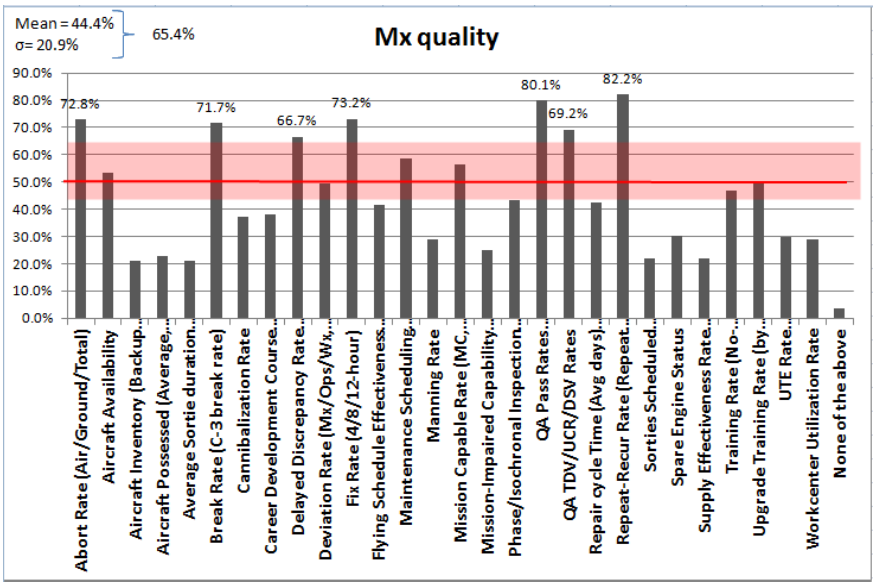


Figure 35: Metric Assignment to Maintenance Quality

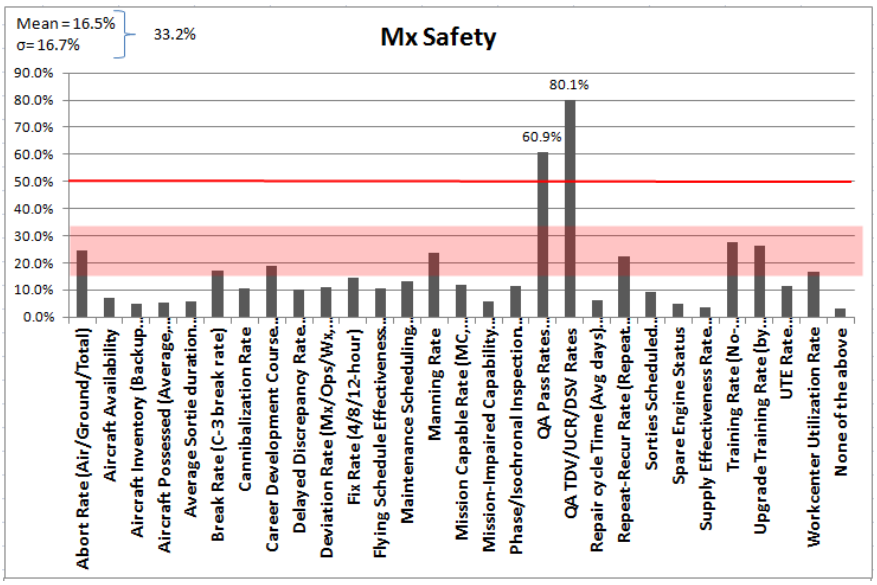


Figure 36: Metric Assignment to Maintenance Safety

Respondent analysis of adequacy: Enough respondents felt selected measures were adequate to meet the inclusion criteria (50% minimum threshold and the 1 standard deviation from the mean threshold) (Figure 37).

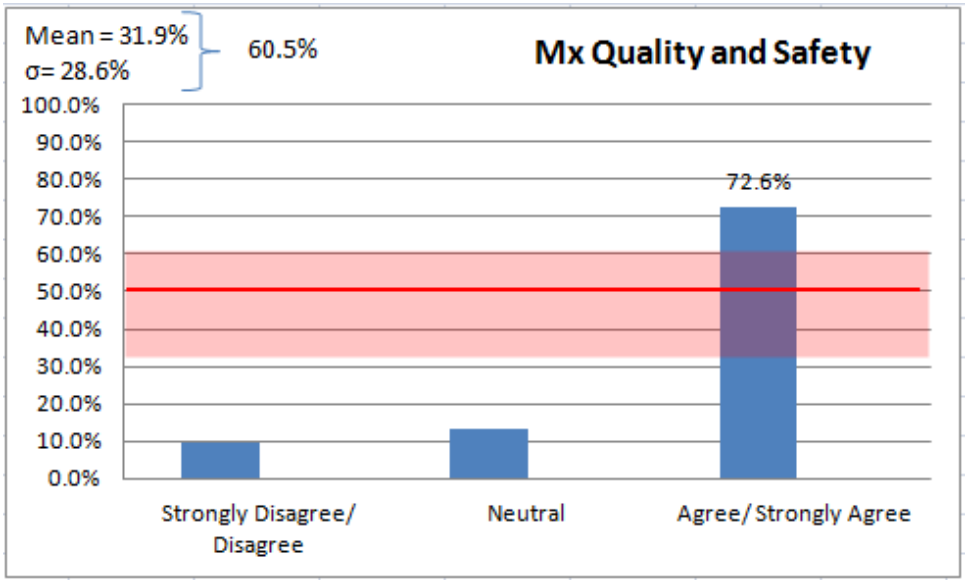


Figure 37: Adequacy of Available Metrics for Maintenance Quality and Safety

Respondents felt measures were inadequate, and no measures fell above one standard deviation from the mean—content analysis was not required.

Maintainer Skill Level and Maintainer Experience Level

Filtering Process: Four metrics met the inclusion criteria for Maintainer Skill Level: CDC Pass Rates, QA Pass Rates, QA TDV/UCR/DSV Pass Rates, and Upgrade Training Rate (Figure 38). Maintainer Experience Level had four metrics meet the inclusion criteria: Fix Rate, QA Pass Rate, QA TDV/UCR/DSV Rates, and Repeat/Recur Rate (Figure 39). Respondents indicated these metrics are the most relevant to Maintainer Skill Level and Maintainer Experience Level and should be included in the Maintenance Group's Balanced Scorecard.

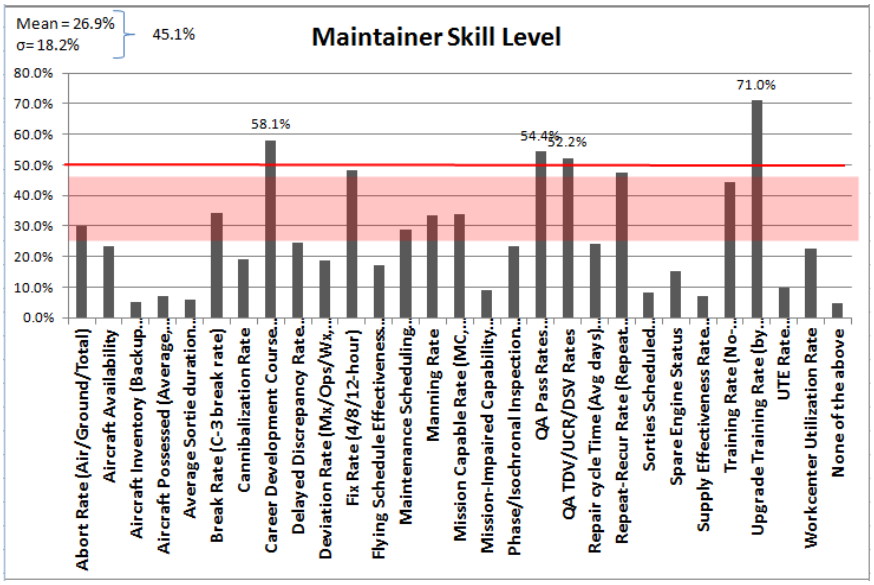


Figure 38: Metric Assignment to Maintainer Skill Level

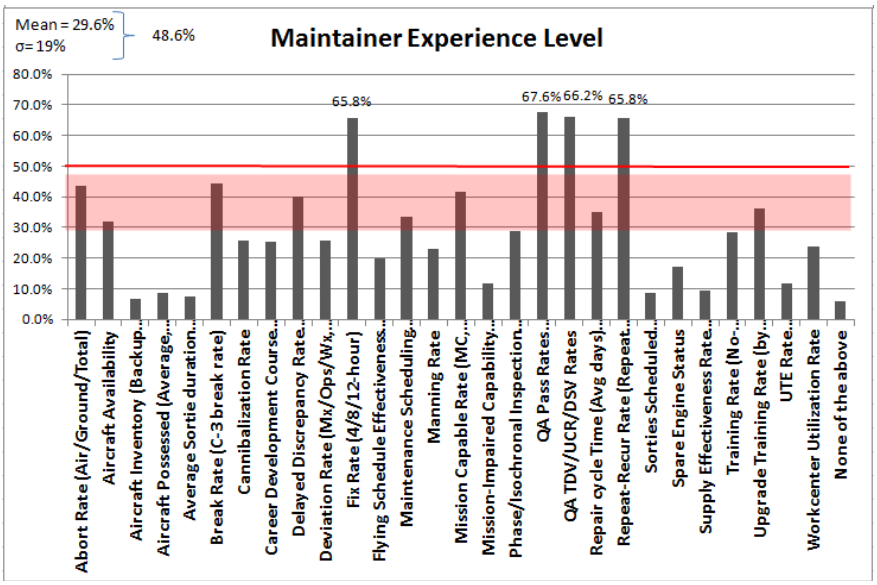


Figure 39: Metric Assignment to Maintainer Experience Level

Respondent analysis of adequacy: Enough respondents felt selected measures were adequate to meet the 50% minimum threshold and the 1 standard deviation from the mean threshold (Figure 40).

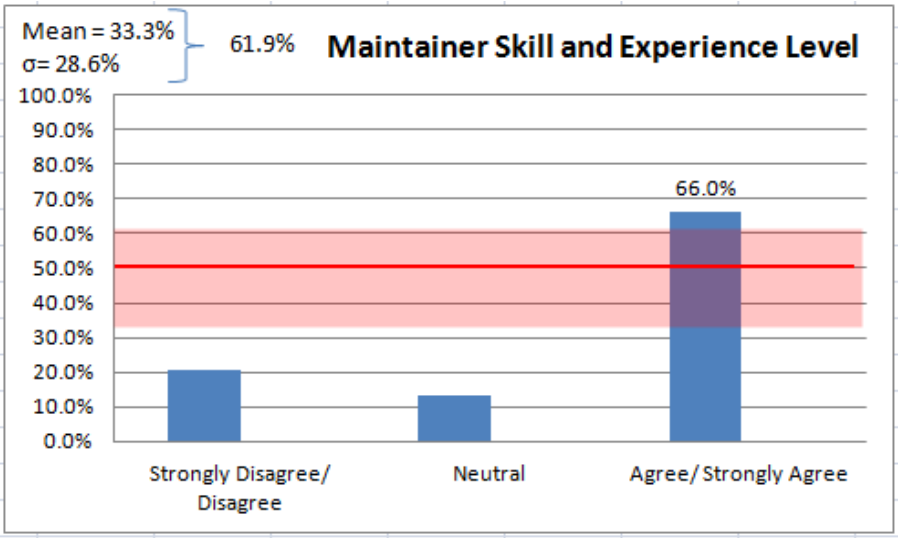


Figure 40: Adequacy of Available Metrics for Maintainer Skill and Experience Level

Respondents felt measures were adequate, and four measures fell above one standard deviation from the mean—content analysis was not required.

Maintainer Discipline and Maintainer Retention

Filtering Process: When respondents considered metrics for Maintainer Discipline, four metrics met the inclusion criteria: QA Pass Rates, QA TDV/UCR/DSV Rates, Repeat/Recur Rate and Training Rate (Figure 41). Zero metrics met the 50% selection rate for Maintainer Retention (Figure 42).

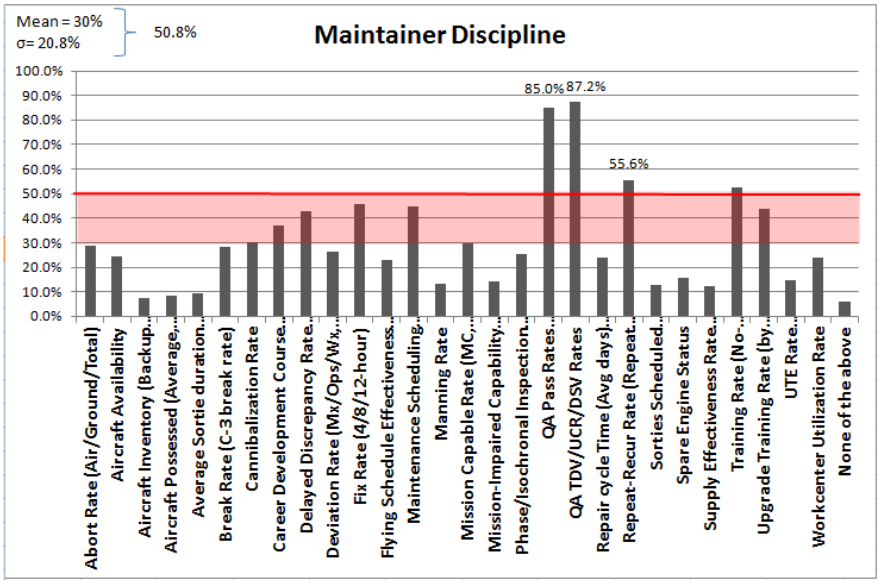


Figure 41: Metric Assignment to Maintainer Discipline

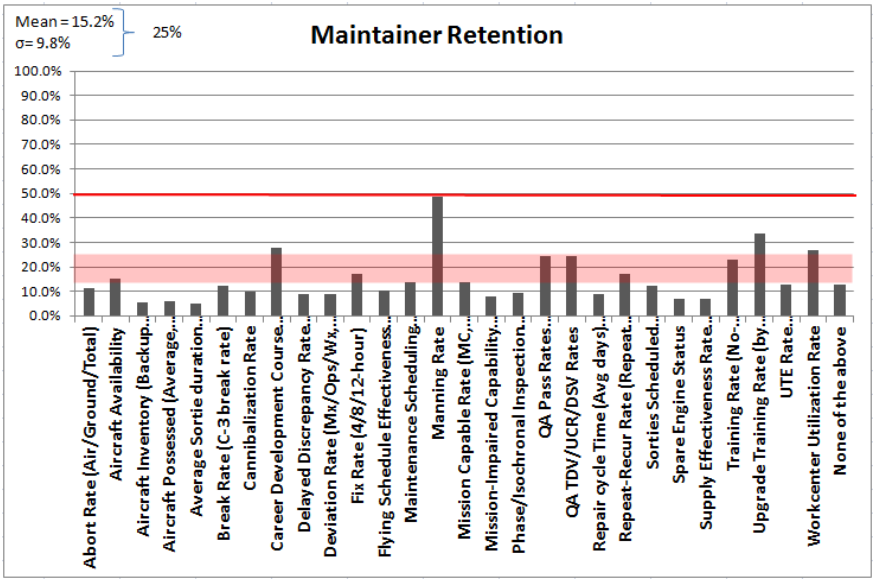


Figure 42: Metric Assignment to Maintainer Retention

Respondent analysis of adequacy: When considering the adequacy of available metrics, responses indicate less than 50% felt the available measures were adequate (Figure 43).

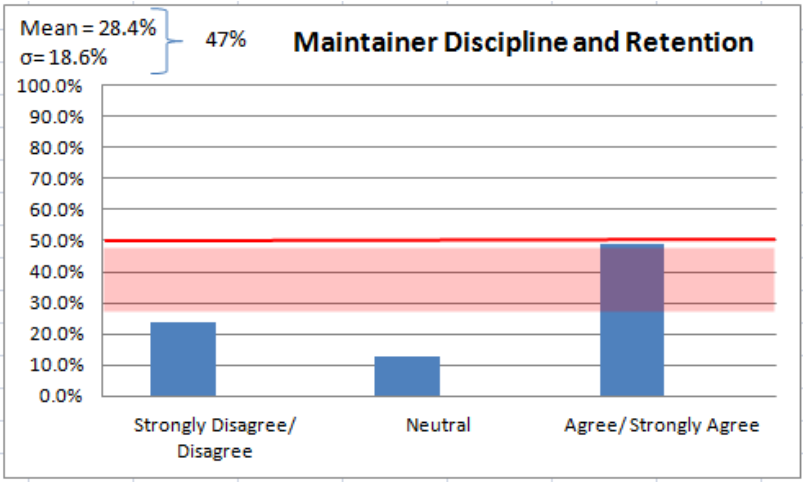


Figure 43: Adequacy of Available Metrics for Maintainer Discipline and Retention

Respondents felt measures were inadequate when asked generally about both categories; however, Maintainer Retention Category had zero metrics that met the criteria for inclusion. Therefore, content analysis was required, and focused on the Maintainer Retention Category.

Trend issues with available metrics: When the researcher reviewed the respondents' comments there was a general feel that retention is a concern for the Maintenance Community, but had a wide spread of views on how to measure it. Additionally, factors such as sequestration, force shaping, voluntary separation programs, and involuntary separations make maintainer retention a fluid situation that would be difficult to meaningfully measure at the Group level (Figure 44).

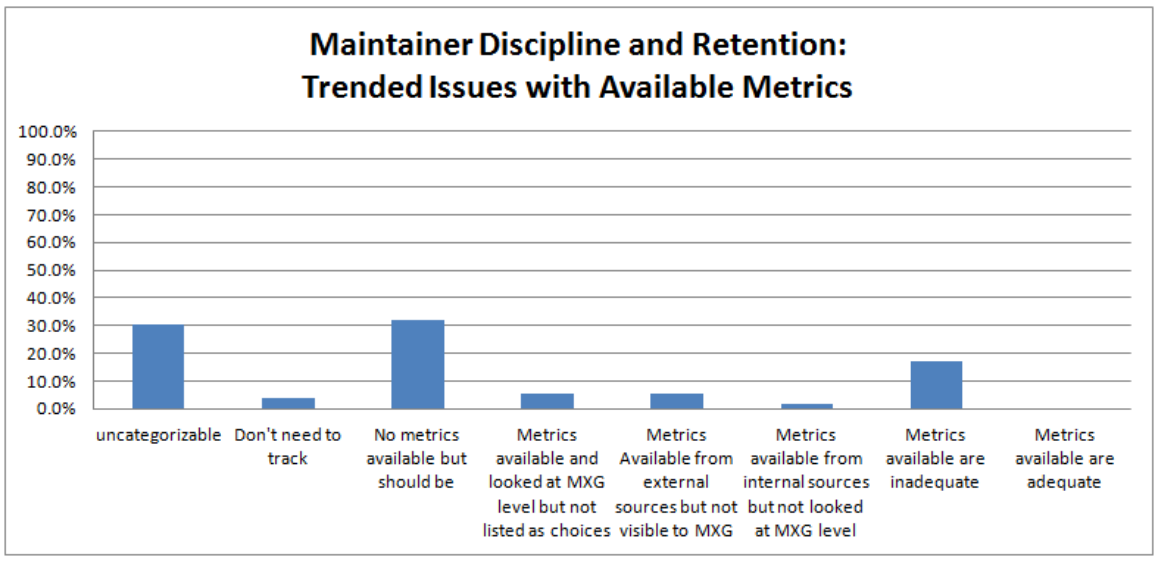


Figure 44: Maintainer Retention Metrics Issues

Trend suggested metrics: When asked to suggest metrics that could better articulate Maintainer Retention, most respondents believed a re-enlistment rate would be beneficial to the Maintenance Group as a lagging indicator. The other trend amongst comments were to track items that that they believed contributed to job dissatisfaction, which could be correlated to retention rate--Weekend Duty Rate, Overtime Rate were the most commonly suggested metrics as more "leading indicators" to the re-enlistment rate "lagging indicator" (Figure 45).

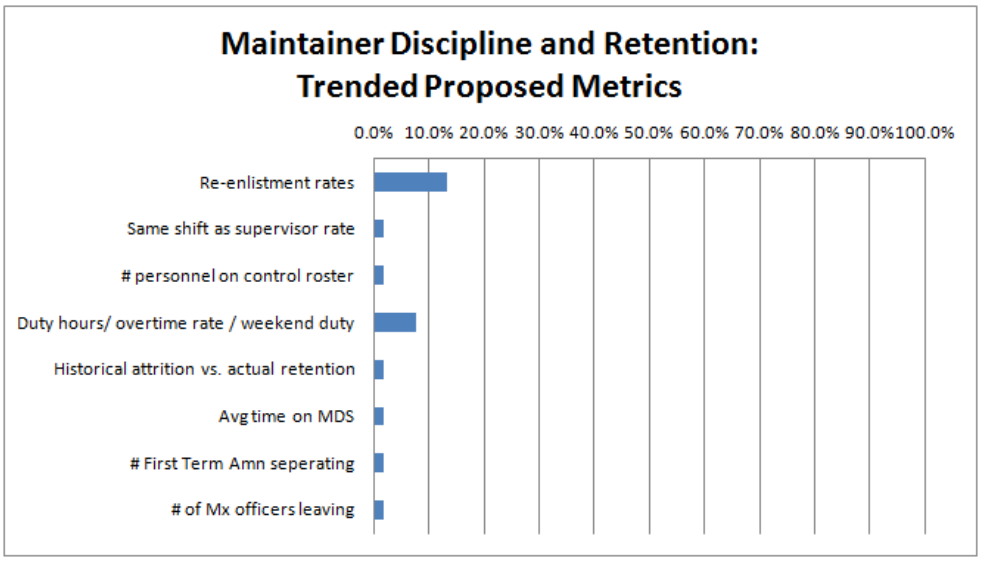


Figure 45: Maintainer Retention Suggested Metrics

Balanced Scorecard utility and frequency

The purpose of the next section of the survey was to determine the utility of the balanced scorecard framework in Maintenance Group. If deemed beneficial by Maintenance experts surveyed, the next step would be to determine the optimal frequency of analysis of the metrics in each perspective. The survey asked respondents to assess the benefit of examining metrics representing each perspective in the same meeting, in order for the researcher to determine field support or opposition of the concept. The responses indicated that 60% of the surveyed population Agreed or Strongly Agreed that the balanced scorecard concept would be beneficial to study metrics from each perspective in the same meeting (Figure 46).

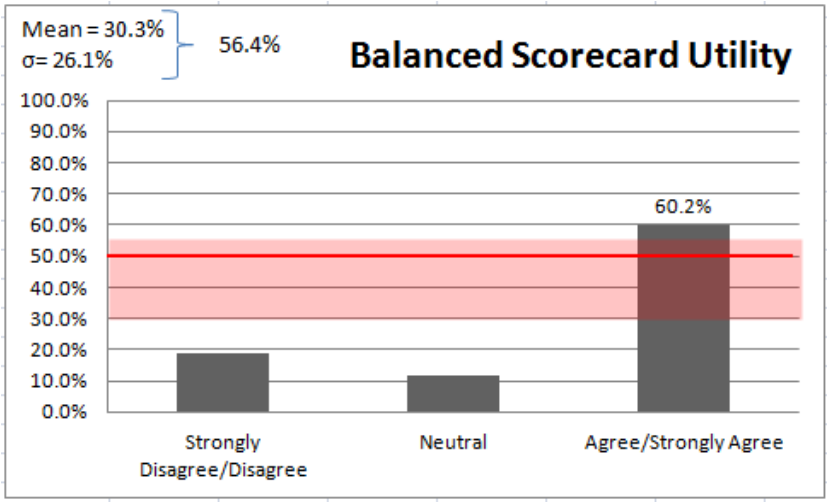


Figure 46: Balanced Scorecard Utility Perception

The next question asked respondents to indicate at what management level and at what frequency the balanced scorecard framework should be studied to gain optimal utility and understanding from the metrics.

Filtering Process: Respondents felt that the balanced scorecard framework would have most utility when studied at the Wing Level quarterly, and at the Group Level monthly. Responses also indicated preferred frequencies for Squadron level and flight level review; however, these responses did not meet the 50% minimum threshold of responses (Figure 47).

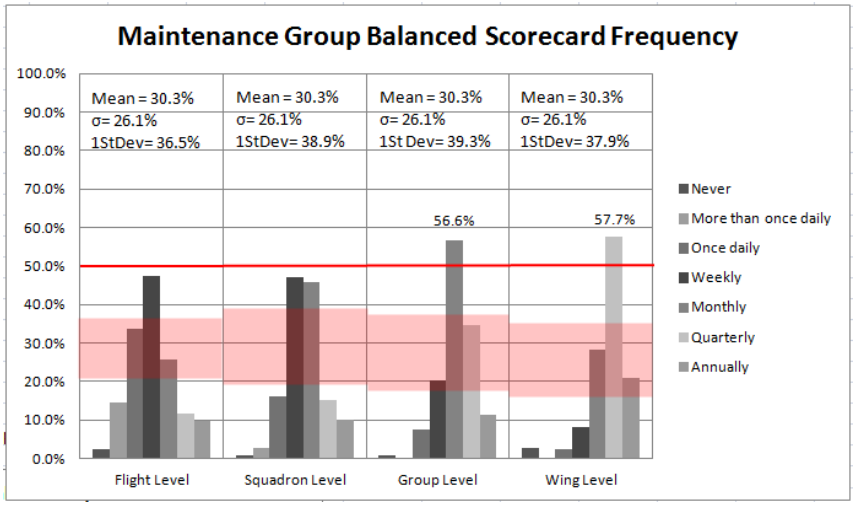


Figure 47: Balanced Scorecard Frequency Recommendations

Efficacy of Individual Metrics

Filtering Process: The last section of the survey asked respondents to evaluate 28 individual maintenance metrics based on their experience utilizing and analyzing metrics. The survey asked respondents to select every metric they believe is not "good" for any reason, and then asked them to explain their reason for each metric selected. Aircraft inventory, Fix Rate, and Workcenter Utilization rate fell above one standard deviation from the mean number of responses, and therefore were flagged as suspect metrics (Figure 48).

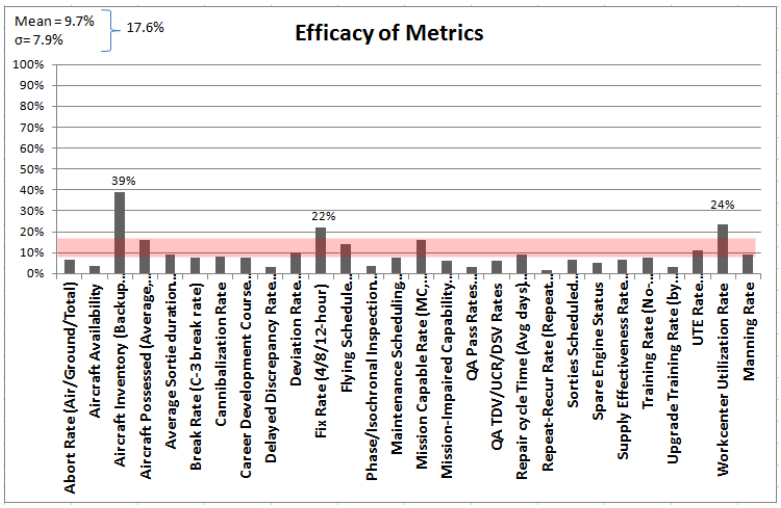


Figure 48: Individual Metrics Efficacy Response

Additionally, the researcher found that for the 19 perspective categories outlined in this study, five metrics were not associated with *any* perspective category in the Appendix H cross tabulation because they did not meet the 50% minimum response threshold in addition to the one standard deviation standard. Between the responses to survey question evaluating efficacy of individual metrics, and the actual assignment of metrics to perspective categories, the seven metrics identified for Content Analysis were:

Aircraft Inventory

The responses involving Aircraft Inventory (Figure 49) were that this metric did not drive action, as the number of aircraft assigned to wings was beyond the Maintenance Group's control.

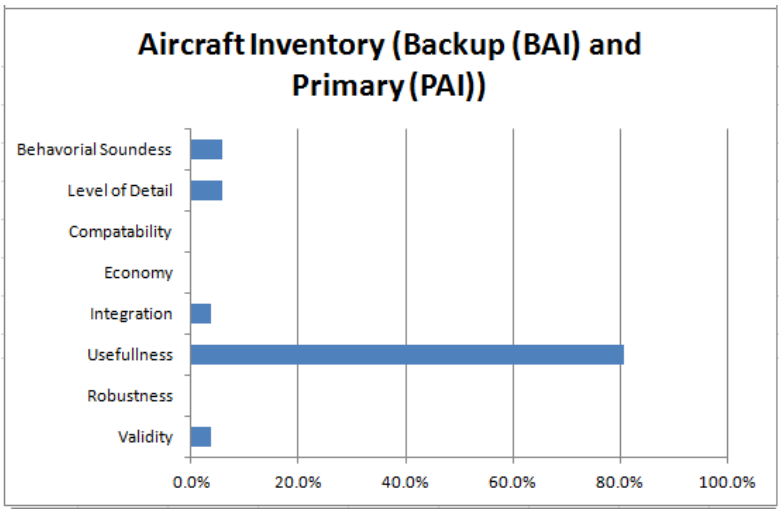


Figure 49: Aircraft Inventory Efficacy Evaluation

Fix Rate

The Fix Rate (Figure 50), of all the metrics that directly measure aircraft maintenance actions, was viewed by respondents to be of the least utility for multiple reasons. Comments regarding the Fix Rate largely addressed the rate's lack of behavioral soundness because of its propensity to incite behavior counterproductive to sound aircraft maintenance practices and quality aircraft repairs. Respondents' comments indicate that emphasis on the Fix Rate causes rushed maintenance action and a subsequent rise in the Repeat/Recur Rate. One officer stated that the Fix Rate is "counter to every other tenet of aircraft maintenance (safe, reliable, and by the book)." Additionally, many respondents felt the 4-, 8- or 12-hour standards for this rate were arbitrary, antiquated and relatively useless in modern day aircraft maintenance where aging aircraft require more time to fix and the newest 5th generation aircraft can't possibly achieve the standard when performing low observable (LO) intrusive repairs. Comments indicate that a more relevant measure of repair efficiency would be a metric that measures completion times

as compared to a job standard repair time and that encompassed all maintenance actions rather than just pilot reported discrepancies. Without established job standard repair times, many felt the Fix Rate lacked sufficient level of detail and was considered benign.

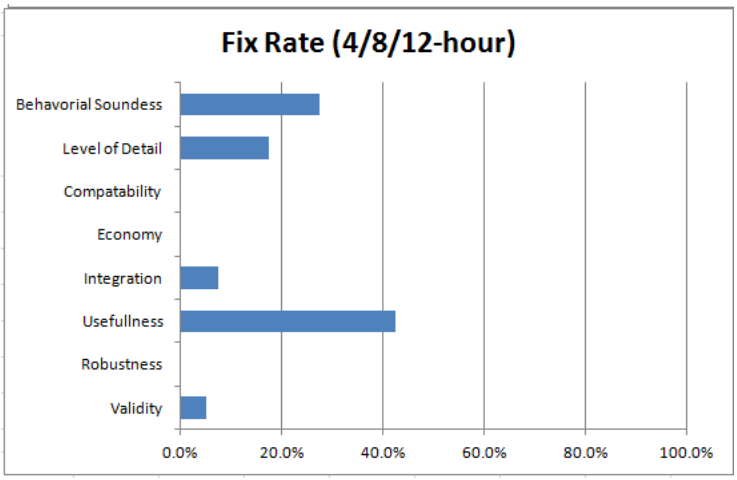


Figure 50: Fix Rate Efficacy Evaluation

Workcenter Utilization Rate

The researcher noticed that responses trending around Workcenter Utilization Rate (Figure 51)were that the data input into the information system, IMDS, was not reliable and therefore this metric was not of use to them.

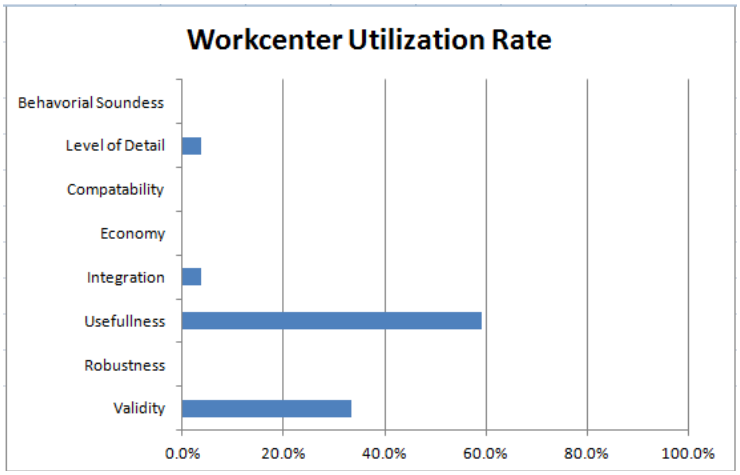


Figure 51: Workcenter Utilization Rate Efficacy Evaluation

Aircraft Possessed

The responses involving Aircraft Possessed (Figure 52) were very similar to comments regarding Aircraft Inventory; this metric did not drive action, as the number of aircraft possessed to wings was largely beyond the Maintenance Group's control and was generally used as part of calculations in other, controllable metrics.

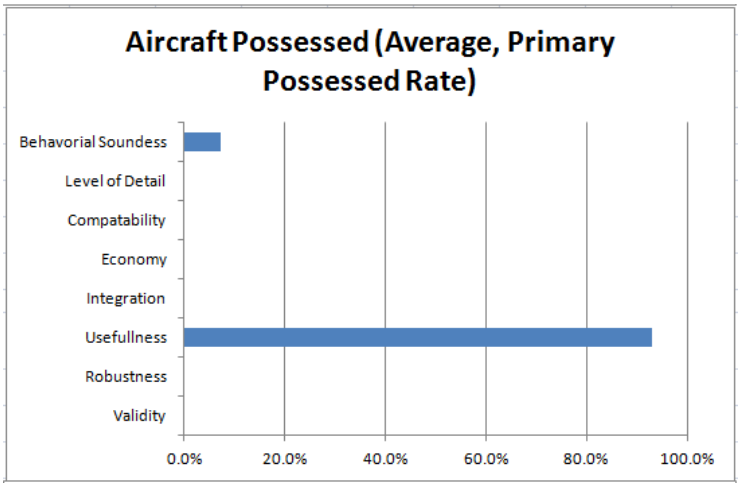


Figure 52: Aircraft Possessed Efficacy Evaluation

Cannibalization Rate

The number of responses assigning this metric to the 19 perspective categories did not meet the filtering criteria for representing any. Respondents who commented on the Cannibalization Rate (Figure 53) felt it that it provided a guide for action not for the Maintenance Group, but for Supply and the Mission Support Group. One respondent commented, "MICAP/CANN or supply effectiveness rates are only good if they generate an improvement in the overall contract/supply process... the end user (Aircraft Maintenance Unit OIC) is usually the one briefing the MICAP or CANN rate, instead of an LRS officer being required to brief the MICAP/CANN/Supply Effectiveness rates to the AMU OIC."

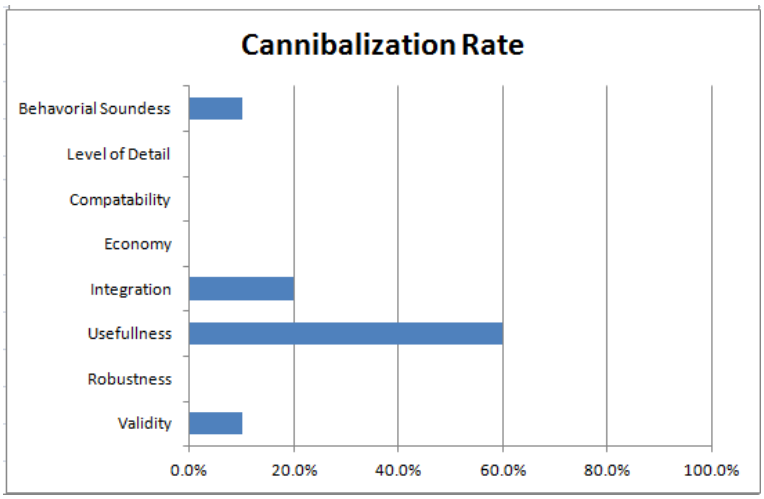


Figure 53: Cannibalization Rate Efficacy Evaluation

Mission Impaired Capability (MICAP)

Similar to the Cannibalization rate, the MICAP Rate (Figure 54) did not meet the filtering criteria to be considered in any of the 19 perspective categories. All respondent comments indicated the MICAP rate was a supply metric and maintenance had no influence over the supply chain and subsequently could not influence the MICAP Rate. When considering metrics regarding supply issues, maintainers find much more utility in the Non-Mission Capable for Supply (NMCS) Rate because it shows most clearly the effect of supply on combat capability. As for the MICAP rate, respondents rated its usefulness minimal at best.

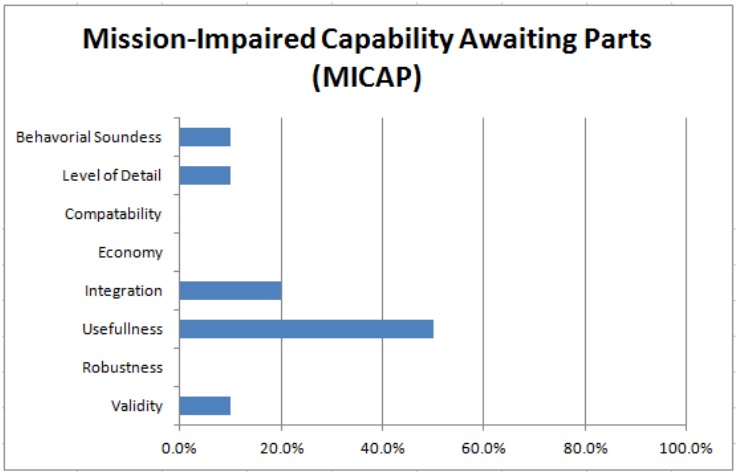


Figure 54: Mission-Impaired Capability Rate Efficacy Evaluation

Supply Effectiveness Rate

As with other supply chain oriented metrics, respondents felt the Supply Effectiveness Rate (Figure 55) was not worthy of consideration to be represented in any of the 19 perspective categories. Citing an inability to influence the supply chain or the metric, the Supply Effectiveness rate may be of use to supply analysts in the Support Group, but it has nearly no utility being tracked as a metric for the Maintenance Group. Once again, the NMCS Rates is far more useful to maintainers because it clearly shows the impact to combat capability.

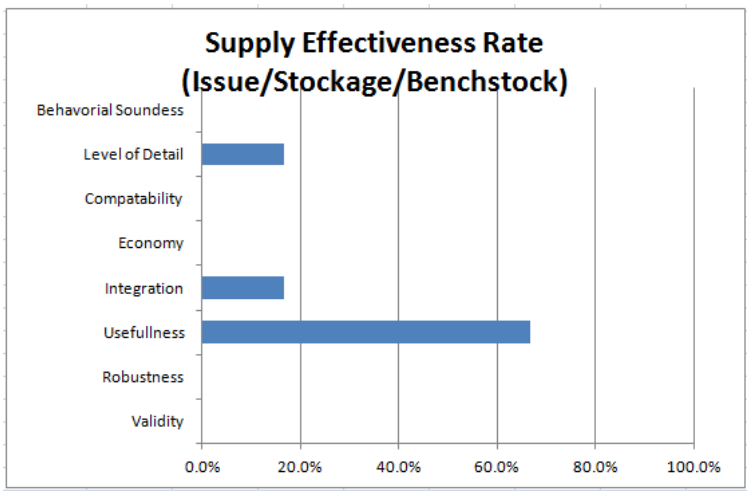


Figure 55: Supply Effectiveness Rate Efficacy Evaluation

Maintenance Group Balanced Scorecard Initial Rollup

Using the list of metrics that met the criteria for inclusion under each category, combined with the evaluation of individual metrics to ensure metrics included are sound, the researcher developed the initial Maintenance Group Balanced Scorecard shown in Figure 56. The researcher will use contents of this initial version to perform a Correlation Analysis to further adjust, refine, and produce the final proposal for the Maintenance Group Balanced Scorecard.

Internal Process Perspective					
Aircraft Mx scheduling process	Aircraft Mx execution process	Equipment Mx scheduling	Equipment Mx execution	Mx Training Scheduling	Mx Training Execution
Aircraft Availability	Abort Rate	Maintenance Scheduling Effectiveness Rate	Equipment MC Rate/In-commision Rate	Career Development Course Success	Career Development Course Success
Delayed Discrepancy Rate	Break Rate		Equipment Availability	Training Rate	Training Rate
Maintenance Scheduling Effectiveness Rate	Fix Rate (4/8/12-hour)		Break Rate	Upgrade Training Rate	Upgrade Training Rate
Phase/Isochronal Inspection Rate	Maintenance Scheduling Effectiveness Rate		Equipment MSE		
	Mission Capable Rate		Fix Rate		
	Repeat-Recur Rate				

Customer Perspective			
Flying Scheduling Process	Flying Execution Process	Aircrew Mission/ Training scheduling	Aircrew Mission/ Training execution
Aircraft Availability	Abort Rate	Average Sortie duration	Abort Rate
Flying Schedule Effectiveness Rate	Average Sortie duration	Flying Schedule Effectiveness Rate	Average Sortie duration
Maintenance Scheduling Effectiveness Rate	Break Rate	Operations Scheduling Effectiveness Rate	Break Rate
Phase/Isochronal Inspection Rate	Deviation Rate	RAP Milestones Rate	Deviation Rate
Sorties Scheduled	Flying Schedule Effectiveness Rate		Flying Schedule Effectiveness Rate
UTE Rate			Mission Effectiveness Rate

Maintenance Group Strategic Objective: Maintain aircraft, equipment and personnel in a safe, serviceable and ready condition to facilitate mission-readiness of the flying wing.

Readiness Perspective		
Maintainer readiness	Aircraft readiness	Equipment readiness
Career Development Course Success Rate	Abort Rate	Repair cycle Time
Manning Rate	Aircraft Availability	Spare Engine Status
QA Pass Rates	Break Rate	
QA TDV/UCR/DSV Rates	Delayed Discrepancy Rate	
Training Rate	Mission Capable Rate	
Upgrade Training Rate		

Workforce Quality Perspective					
Mx quality	Mx safety	Maintainer skill level	Maintainer experience level	Maintainer Discipline	Maintainer Retention
Abort Rate	QA Pass Rates	Career Development	Fix Rate (4/8/12-hour)	QA Pass Rates	Re-enlistment Rate
Break Rate	QA TDV/UCR/DSV Rates	QA Pass Rates	QA Pass Rates	QA TDV/UCR/DSV Rates	Weekend Duty Rate
Delayed Discrepancy Rate		QA TDV/UCR/DSV Rates	QA TDV/UCR/DSV Rates	Repeat-Recur Rate	Overtime Rate
Fix Rate (4/8/12-hour)		Upgrade Training Rate	Repeat-Recur Rate	Training Rate	
QA Pass Rates					
QA TDV/UCR/DSV Rates					
Repeat-Recur Rate					

Figure 56: Initial Maintenance Group Balanced Scorecard

Correlation Analysis

Perspective Category Correlation

The perspective category combinations and their correlation coefficients are outlined in Appendix I. The researcher found that many of the high correlations occurred

were due to corresponding low selection rates for metrics assignments to perspective categories. Even though high correlation coefficients were observed in many cases, the metrics that were assigned to process categories weren't always the metrics that caused high correlations. However, in several cases, metrics that were in the top three or four selections of perspective categories were highly correlated between perspective categories and worthy of analysis and discussion. During correlation analysis, the researcher identified several areas of concern, where metrics assigned to different perspective categories overlapped excessively.

The first area of concern highlighted by high correlations was between Maintainer Training Scheduling and Execution, Maintainer Readiness, and all Workforce Quality Perspective categories. QA Pass rates, QA STV/TDV/UCR rates, Training rates, Upgrade Training Rates, Repeat/Recur Rates and CDC Pass Rates were highly correlated between all of these categories. Since Maintenance Quality, Maintenance Safety, and Maintenance Discipline are all measured during QA inspections and represented in specific QA rates, the researcher elected to combine these three Workforce Quality Perspective categories into one category called Maintenance Quality, Safety and Discipline, and eliminate those metrics from being represented among the other categories.

Maintainer Experience

Metrics selected for Skill Level and Experience Level under the Workforce Quality Perspective were very closely correlated, concerning the researcher and forcing closer examination through Content Analysis. As described in Chapter II, skill level is awarded after completion of a set of tasks in the CFETP; however, a technician's skill

level does not necessarily equate to experience level or expertise. The problem with skill level is, once achieved, it remains with an Airman regardless of assignment or type of airframe. For example, a Staff Sergeant that earns his 7-level while working and training on the F-15 may be considered a craftsman of substantial skill because of his experience, until he is assigned to an A-10 unit in Korea and finds himself at a disadvantage because of his lack of experience on the dissimilar airframe. The simple fact of the matter is, experience level on an airframe matters and it cannot be equated with skill level. An Airman with 4 years experience on an airframe, although only a 5-level, is most often more capable than a 7-level with only 3 months on that same airframe. MDS experience level has become increasingly relevant in recent years as corporate knowledge on the flightline dwindles with the manning cuts. The researcher elected to perform additional content analysis on comments between these two perspectives to investigate whether the high correlation was due to redundant categories, or if metrics were lacking.

Trend issues with available metrics: During content analysis, the evidence was overwhelming that a lack of metrics was the culprit for the high correlation. Over 60% of the respondents assessed that there were adequate metrics to measure skill level, but inadequate metrics to measure experience level of the workforce (Figure 57).

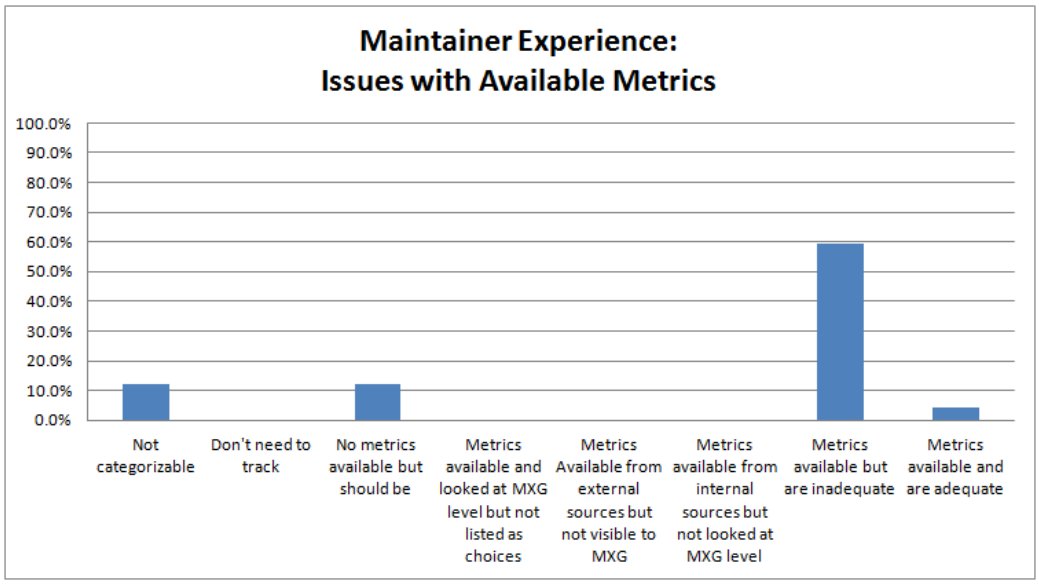


Figure 57: Experience Level Metrics Issues

Trend suggested metrics: The majority of respondents believed that a metric measuring Experience Level, especially with looming manning cuts, is required for units to truly understand their capabilities. Many suggested that measuring time on an MDS is a good place to start measuring experience level. Skill Experience Identifiers are meant to measure this, but many respondents indicated this process was "broken" and not meaningful. Overall, respondents felt it was critical to separate skill level from experience level and should be given as much, if not more, consideration as skill levels are given when assessing manning situations. For this reason, other metrics were eliminated from this category and replaced with "experience level" as a more direct measure (Figure 58).

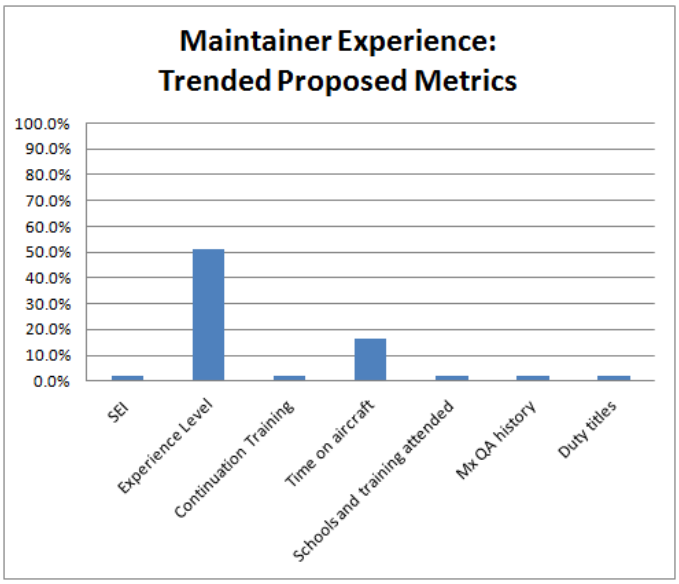


Figure 58: Experience Level Suggested Metrics

Maintainer Readiness

The researcher explored the issue of correlation in the Maintainer Readiness category next. The intent of readiness categories is to give leaders and commanders a bottom-line view of the readiness of aircraft, equipment, and personnel; however, Maintainer Readiness is currently being measured with six different metrics, all which could be considered "leading indicators" versus the "lagging indicator that is meant to be shown in this perspective. Additionally, the assigned metrics were used to measure other categories, specifically, the Maintenance Training and Execution and Workforce Quality categories. The researcher opted to perform additional content analysis on Readiness Rates to understand the context of selections.

Trend issues with available metrics for Maintainer Readiness: As depicted in Figure 59, respondents felt the main issues with metrics measuring Maintainer Readiness were that they weren't available, or metrics that were available were inadequate.

Generally, the responses indicated the inadequacy meant the available metrics only indirectly painted the picture of Maintainer Readiness--Maintainer Readiness had to be inferred based on maintenance performance metrics or training metrics.

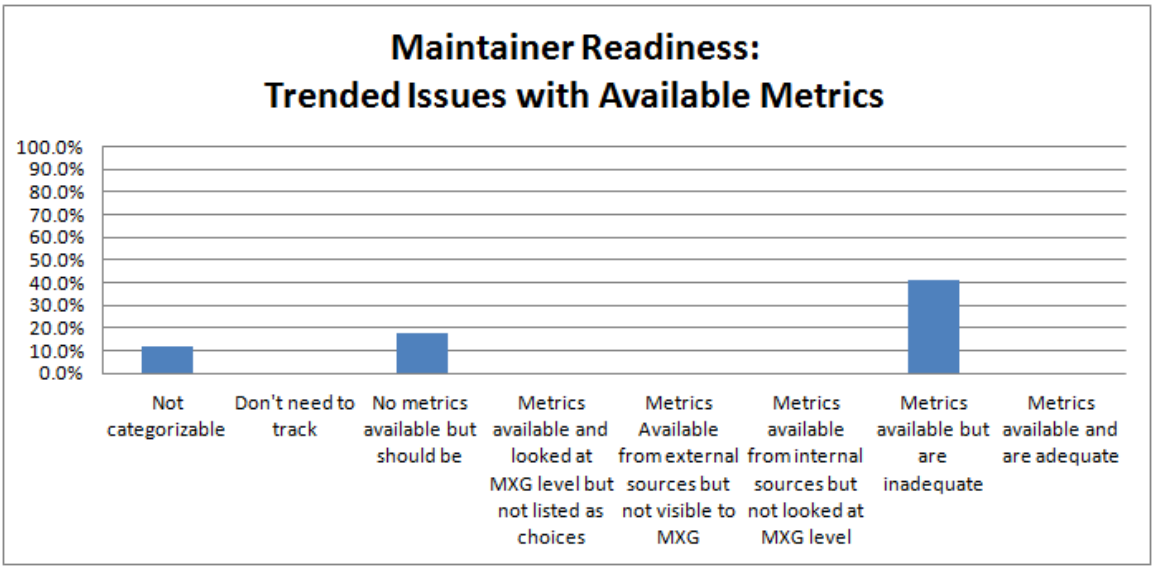


Figure 59: Maintainer Readiness Metrics Issues

Trend suggested Maintainer Readiness metrics: Suggestions for better metrics were numerous and diverse, but similar to metrics assigned to Aircraft Readiness category, Capability and Availability were among the suggestions (Figure 60). Some respondents suggested that a Capability Metric be rolled up from Skill levels and Experience levels, and availability be represented by the number of Airmen, who fill the proper manning slot of unit manning documents, and are available for duty. For this reason, the researcher suggested Maintainer Capability and Maintainer Availability for the Maintainer Readiness category, and moved other "leading indicators" to either Training Scheduling or Execution Category, or to the Maintenance Quality, Safety and Discipline Category. Additionally, several respondents mentioned duty hours as factors

as well as resiliency indicators were suggested as well; as these types of metrics were already largely categorized under Maintainer Retention, the researcher elected to include those responses under that category

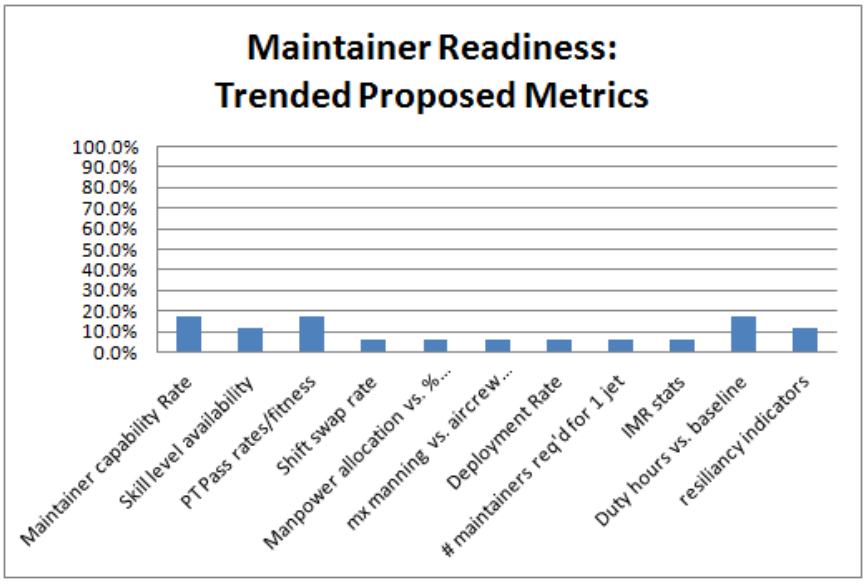


Figure 60: Maintainer Readiness Proposed Metrics

Maintenance Training and Execution Process

This left Maintenance Training and Execution as the final area to be addressed under the first set of correlation concerns. As Maintenance Training and Execution processes seem to be well represented with the leading indicators of Career Development Course Success Rate, Training Rate, and Upgrade Training Rate, the researcher elected to remove those metrics from all other categories and solely represent them in the Maintenance Training and Execution Process category.

Aircrew Mission/Training Scheduling and Execution Process and Flying Scheduling and Execution

The next area of concern fell between the Aircrew Mission/Training Scheduling and Execution Processes and the Flying Scheduling and Execution Processes. The researcher determined that the high correlation between those two categories was a result of lack of better metrics to measure the former. Aircrew Mission/Training Scheduling and Execution Processes refer specifically to the efficiency and effectiveness of Aircrew Training requirements. Flying Scheduling Effectiveness refers to take off and land times, and deviations from the flying schedule, with little consideration for deviations from planned, briefed and flown Missions that Aircrew are required to accomplish. Abort rate would logically, albeit loosely, tie these processes together, but an abort doesn't necessarily mean a spare wasn't provided and the mission was accomplished as planned. As determined in the Content Analysis of Aircrew Mission/Training Scheduling and Execution, this correlation corroborated the need for different and unique metrics to properly measure efficiency and effectiveness of this process, which are the RAP/Mission Effectiveness Rate and Mission Planning Deviation rates.

Equipment Maintenance Scheduling and Execution and Equipment Readiness

Another area of concern was the high correlation between Equipment Maintenance Scheduling and Execution, and Equipment Readiness. As pointed out in the Content Analysis of Maintainer Readiness, the intent of readiness categories is to give leaders and commanders a bottom-line view of the readiness of aircraft, equipment, and personnel; however, two of the metrics in the Equipment Maintenance Scheduling and

Execution category are considered “lagging indicators”, which are more appropriate for the Equipment Readiness category. The researcher opted to perform additional content analysis on Readiness Rates to understand the context of selections.

Trend issues with available metrics for Equipment Readiness: As depicted in Figure 61, respondents felt the main issues with metrics measuring Equipment Readiness were that they weren’t available, or metrics that were available were inadequate. Generally, the responses indicated the inadequacy meant the available metrics only indirectly painted the picture of Equipment Readiness--Equipment Readiness only had Spare Engine status to represent it, currently, while there are many more pieces of equipment in which Readiness is also critical.

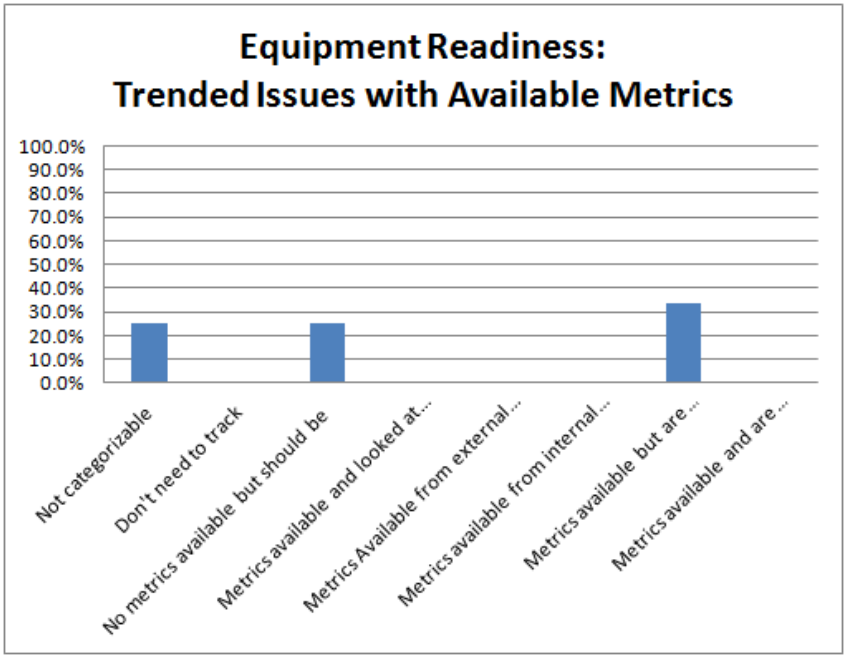


Figure 61: Equipment Readiness Issues with Available Metrics

Trend suggested Equipment Readiness metrics: Suggestions for better metrics were straightforward. Similar to metrics assigned to Aircraft Readiness category, and

proposed for Maintainer Readiness category, Mission Capability, In-commission Rates and Equipment Availability were the top suggestions (Figure 62). The researcher moved the only "leading" metric currently listed in the category, repair rates, to the Equipment Maintenance Scheduling and Category to maintain the integrity of the "bottom-line indicators" of the Equipment Readiness category.

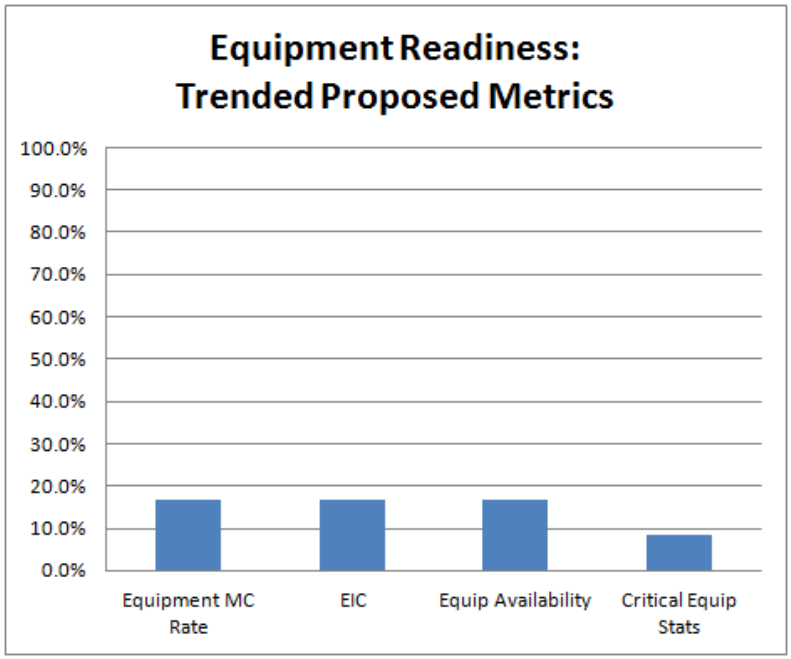


Figure 62: Equipment Readiness Proposed Metrics

Aircraft Scheduling and Execution and Equipment Maintenance Scheduling and Execution

Another area of concern during this correlation analysis was between the Aircraft Scheduling and Execution Processes, and the Equipment Maintenance Scheduling and Execution Processes. Considering that no Equipment-specific measures were listed, there should have been very low correlation between these four process categories. The researcher felt it was safe to assume that the respondents' intent when assigning these

aircraft-specific metrics such as MSE, Fix Rate, Break Rate, and Mission Capable Rate were meant to be equipment-related metrics. Equipment MSE, Equipment Break Rate, and Equipment Repeat/Recur Rate should be considered different metrics from their aircraft counterparts and included in the Equipment Maintenance Execution category.

Scheduling and Execution

The last area of concern was between Scheduling and Execution Processes in general. While efficiency and effectiveness in a Scheduling process could theoretically be measured differently than efficiency and effectiveness in an Execution Process, the reality of measuring them in a unique manner from each other makes a case for combining those measures together. How else can one measure efficiency in scheduling, except to see the fruits of the execution of the schedule? An effective schedule means fewer changes to the schedule during execution. An efficient scheduling process could measure the man-hours it takes to route a schedule through the chain of command for approval, but economy of effort to capture that data could be focused elsewhere. For this reason, the researcher elected to combine scheduling and execution for all of the process perspective categories.

After combining the Scheduling and Execution Process categories, the researcher noticed the top metrics for Aircraft Maintenance Scheduling and Execution reflected two different actions--scheduled and unscheduled maintenance. As such, the efficiency and effectiveness of execution of scheduled and unscheduled maintenance actions should be measured with different yardsticks. Unscheduled maintenance actions are just that--unscheduled, so the MSE rate, while highly telling of the efficiency of scheduled

maintenance, is not applicable. The researcher elected to break this perspective category into Unscheduled and Scheduled Maintenance activities.

Correlation analysis proved to be extremely useful, even after rigorous filtering and content analysis performed earlier in the methodology. First, the researcher was able to identify redundancies among category intent. Additionally, the researcher was able to identify where respondents assigned metrics to categories not because they were ideal, but because they were the merely the best they had to choose from. Following additional content analysis from these revelations, the researcher felt confident that the revised Balanced Scorecard could meet the needs of maintenance leaders and decision makers in understanding the performance in processes towards meeting customer requirements, readiness, and workforce quality issues.

V. Discussion, Recommendations and Conclusions

Discussion

This chapter first addresses the assumptions and limitations identified throughout the research process. After these assumptions are addressed, the researcher will answer the three Research Questions outlined in Chapter I of this paper. Implications of this research will then be covered, followed by several recommendations for future research. Finally, other recommendations will be presented

Assumptions and Limitations

To support this study of the utility of the balanced scorecard framework and utility of metrics already in use in aircraft maintenance, the researcher conducted a survey to capture the opinions of maintenance officers serving in the CAF. The survey canvassed as many officers as possible to ensure a well-rounded, unbiased perspective and for a credible reference throughout the research process. The researcher must assume that the responses and opinions of the survey respondents are an accurate representation of the opinions of the entire Aircraft Maintenance community.

The researcher used personal judgment to interpret the meaning of the respondents' comments during the coding process of Content Analysis. Although an external auditor was used to validate the results of the coding process, it must be acknowledged that interpretation of comments is subject to error when clarification or amplification of responses is not possible. The researcher assumed, for the purpose of the research, that the respondents' comments were interpreted correctly.

The researcher investigated multiple criteria to assess the current aircraft maintenance metrics set, but limited the discussion to the criteria presented by Caplice

and Sheffi based on her personal assessment of the criteria as compared to others. This study assumes the author was objective in her choice of criteria and did indeed choose the most comprehensive and complete criteria to develop the survey.

The researcher did not include formulas for the metrics evaluated in the survey, and assumed that the maintenance officers who participated in the survey had knowledge of these formulas or had access to the metrics formulas if they required them.

Implementation of the Maintenance Group Balanced Scorecard framework could be limited by Department of Defense classification standards for readiness-related information. In addition, current information systems may not be equipped to capture required data to implement the proposed metrics outlined in this study.

Recommendations

The researcher's investigation revealed information gaps provided by the current aircraft maintenance metrics set and the method and frequency of their study, and recommends several metrics be refined, created, or eliminated to populate the Maintenance Group Balanced Scorecard, as indicated by respondents.

Metrics to Create

First, the researcher recommends the current Fix Rate be refined to eliminate the negative behavior described by respondents before incorporating into the balanced scorecard. The researcher recommends the length of time it takes to fix a particular discrepancy be measured against an established job standard time versus against an arbitrary 4-, 8-, or 12-hour standard. The proposed "Job Standard Fix Rate" would provide maintainers clear expectations of performance for individual task accomplishment and enable more accurate measurement of efficiency of repairs than an

arbitrary standard. The clarity and objectivity provided by the Job Standard Fix Rate would reduce safety and quality concerns as maintainers would be less likely to be pressured by an unrealistic expectation of their work tempo. An additional benefit of the Job Standard Fix Rate would be a clear depiction of training deficiencies or process inefficiencies on specific tasks. For example, if engine changes consistently exceeded an established job standard time, managers would have statistical evidence that increased training is required or be able to examine the process to eliminate non-value added elements hindering optimization. The Job Standard Fix rate would be useful in both the internal process perspective and the learning and growth perspective of the Maintenance Group's Balanced Scorecard.

Examination of survey responses regarding Equipment Maintenance processes exposed information gaps and opportunities for improvement as well. The researcher recommends the creation of metrics to measure efficiency and effectiveness of Equipment Maintenance Scheduling and Execution, including Equipment In-commission Rate, Equipment Availability Rate, an Equipment Maintenance Scheduling Effectiveness Rate, and an Equipment Break Rate.

Another valuable discovery of this research was the need for increased visibility of Aircrew Mission/Training Scheduling and Execution processes. Although Operations' processes do not fall into the Maintenance Group's sphere of control, the Maintenance Group has significant impact on the efficiency and effectiveness of those processes. Survey responses indicate that increased transparency of metrics articulating customer perspective, and specifically the Maintenance Group's impact on them, could lead to improved efficiency in Maintenance Group processes. Respondents indicated a need to

know exactly how maintenance operations affect Aircrew, and to know the results of what they were providing for from a RAP perspective. These metrics include Operations Scheduling Effectiveness Rate (Missions briefed vs. Missions planned), a Mission Effectiveness Rate (Missions flown vs. Mission Planned), and a RAP Rate (RAP plan met for month/quarter). The researcher received several personal emails from Maintenance Officers whose organizations were already pursuing these types of metrics and have established programs that could lay the groundwork for implementation of these metrics CAF-wide.

Furthermore, the researcher recommends metrics to close gaps in the bottom-line measures of maintenance personnel and equipment readiness. Respondents indicated that measures similar to those studied for Aircraft, such as Capability and Availability, would be helpful in decision making and optimizing the impact of these important enablers of airpower. Respondents suggested that the Maintainer Capability measure would best serve the needs of managers if it were a roll-up of skill level and experience level.

The development/study of Workforce Quality measures is imperative to maximizing the contribution and effectiveness of the increasingly limited workforce. The researcher recommends Workforce Quality indicators be created to understand the condition of the enablers of the mission-execution--the maintainers. Recommended measures under this perspective include measures that could affect retention such as Overtime Rate, and Weekend Duty Rate. Also, a separate evaluation of skill level and experience level is recommended under this perspective as one of the unintended consequences of force reduction and restructuring is that skill level and airframe experience level have become disparate.

Metrics to Reassess

The researcher recommends a reassessment of Supply-related metrics. Respondents largely felt that rates such as MICAP rate, Cannibalization Rate, and Supply Effectiveness Rate could not be controlled at the Maintenance Group level, and these metrics would be more useful in the hands of members of the Logistics Squadrons. As the Proposed Maintenance Group Balanced Scorecard did not include this, an area to be explored for incorporation into the balanced scorecard is a Supplier Performance Section, to include external agencies performance in providing to the Maintenance Group. Scrutiny of Supplier Performance is necessary to ensure supply enablers remain vested in the success of the Maintenance Group.

The researcher recommends reassessment of Workcenter Utilization rate, how data is gathered to feed this metric, and what this metric is used for. In an environment as dynamic as maintenance, many expressed the difficulty in obtaining accurate time that maintainers spent on a job, and expressed concern that inaccurate data is being used to make decisions about manning and force structure. It is important to note, that a reevaluated and improved Workcenter Utilization Rate considered with the Job Standard Fix Rate could reveal useful information regarding Workforce Quality and how efficiently the workforce is employed.

Recommendation Summary/Research Question

The summary of the preceding recommendations for action for each of the 28 metrics evaluated, as well as recommendations for metrics proposed by respondents, are detailed in Figure 63, and illustrated in the Figure 64, the Final Maintenance Group Balanced Scorecard, and serve to answer the research question:

What metrics should be used in the Maintenance Group Balanced Scorecard framework to meet the needs of the CAF Maintenance Community?

Metrics	Recommendation
Abort Rate (Air/Ground/Total)	Incorporate
Aircraft Availability	Incorporate
Aircraft Inventory (Backup (BAI) and Primary (PAI))	Eliminate
Aircraft Possessed (Average, Primary Possessed Rate)	Eliminate
Average Sortie duration (Actual/Programmed)	Incorporate
Break Rate (C-3 break rate)	Incorporate
Cannibalization Rate	Re-evaluate
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	Incorporate
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	Incorporate
Deviation Rate (Mx/Ops/ATC/Wx/HHQ/SYM/OTH/SUP/UTE, Chargeable/Non-Chargeable)	Incorporate
Fix Rate (4/8/12-hr)	Eliminate
Flying Schedule Effectiveness rate (FSE)	Incorporate
Maintenance Scheduling Effectiveness Rate (MSE)	Incorporate
Manning Rate	Incorporate
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	Incorporate
Mission-Impaired Capability Awaiting Parts (MICAP)	Re-evaluate
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/Phase Inspection Flow/ISO)	Incorporate
QA Pass Rates (KTL/PE/RIL/QVI/SI)	Incorporate
QA TDV/UCR/DSV Rates	Incorporate
Repair cycle Time (Avg days/Processing Rate) (Pre-Mx Time, Post-Mx Time, Repair Time) (Base Repair Cycle Time) (Overall Base Repair Cycle Processing Time)	Incorporate
Repeat-Recur Rate (Repeat rate, Recur Rate)	Incorporate
Sorties Scheduled (Adjusted/Total)	Incorporate
Spare engine Status	Incorporate
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	Re-evaluate
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	Incorporate
Upgrade Training rate (by skill level) (school backlogs)	Incorporate
UTE Rate (Actual/Programmed) (Sortie/Hourly)	Incorporate
Workcenter Utilization Rate	Re-evaluate
Job Standard Fix Rate	Create
Equipment Maintenance Scheduling Effectiveness Rate	Create
Equipment Effectiveness/Break Rate	Create
Equipment Fix Rate	Create
Equipment MICAP Rate	Create
Maintainer Availability	Create
Maintainer Capability Rate	Create
Equipment MC/In-Commission Rate	Create
Equipment Availability	Create
Mission Effectiveness Rate	Create
Operations Scheduling Effectiveness Rate	Create
RAP Milestones Rate	Create
Maintainer Experience Level	Create
Maintainer Skill Level	Create
Overtime Rate	Create
Weekend Duty Rate	Create
Re-enlistment Rate	Create

Figure 63: Maintenance Group Balanced Scorecard Metrics Recommendations

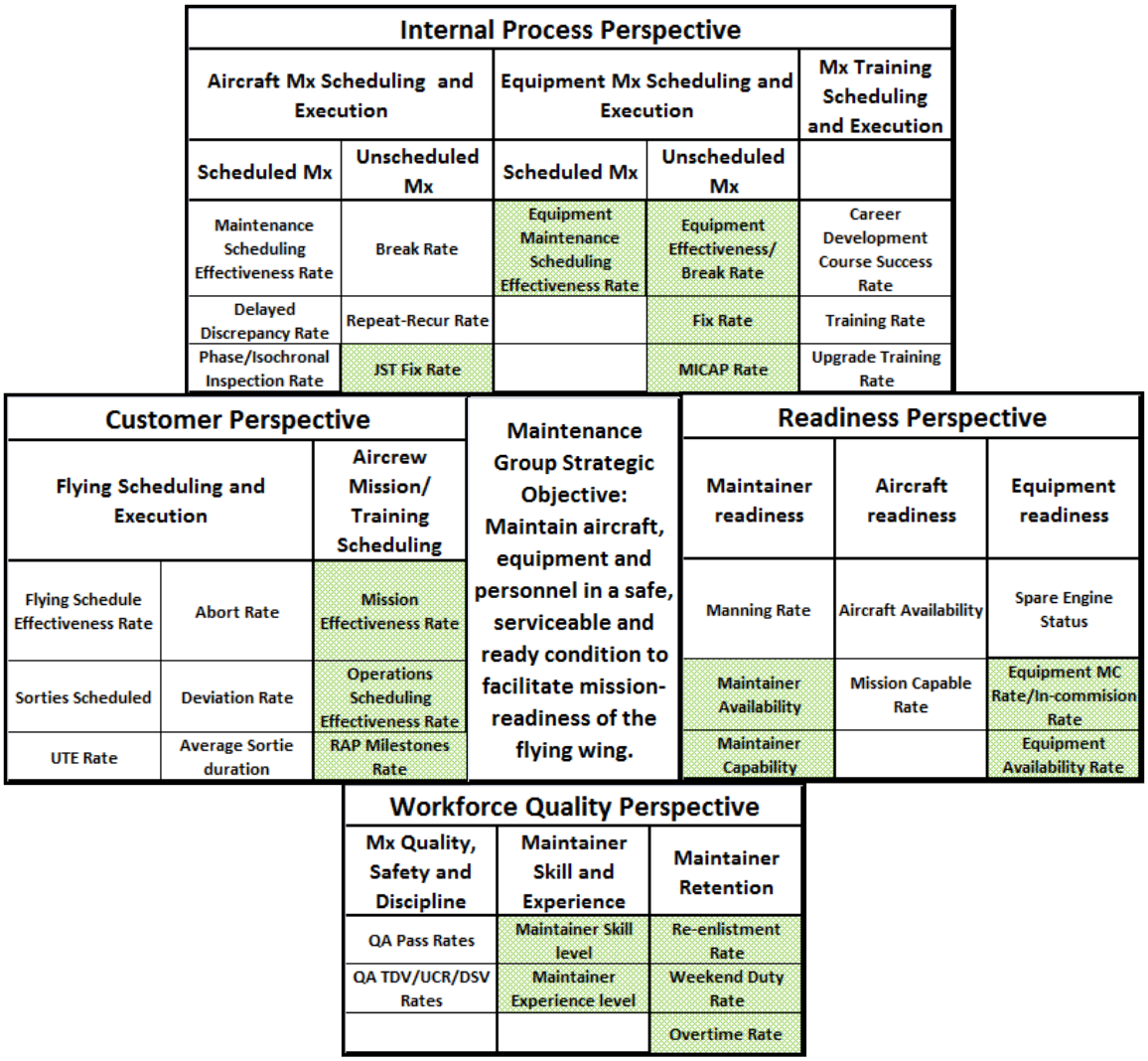


Figure 64: Final Maintenance Group Balanced Scorecard

These recommendations for refinement, addition, or reassessment of metrics were compared to the results of related metrics research by Capt Brian Waller and Capt Emily Harris, and Nachtman, et al, whose work was mentioned in the Literature Review. Although the methodologies used in each of these pieces of research differed, and the scopes of each piece of literature varied, there were several similarities in metrics proposed for use or recommended for incorporation, reevaluation or elimination. The results of this comparison are listed in Appendix K.

Other Recommendations

Recommend the standardization of maintenance metrics vocabulary between publications where they are addressed, and expand the metrics study publication, ACCI 21-118 to specifically list recommended metrics to be studied at the Group Level from the Maintenance Group Balanced Scorecard framework presented, including recommended new metrics, and recommended refined metrics.

Recommend the centralization of Maintenance Group Analysis shops at the wing level to perform analysis functions for both the Operations Group and the Maintenance Group as the Wing Analysis function to facilitate a holistic view of the performance of the entire flying wing, instead of purely the performance of the Maintenance Groups.

Recommendations for Future Research

First, a Delphi Study could be performed using the results of this study to obtain follow-up inputs on the final proposed Maintenance Group Balanced Scorecard, including formulas for the metrics, and incorporating a Supplier Perspective, as mentioned in recommendations.

A follow-on study could also address issues of data integration with current maintenance data system capabilities, as maintenance information systems such as Integrated Maintenance Data System or GO-81 may not currently have the capability to capture required data to implement proposed metrics.

The need for a Supplier Performance Perspective was a revelation revealed late in the research process and warrants further consideration and research beyond the scope of this thesis. The researcher strongly recommends further research to validate including a

Supplier Performance Perspective on the Maintenance Group's Balanced Scorecard as Supplier Performance measures would be especially relevant to 5th generation aircraft under the influence of the corporate contributors, vendors and manufacturers. Supplier Performance measures are an absolute necessity to limit sustainment vulnerabilities as programs such as the F-22, F-35 and KC-46 mature.

To clearly understand the Maintenance Group's value proposition in dealing the Aircrew as the customer, a follow-on study could expand survey to include pilots in the Operations Groups up to the MAJCOM and HAF-level A3.

Finally, since this research was focused on CAF metrics, future research could expand this study to Mobility Air Forces (MAF) and their unique set of aircraft maintenance and operations metrics.

Conclusions

Since the beginning of Aircraft Maintenance, leaders have relied upon performance metrics as tools to help guide decisions, improve processes and maximize performance. Maintainers and their stakeholders continue to need to plainly see and understand the link between the processes of a Maintenance Group, the customers they provide for, the maintainers that enable it, and the bottom-line readiness of all entities involved. The Balanced Scorecard approach to looking at maintenance metrics first helps to focus the Maintenance Group's analysis around their strategic objective and helps leaders to understand who their customer is, what processes are critical to achieving their strategic objectives and customer's needs, and gives a bottom-line view of readiness of the entities of the Maintenance Group. Finally, the Maintenance Group Balanced Scorecard framework helps leaders and decision-makers to view the health of the

enablers of the entire operation--the maintainers--and understand factors that contribute to their job satisfaction, the quality of their work, and their skills and experience in their work.

An organization as complex and dynamic as the Maintenance Group demands a metrics framework that is comprehensive enough to understand all aspects of the performance of the organization, but structured enough to directly see how positive or negative dynamics of one process may be affecting another. Metrics have helped to guide Aircraft Maintenance through decades of challenge and change; with an aging fleet, budget constraints, and slashed manning levels as the backdrop for current and future operations, there has never been a more critical time to implement a clear, holistic metrics framework that meets the needs of the leaders and decision makers who are navigating through the turbulent times ahead..

Appendix A: Literature Review Classification

Literature			Sector			Focus Area				Topic					Methodology					
Author	Year	Title	General/ Private or Public/ Logistics/ SCM	DoD/USAF/ Aircraft Mx/Logistics Research	DoD/ USAF Regulations/ Instructions	Conceptual Model/ Framework	Performance Measurement Systems	Specific/ Individual Metrics	Purpose/ Importance/ Characteristics	Proposal	Design/ development/ selection	Implementation/ Analysis	Management	Evaluation	Literature Review/ Content Analysis	Case-Study based	Survey/ interview based	Conceptual Model/ Framework	Expert opinion	Mathematical /statistical analysis
Artley, Will; Stroh, Suzanne	2001	The Performance-Based Management Handbook: A Six-Volume Compilation of Techniques and Tools for Implementing the Government Performance and Results Act of 1993	x			x	x		x	x								x		
Kaplan, Robert S. and David P. Norton	1992	The Balanced Scorecard--Measures that Drive Performance	x			x				x	x							x		
Griffin, Stanley E., Martha Cooper, Thomas J. Goldsby , David J. Closs	2004	Performance Measurement: Measure Selection Based upon Firm Goals and Information Reporting Needs	x			x				x				x			x			
National Institute of Standards and Technology, U.S. Department of Commerce	2010	Baldrige Performance Excellence Program	x			x				x								x		
European Foundation for Quality Management	2013	EFQM Excellence Model	x			x				x								x		
Lynch, K.L. and Cross, K.F.	1991	Measure Up – The Essential Guide to Measuring Business Performance	x			x				x								x		
Kaplan, R.S. and Norton, D.P	1996	The Balanced Scorecard – Translating Strategy into Action	x			x				x								x		
Keegan, D.P., Eiler, R.G., and Jones, C.R	1989	Are your performance measures obsolete?	x			x				x								x		

Brown, M.G.	1996	Keeping score: Using the Right Metrics to Drive World-Class Performance	x			x				x								x		
Niven, Paul r.	2002	Balanced Scorecard: Step by Step: Maximizing Performance and Maintaining Results	x			x						x						x		
Fitzgerald, L., Johnston, R., Brignall, T.J., Silvestro, R., and Voss, C.	1991	Performance Measurement in Service Businesses	x			x				x								x		
Nerreklit, Hanne	1999	The balance on the balanced scorecard--a critical analysis of some of its assumptions	x				x		x				x					x		
Melnyk, Steven A. , Douglas M. Stewart, Morgan Swink	2004	Metrics and performance measurement in operations management: dealing with the metrics maze	x				x		x						x					
Bourne, Mike and Andy Neely	2003	Implementing performance measurement systems: a literature review	x				x				x	x			x					
Evans, James R.	2004	An exploratory study of performance measurement systems and relationships with performance results	x				x				x	x					x			
Fawcett, Stanley E. and M. Bixby Cooper	1998	Logistics Performance Measurement and Customer Success	x				x				x		x				x			
Eccles, Robert G.	1991	The Performance Measurement Manifesto	x				x				x			x					x	
Neely, Andy and John Mills, Ken Platts, Huw Richards, Mike Gregory, Mike Bourne, Mike Kennerley	2000	Performance measurement system design: developing and testing a process-based approach	x				x				x							x		

		Supply chain performance measurement: a literature review	Performance measurement and performance management	Performance measures and metrics in logistics and supply chain management: a review of recent literature (1995–2004) for research and applications	Evaluating the Effectiveness of Performance Measurement	A Review and Evaluation of Logistics Metrics	The Use of Decision Models in the Development of a Collaborative Integrated Solutions System	Headquarters Air Force Material Command Customer Relationship Management	Statistical Process Control: An Application in Aircraft Maintenance Management	Evaluation of Air Force Aircraft Maintenance Metrics for Integration into the Expeditionary Combat Support System	Establishing a Standardized Set of Base-level Transportation Metrics	Air Force Material Command: A Survey of Performance Measures	Measuring Success: Metrics that Link Supply Chain Management to Aircraft Readiness
Akyuz, G.A. and T.E. Erkan	2009	x											
Lebas, Michel J.	1995	x	x	x	x	x	x	x	x	x	x	x	x
Gunasekaran, Angappa & Bulent Kobu	2007	x		x		x	x	x	x		x		
Weidinger, Claus and Ken Platts	2012	x			x							x	
Caplice, Chris and Yossif Sheffi	1994	x				x						x	
Nachtmann, Heather and Justin Hunter, Bryan Hill, Brian Waters, David Rieske, Jonathan King	2003						x	x		x			x
Sullivan, Christopher B.	2006							x				x	
Beabout, Bradley A.	2003								x				
Waller, Capt Brian D.	2009									x			
Marsh, Kyle D.	1995										x		
Leonard, Marcia	2004											x	
Balestreri, William G. and Patrick S. McDaniel	2002												

Appendix B: Exhaustive List of Metrics

Metric Name	AFTTP 3-3.Aircraft Maintenance Tactics, Techniques and Procedures	AFI 11-102 Flying Hour Program Management	AFI 36-2232 Maintenance Training	ACCI 21-118 Logistics Maintenance Performance Indicator Reporting Procedures	AFI 21-103 Equipment Inventory, Status and Utilization Reporting	AFLMA "Blue Book"	AFI 21-165 Aircraft Flying and Maintenance Scheduling Procedures	AFI 21-101 Aircraft and Maintenance Equipment Management
Abort Rate (Air/Ground/Total)	x			x		x		
Aircraft Availability	x			x	x			
Aircraft Inventory (Backup (BAI) and Primary (PAI))				x	x			
Aircraft Possessed (Average, Primary Possessed Rate)	x			x				
Average Sortie duration (Actual/Programmed)	x			x	x	x		
Break Rate (C-3 break rate)	x			x		x		
Cannibalization Rate	x			x		x		
Cannot Duplicate Rate (CND)	x							
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	x		x			x		
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	x			x		x		
Depot Rate	x							
Deviation Rate (Mx/Ops/ATC/Wx/HHQ/SYM/OTH/SUP/UTE, Chargeable/Non-Chargeable)	x			x		x		
EW Pod MC/AWP Rate						x		
Fix Rate (4/8/12-hr)	x			x		x		
Flying Schedule Effectiveness rate (FSE)	x			x		x	x	
Fully Mission-Capable Rate (FMC)	x					x		
Functional Check Flight (FCF) Release Rate						x		
Hangar Queens (Avg, Avg Cat 1/2/3)				x				
Isochronal/Phase Inspection Rate (TDI/Phase Flow Average/Phase Inspection Flow/ISO)	x			x				
LANTIRN POD MC Rate						x		
LANTIRN Test Station MC Status						x		
Maintenance Man-Hours per Flying Hour				x				
Maintenance Scheduling Effectiveness Rate (MSE)	x			x		x	x	
Manning Rate	x			x				
Mission-Capable Rate (MC)	x			x	x	x		
Mission-Impaired Capability Awaiting Parts (MICAP)				x		x		
MMCL Backlog								
Monthly Job Data Documentation (JDD) Error Rate (Before/After Corrections)				x				
MTF and FTD Demand Response and Utilization Rate			x					
Not Mission Capable (NMC) (Supply/Mx/Both) Rate	x			x		x		
Partially mission capable rate (PMC) (Supply/Mx/Both)	x					x		
Percent of Munitions (2W0) task qualified >70%			x					
Personnel Availability rate (PA)				x				
QA Pass Rates (KTL/PE/RIL/QVI/SI)	x							x
QA TDV/UCR/DSV Rates			x					x
Repair cycle Time (Avg days/Processing Rate) (Pre-Mx Time, Post-Mx Time, Repair Time) (Base Repair Cycle Time) (Overall Base Repair Cycle Processing Time)				x		x		
Repeat-Recur Rate (Repeat rate, Recur Rate)	x			x				
Sorties Scheduled (Adjusted/Total)				x			x	
Spare engine Status	x					x		
Special Experience Identifier								
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	x			x		x		
Total Not Mission-Capable rate (TNMC) (Supply/Mx/Both)	x			x	x	x		
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	x		x			x		
Unit Possessed Not Reported (UPNR)	x							
Upgrade Training rate (by skill level) (school backlogs)	x			x		x		
UTE Rate (Actual/Programmed) (Sortie/Hourly)	x	x		x		x		
Weapons Release Reliability/Gun Fire-out Rates								x
Workcenter Utilization Rate	x			x				

Appendix C: Consolidated List of Metrics

Metric Name	AFTTP 3-3.Aircraft Maintenance Tactics, Techniques and Procedures	AFI 11-102 Flying Hour Program Management	AFI 36-2232 Maintenance Training	ACCI 21-118 Logistics Maintenance Performance Indicator Reporting Procedures	AFI 21-103 Equipment Inventory, Status and Utilization Reporting	AFLMA "Blue Book"	AFI 21-165 Aircraft Flying and Maintenance Scheduling Procedures	AFI 21-101 Aircraft and Maintenance Equipment Management
Abort Rate (Air/Ground/Total)	x			x		x		
Aircraft Availability	x			x	x			
Aircraft Inventory (Backup (BAI) and Primary (PAI))				x	x			
Aircraft Possessed (Average, Primary Possessed Rate)	x			x				
Average Sortie duration (Actual/Programmed)	x			x	x	x		
Break Rate (C-3 break rate)	x			x		x		
Cannibalization Rate	x			x		x		
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	x		x			x		
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	x			x		x		
Deviation Rate (Mx/Ops/ATC/Wx/HHQ/SYM/OTH/SUP/UTE, Chargeable/Non-Chargeable)	x			x		x		
Fix Rate (4/8/12-hr)	x			x		x		
Flying Schedule Effectiveness rate (FSE)	x			x		x	x	
Fully Mission-Capable Rate (FMC)	x					x		
Isochronal/Phase Inspection Rate (TDI/Phase Flow Average/Phase Inspection Flow/ISO)	x			x				
Maintenance Scheduling Effectiveness Rate (MSE)	x			x		x	x	
Manning Rate	x			x				
Mission-Capable Rate (MC)	x			x	x	x		
Mission-Impaired Capability Awaiting Parts (MICAP)				x		x		
Not Mission Capable (NMC) (Supply/Mx/Both) Rate	x			x		x		
Partially mission capable rate (PMC) (Supply/Mx/Both)	x					x		
QA Pass Rates (KTL/PE/RIL/QVI/SI)	x							x
QA TDV/UCR/DSV Rates			x					x
Repair cycle Time (Avg days/Processing Rate) (Pre-Mx Time, Post-Mx Time, Repair Time) (Base Repair Cycle Time) (Overall Base Repair Cycle Processing Time)				x		x		
Repeat-Recur Rate (Repeat rate, Recur Rate)	x			x				
Sorties Scheduled (Adjusted/Total)				x			x	
Spare engine Status	x					x		
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	x			x		x		
Total Not Mission-Capable rate (TNMC) (Supply/Mx/Both)	x			x	x	x		
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	x		x			x		
Upgrade Training rate (by skill level) (school backlogs)	x			x		x		
UTE Rate (Actual/Programmed) (Sortie/Hourly)	x	x		x		x		
Workcenter Utilization Rate	x			x				

Appendix D: Mandated Meeting Frequency and Content

	Meeting:	Level Held:	Required Frequency:	Required Participants	Recommended participants	Purpose of meeting	Required agenda	Recommended Agenda	Metrics discussed?
1	TCI Meeting								N
2	TCTO review meeting		Monthly	PS&D (Chair)			supply reconciliation, supply status, scheduling factors, current TCTO status and anticipated problems for all active TCTOs		N
				QA					
3	Pre/Post Dock Meeting			Aircraft Section Technicians					N
				Specialist Section NCOIC					
				Units publish in OI to determine/standardize					
				PS&D					
4	MSEP	Group		Squadron CC			Review MSEP data		Y
				Squadron MOO/Supt					
				WWM					
				Chief Inspector					
				Senior Analysts					
	MSEP monthly summary (report)	Monthly					The MSEP summary will include visual information, graphs, narratives, quality trends identified through inspections and evaluations, discussion of common problem areas and descriptions of successful programs or initiatives		Y
							Compliance with and currency of TOs and directives to include unit. 8.10.19.2. Aircraft and equipment forms documentation. 8.10.19.3. Compliance and Management of Safety, Environmental, Housekeeping, and FOD Programs. 8.10.19.4. Training Program. 8.10.19.5. Key Task List (KTL). 8.10.19.6. Routine Inspection List (RIL). 8.10.19.7. Munitions Program. 8.10.19.8. High-missed carded items.		
							8.10.19.9. Narrative Report: The monthly narrative report must contain an analysis of the MSEP results, a summary of significant CAT I and II discrepancies, technical inspections and recommendations for improvement. Prior to preparing the narrative report, QA must conduct a study of trends		
							8.10.19.10. Trend Analysis		
5	MSEP	Wing	Quarterly	Wing CC (Chair)			Quality issues		Y
							actionable feedback for unit leadership concerning overall health of mx		
							stay abreast of Mx Issues		
6	IREP	Wing	Quarterly	Wing/CV (Chair)	LRS	increase overall base self-sufficiency for repair and reduce the overall cost of operations	key elements of asset management and costs associated with each of the maintenance stock fund divisions		Y
				MXG/CC	LRS, FSC, representatives from maintenance units, O&M resource advisors, maintenance analysis, AFREP (if applicable), QA, and others		Asset Profile/Top Projected MICAP Situations		
				MSG/CC			Test Station Equipment Profile		
							Wing Self-Sufficiency Initiatives		
							High Cost Maintenance		
							Top CANN Items		
							Unit Aircraft Engine Status Review		
							Repair Cycle Bottlenecks		
							AWP Summary		
							Repair Cycle Throughput		
							Part Store Issue Effectiveness		
							Discuss product improvement initiatives and maintenance related to Innovation Development through Employee Awareness (IDEA) submissions		
7		Group	Quarterly				critical support equipment status		Y

8	PIP R&M Meeting	Group		MXG/CC (Chair)						Y
9	Wing Standup	Wing	Daily	Wing Commander (Chair)			Review of previous day activities			Y
							Review of current day activities			
							Identify and resolve issues with executing established maintenance schedule			
							Cat 2 and 3 CANN Aircraft Mx and Supply Status			
10	Scheduling Meeting	Wing	Monthly	Wing Commander (Chair)			Stay abreast of Mx Issues			Y
				dedicated scheduler			outlines past accomplishments, status of flying goals, problems encountered and detailed needs for the next month. PS&D outlines projected maintenance capability and aircraft/equipment availability. If conflicts arise between operational requirements and maintenance capability, present alternatives and limitations. MXG/CC, OG/CC and WG/CC decide what portion of the mission to support and to what deg			
				AVDO						
11	Munitions Scheduling and Training Meeting	Group...Munitions Flight	Monthly(?)							
12	Meeting to establish priorities	Group	beginning of exercises and contingincies							?
13	Mx Production and Scheduling Meeting	Group	Daily	MXG/CD (Chair)		Verify aircraft and equipment utilization requirements for next day	aircraft status			Y
				MXG/CD designates mandatory attendees		scheduled maintenance requirments for next day	MICAP and Repair Cycle Status			
				Squadron MOO/Supt		establish work priorities	AF IMT 2407 actions			
				MOC Senior Coordinator		coordinate schedule changes	current day flying execution			
				EM Section		Ensure critical equipment, facilities, and materiel resources are allocated and establish overall priorities	current day mx execution			
				AVDO			remaining portion of current day schedule			
							review previous day flying deviations			
							review previous day mx schedule deviations			
							supply micaps			
							prioritizing aircraft requiring shared resources			
							review SI, TCI, TCTOs			
							review DFT/CFT schedules			
							daily resolution of configuration management notices utilizing screen 690 or applicable MIS screen discrepancies			
14			weekly				review next week's flying and mx schedule			Y
							review overdue special inspections and TCIs			
							review TCTOs that will ground within 30 days			
							DFT/CFT schedule requirements			
							review previous week's deviations to flying schedule			
							review previous week's deviations to mx schedule			
15	Status of Training	Squadron	monthly	Squadron CC		Ensure upgrade training and maintenance qualification programs emphasize quality and are not primarily focused on meeting minimum upgrade time frames				Y
16	Status of Training Briefing	Group	Monthly	Group CC						Y
17	Status of Training Briefing	Wing	Quarterly	Wing CC						Y
18	AMU Maintenance Production Meeting	AMU/Flight	daily	AMU OIC/Supt						Y
19	DIT Meeting		Lead Command Determines							Y
20	Scheduling Meeting	Group	Quarterly (NLT 14 days before the next quarter)	MXG/CC, OG/CC (chair)			unit's quarterly plan and includes operational requirements, support capability and any difficulties expected			Y
				dedicated scheduler						
				AVDO						
21			Weekly	dedicated scheduler			evaluate the past week's accomplishments (to include flying and MSE) and negotiate/approve refinements to the coming week's schedule			Y
				AVDO						

22	Wing Weapons Meeting	Wing	Monthly	WWM (Chair)	Weapons AFETS	discuss and resolve any wing weapons issues, concerns or problems			?
				WS					
				wing safety					
				quality assurance					
				munitions flight					
				armament flight					
				weapons sections					
23	FOD Prevention Committee		Monthly when units exceed standard	Wing/CV		identify negative trends and develop action plans to resolve them		Total number of airframe, engine, and tire FOD incidents during the reporting period. Indicate quantity and cause. Current status of all other pending incidents will be discussed.	Y
			Quarterly if FOD rates less than standard	Group Commanders				Mechanical/vacuum sweeper status.	
				Directors				Review and refinement of the existing FOD prevention program.	
				Commanders of units with Mx personnel				New directives/actions established to minimize FOD.	
				Safety				Status and condition of engine run-up screens as applicable.	
				CE				Results of X-rays for FOs during engine bay inspections, acceptance inspections, and phase inspections. Maintenance trends should be discussed when an increase in FO is discovered during these X-rays.	
				Airfield Manager				Identification of potential FOD sources.	
				Security Forces				Lost tools/items.	
				Tenant Unit FOD committees				Increased potential for FOD within the next 30-60 days.	
								Dropped objects. Pay particular attention to those that result in downstream FOD.	
								Breakdown of FOD inspections/assessments.	
								Cockpit FO incidents.	
								Commanders comments.	

Appendix E: Maintenance Metrics Survey

Purpose of Survey

PURPOSE:

The purpose of this survey is to collect and analyze the opinions of maintenance experts regarding maintenance metrics used in the CAF aircraft maintenance community. The results of this survey will be used to:

1) Explore the utility of a metrics framework called "balanced scorecard" for use in a Maintenance Group.

2) Explore the optimal frequency of metrics analysis at each maintenance management level.

3) Evaluate the "goodness" individual maintenance metrics.

4) Aid in determining whether the current metrics set sufficiently meets the needs of decision makers who use them.

5) Recommend changes to the existing metrics framework to Headquarters Air Force Director of Logistics (AF/A4L).

CONFIDENTIALITY:

All answers will be kept strictly confidential. In no way will the information you provide be used to determine who you are. The demographic information is valuable to this research and will only be used in analysis of the results. No one other than the researcher will see your responses. Group trends and statistical findings may be published and briefed to leadership personnel as part of this research.

PARTICIPATION:

Participation is strictly voluntary. You are not required to participate in this survey. This survey should take approximately 20 to 30 minutes to complete. You may exit this survey and return to it at any time if you do not finish on your first attempt.

INSTRUCTIONS:

- Please base your answers on your own thoughts and experiences
- Please make your answers clear and concise when asked to answer in a response or when providing comments
- Be sure to select the correct option button when asked

CONTACT:

If you have questions about this survey please contact adrienne.stahl@afit.edu.

Maintenance Experience demographics

1. What is your rank?

- ◯ 2Lt (O-1)
- ◯ 1Lt (O-2)
- ◯ Captain (O-3)
- ◯ Major (O-4)
- ◯ LtCol (O-5)
- ◯ Colonel (O-6)

2. Which most closely describes your current MAJCOM (or equivalent)?

- ◯ ACC
- ◯ AETC
- ◯ AFGSC
- ◯ AFMC
- ◯ AFSC
- ◯ AFSOC
- ◯ AMC
- ◯ Direct Reporting Unit (DRU)
- ◯ DLA
- ◯ Forward Operating Agency (FOA)
- ◯ HAF
- ◯ PACAF
- ◯ USAFCENT
- ◯ USAFE
- ◯ Other (please specify)

3. What is the management level of your current position?

- ◯ Flight Commander
- ◯ AMU OIC
- ◯ EMS/CMS/MXS/Muns/MOS Operations Officer
- ◯ AMXS Operations Officer
- ◯ Squadron Commander
- ◯ Deputy or Group Commander
- ◯ MAJCOM
- ◯ Depot
- ◯ Other (please specify)

4. How many years of experience do you have in Aircraft Maintenance?

5. How many years of experience do you have in a Combat Air Forces (CAF) flying wing?

6. What levels of maintenance have you managed? Please select all that apply.

- ☐ Flight Commander
- ☐ AMU OIC
- ☐ EMS/CMS/MXS/Muns/MOS Operations Officer
- ☐ AMXS Operations Officer/Squadron Maintenance Officer (SMO)
- ☐ Squadron Commander
- ☐ Deputy or Group Commander
- ☐ MAJCOM
- ☐ Depot
- ☐ Other (please specify)

7. How much experience do you have analyzing or reporting maintenance metrics?

Balanced Scorecard Overview

The purpose of this portion of the survey is to assess the utility of the balanced scorecard concept for use in the Maintenance Group.

The balanced scorecard is a metrics framework that suggests a "balanced" focus on metrics represented in four perspectives. The four perspectives are defined as:

1) Customer Perspective: Entity the Maintenance Group provides for
2) Readiness Perspective: Bottom-line mission or combat capability
3) Processes Perspective: Actions required to meet customer needs
4) Workforce Quality Perspective: Ability/skill to meet standards

The survey questions will assess which existing metrics could fall under each perspective, and identify where shortfalls in metrics representing each perspective may exist.

Assessment of a Maintenance Group's Strategic Objectives

Most CAF Maintenance Groups have vision and mission statements describing their goals and objectives; however, these vision and mission statements can vary from wing to wing.

The purpose of this section is to determine the over-arching strategic objectives of a typical CAF Maintenance Group.

8. What is your assessment of the following statement?

The primary strategic objective of a CAF Maintenance Group is to facilitate and ensure combat/mission-readiness of the flying wing.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Comments:

Balanced Scorecard Perspective #1: Maintainers as Customers

The purpose of this section is to identify the customer(s) for use in the Maintenance Group balanced scorecard.

***9. Do you believe the Maintenance Group should view Maintainers as customers, in terms of providing them support, training or services?**

- ◯ Yes
- ◯ No
- ◯ I don't know

Comments:

Balanced Scorecard Perspective #1: Ops/Aircrew as Customer

***10. Do you believe the Maintenance Group should view Aircrew as customers, in terms of providing them support, training or services?**

- ◯ Yes
- ◯ No
- ◯ I don't know

Comments:

Balanced Scorecard Perspective #1: Equipment as Customer

***11. Do you believe the Maintenance Group should view Equipment as a customer, in terms of providing support, training or services?**

- ◯ Yes
- ◯ No
- ◯ I don't know

Comments:

Balanced Scorecard Perspective #1: Aircraft as Customer

***12. Do you believe the Maintenance Group should view Aircraft as a customer, in terms of providing support, training or services?**

- ◯ Yes
- ◯ No
- ◯ I don't know

Comments:

Balanced Scorecard Perspective #2: Processes for Maintainers as Customer

The purpose of this section is to identify the critical processes in the Maintenance Group that ensure the satisfaction of their customers.

13. Please rate the importance of each of the following processes in providing for Maintainers as the customer.

Example: The ____ process is critical in providing for Maintainers as the customer.

	Unimportant	Of little importance	Moderately important	Important	Critical
Aircraft flying scheduling	◯	◯	◯	◯	◯
Aircraft flying execution	◯	◯	◯	◯	◯
Aircraft maintenance scheduling	◯	◯	◯	◯	◯
Aircraft maintenance execution	◯	◯	◯	◯	◯
Equipment maintenance scheduling	◯	◯	◯	◯	◯
Equipment maintenance execution	◯	◯	◯	◯	◯
Maintenance training scheduling	◯	◯	◯	◯	◯
Maintenance training execution	◯	◯	◯	◯	◯
Aircrew Mission/Training scheduling	◯	◯	◯	◯	◯
Aircrew Mission/Training execution	◯	◯	◯	◯	◯

Comments:

Balanced Scorecard Perspective #2: Processes for Aircrew as Customers

The purpose of this section is to identify the critical processes in the Maintenance Group that ensure the satisfaction of their customers.

14. Please rate the importance of each of the following processes in providing for Aircrew as the customer.

Example: The ___ process is critical in providing for Aircrew as the customer.

	Unimportant	Of little importance	Moderately important	Important	Critical
Aircraft flying scheduling	◯	◯	◯	◯	◯
Aircraft flying execution	◯	◯	◯	◯	◯
Aircraft maintenance scheduling	◯	◯	◯	◯	◯
Aircraft maintenance execution	◯	◯	◯	◯	◯
Equipment maintenance scheduling	◯	◯	◯	◯	◯
Equipment maintenance execution	◯	◯	◯	◯	◯
Maintenance training scheduling	◯	◯	◯	◯	◯
Maintenance training execution	◯	◯	◯	◯	◯
Aircrew Mission/Training scheduling	◯	◯	◯	◯	◯
Aircrew Mission/Training execution	◯	◯	◯	◯	◯

Comments:

Balanced Scorecard Perspective #2: Processes for Equipment as Customer

The purpose of this section is to identify the critical processes in the Maintenance Group that ensure the satisfaction of their customers.

15. Please rate the importance of each of the following processes in providing for Equipment as the customer.

Example: The ___ process is critical in providing for Equipment as the customer.

	Unimportant	Of little importance	Moderately important	Important	Critical
Aircraft flying scheduling	◯	◯	◯	◯	◯
Aircraft flying execution	◯	◯	◯	◯	◯
Aircraft maintenance scheduling	◯	◯	◯	◯	◯
Aircraft maintenance execution	◯	◯	◯	◯	◯
Equipment maintenance scheduling	◯	◯	◯	◯	◯
Equipment maintenance execution	◯	◯	◯	◯	◯
Maintenance training scheduling	◯	◯	◯	◯	◯
Maintenance training execution	◯	◯	◯	◯	◯
Aircrew Mission/Training scheduling	◯	◯	◯	◯	◯
Aircrew Mission/Training execution	◯	◯	◯	◯	◯

Comments:

Balanced Scorecard Perspective #2: Processes for Aircraft as Customer

The purpose of this section is to identify the critical processes in the Maintenance Group that ensure the satisfaction of their customers.

16. Please rate the importance of each of the following processes in providing for Aircraft as the customer.

Example: The ___ process is critical in providing for Aircraft as the customer.

	Unimportant	Of little importance	Moderately important	Important	Critical
Aircraft flying scheduling	◯	◯	◯	◯	◯
Aircraft flying execution	◯	◯	◯	◯	◯
Aircraft maintenance scheduling	◯	◯	◯	◯	◯
Aircraft maintenance execution	◯	◯	◯	◯	◯
Equipment maintenance scheduling	◯	◯	◯	◯	◯
Equipment maintenance execution	◯	◯	◯	◯	◯
Maintenance training scheduling	◯	◯	◯	◯	◯
Maintenance training execution	◯	◯	◯	◯	◯
Aircrew Mission/Training scheduling	◯	◯	◯	◯	◯
Aircrew Mission/Training execution	◯	◯	◯	◯	◯

Comments:

Balanced Scorecard Perspective #2: Processes

17. Which of the following processes does the Maintenance Group have an impact on? Please select all that apply.

- ☐ Flying scheduling
- ☐ Flying execution
- ☐ Aircraft maintenance scheduling
- ☐ Aircraft maintenance execution
- ☐ Equipment maintenance scheduling
- ☐ Equipment maintenance execution
- ☐ Maintenance training scheduling
- ☐ Maintenance training execution
- ☐ Aircrew Mission/Training scheduling
- ☐ Aircrew Mission/Training execution

Comments:

18. Please select the metric(s) that depict the efficiency/effectiveness of each process listed.

Example: The ___ rate depicts the efficiency/effectiveness of the Flying Scheduling Process.

	Flying Scheduling Process	Flying Execution Process
Abort Rate (Air/Ground/Total)	☐	☐
Aircraft Availability	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐
Break Rate (C-3 break rate)	☐	☐
Cannibalization Rate	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐
Fix Rate (4/8/12-hour)	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐
Manning Rate	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐
QA TDV/UCR/DSV Rates	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐
Spare Engine Status	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐
Workcenter Utilization Rate	☐	☐
None of the above	☐	☐

19. Please assess the following statement:

There are adequate metrics to depict the efficiency/effectiveness of the Flying Scheduling and Flying Execution processes.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Please suggest any metrics that could better depict efficiency/effectiveness of the Flying Scheduling and Flying Execution processes.

20. Please select the metric(s) that depict the efficiency/effectiveness of each process listed.

Example: The ___ rate depicts the efficiency/effectiveness of the Aircraft Mx Scheduling Process.

	Aircraft Mx scheduling process	Aircraft Mx execution process
Abort Rate (Air/Ground/Total)	☐	☐
Aircraft Availability	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐
Break Rate (C-3 break rate)	☐	☐
Cannibalization Rate	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐
Fix Rate (4/8/12-hour)	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐
Manning Rate	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐
QA TDV/UCR/DSV Rates	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐
Spare Engine Status	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐
Workcenter Utilization Rate	☐	☐
None of the above	☐	☐

21. Please assess the following statement:

There are adequate metrics to depict the efficiency/effectiveness of the Aircraft Mx Scheduling and Aircraft Mx Execution processes.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Please suggest any metrics that could better depict efficiency/effectiveness of the Aircraft Mx Scheduling and Aircraft Mx Execution processes.

22. Please select the metric(s) that depict the efficiency/effectiveness of each process listed.

Example: The ___ rate depicts the efficiency/effectiveness of the Equipment Mx Scheduling Process.

	Equipment Mx scheduling	Equipment Mx execution
Abort Rate (Air/Ground/Total)	☐	☐
Aircraft Availability	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐
Break Rate (C-3 break rate)	☐	☐
Cannibalization Rate	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐
Fix Rate (4/8/12-hour)	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐
Manning Rate	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐
QA TDV/UCR/DSV Rates	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐
Spare Engine Status	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐
Workcenter Utilization Rate	☐	☐
None of the above	☐	☐

23. Please assess the following statement:

There are adequate metrics to depict the efficiency/effectiveness of Equipment Mx Scheduling and Equipment Mx Execution processes.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Please suggest metrics that could better depict efficiency/effectiveness of the Equipment Mx Scheduling and Equipment Mx Execution processes.

24. Please select the metric(s) that depict the efficiency/effectiveness of each process listed.

Example: The ___ rate depicts the efficiency/effectiveness of the Mx Training Scheduling Process.

	Mx Training Scheduling	Mx Training Execution
Abort Rate (Air/Ground/Total)	☐	☐
Aircraft Availability	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐
Break Rate (C-3 break rate)	☐	☐
Cannibalization Rate	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐
Fix Rate (4/8/12-hour)	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐
Manning Rate	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐
QA TDV/UCR/DSV Rates	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐
Spare Engine Status	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐
Workcenter Utilization Rate	☐	☐
None of the above	☐	☐

25. Please assess the following statement:

There are adequate metrics to depict the efficiency/effectiveness of Mx Training Scheduling and Mx Training Execution processes.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Please suggest metrics that could better depict efficiency/effectiveness of the Mx Training Scheduling and Mx Training Execution processes.

26. Please select the metric(s) that depict the efficiency/effectiveness of each process listed.

Example: The _____ rate depicts the efficiency/effectiveness of the Aircrew Mission/Training Scheduling Process.

	Aircrew Mission/Training scheduling	Aircrew Mission/Training execution
Abort Rate (Air/Ground/Total)	☐	☐
Aircraft Availability	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐
Break Rate (C-3 break rate)	☐	☐
Cannibalization Rate	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐
Fix Rate (4/8/12-hour)	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐
Manning Rate	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐
QA TDV/UCR/DSV Rates	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐
Spare Engine Status	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐
Workcenter Utilization Rate	☐	☐
None of the above	☐	☐

27. Please assess the following statement:

There are adequate metrics to depict the efficiency/effectiveness of Aircrew Mission/Training Scheduling and Aircrew Mission/Training Execution processes.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Please suggest metrics that could better depict efficiency/effectiveness of the Aircrew Mission/Training Scheduling and Aircrew Mission/Training Execution processes.

Balanced Scorecard Perspective #3: Readiness

The purpose of this section is to identify the metrics that best depict the readiness of Maintenance Group entities.

28. For each Maintenance Group entity listed (Maintainers, Aircraft and Equipment), please select the metric(s) that depicts the readiness of those entities.

Example: The ___ rate depicts the readiness of Maintainers, the __ rate depicts the readiness of Aircraft, and the __ rate depicts the readiness of equipment.

	Maintainer readiness	Aircraft readiness	Equipment readiness
Abort Rate (Air/Ground/Total)	☐	☐	☐
Aircraft Availability	☐	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐	☐
Break Rate (C-3 break rate)	☐	☐	☐
Cannibalization Rate	☐	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐	☐
Fix Rate (4/8/12-hour)	☐	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐	☐
QA TDV/UCR/DSV Rates	☐	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐	☐
Spare Engine Status	☐	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐	☐
Workcenter Utilization Rate	☐	☐	☐
Manning Rate	☐	☐	☐
None of the above	☐	☐	☐

29. What is your assessment of the following statement?

There are adequate metrics to depict the readiness of Maintenance Group entities.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Please suggest metrics that could better depict the readiness of Maintenance Group entities.

Balanced Scorecard Perspective #4: Workforce Quality

The purpose of this section is to identify the metrics that best depict the quality and skills of Maintainers.

30. Please select the metric(s) that depict each of the Workforce Quality indicators below.

Example: The ___ rate depicts the Quality of Maintenance in the Maintenance Group.

	Mx quality	Mx safety
Abort Rate (Air/Ground/Total)	☐	☐
Aircraft Availability	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐
Break Rate (C-3 break rate)	☐	☐
Cannibalization Rate	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐
Fix Rate (4/8/12-hour)	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐
Manning Rate	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐
QA TDV/UCR/DSV Rates	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐
Spare Engine Status	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐
Workcenter Utilization Rate	☐	☐
None of the above	☐	☐

31. Please select the metric(s) that depict each of the Workforce Quality indicators below.

Example: The ___ rate depicts Maintainer experience level in the Maintenance Group.

	Maintainer skill level	Maintainer experience level
Abort Rate (Air/Ground/Total)	☐	☐
Aircraft Availability	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐
Break Rate (C-3 break rate)	☐	☐
Cannibalization Rate	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐
Fix Rate (4/8/12-hour)	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐
Manning Rate	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐
QA TDV/UCR/DSV Rates	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐
Spare Engine Status	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐
Workcenter Utilization Rate	☐	☐
None of the above	☐	☐

32. Please select all metrics that depict each of the Workforce Quality indicators below.

Example: The ___ rate depicts Maintainer discipline in the Maintenance Group.

	Maintainer Discipline	Maintainer Retention
Abort Rate (Air/Ground/Total)	☐	☐
Aircraft Availability	☐	☐
Aircraft Inventory (Backup (BAI) and Primary (PAI))	☐	☐
Aircraft Possessed (Average, Primary Possessed Rate)	☐	☐
Average Sortie duration (Actual/Programmed)	☐	☐
Break Rate (C-3 break rate)	☐	☐
Cannibalization Rate	☐	☐
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	☐	☐
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	☐	☐
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	☐	☐
Fix Rate (4/8/12-hour)	☐	☐
Flying Schedule Effectiveness Rate (FSE)	☐	☐
Maintenance Scheduling Effectiveness Rate (MSE)	☐	☐
Manning Rate	☐	☐
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	☐	☐
Mission-Impaired Capability Awaiting Parts (MICAP)	☐	☐
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	☐	☐
QA Pass Rates (KTL/PE/RIL/QVI/SI)	☐	☐
QA TDV/UCR/DSV Rates	☐	☐
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	☐	☐
Repeat-Recur Rate (Repeat rate, Recur Rate)	☐	☐
Sorties Scheduled (Adjusted/Total)	☐	☐
Spare Engine Status	☐	☐
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	☐	☐
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	☐	☐
Upgrade Training Rate (by skill level) (school backlogs)	☐	☐
UTE Rate (Actual/Programmed, Sortie/Hourly)	☐	☐
Workcenter Utilization Rate	☐	☐
None of the above	☐	☐

33. What is your assessment of the following statement?

There are adequate metrics to depict the Workforce Quality of the Maintenance Group.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Please suggest metrics that could better depict the Workforce Quality of the Maintenance Group.

Maintenance Metric Set

The purpose of this section is to determine the utility of the Maintenance Group balanced scorecard, and the optimal frequency of analysis of the metrics in each perspective.

34. What is your assessment of the following statement?

It would be beneficial to study metrics representing each perspective (Customer, Readiness, Processes, Workforce Quality) in the same meeting.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
○	○	○	○	○

Comments:

35. At what management level, and how often, should the metrics focusing on all perspectives (Customer, Readiness, Processes, Workforce Quality) be studied? Please select all that you believe should apply.

	Never	More than once daily	Once daily	Weekly	Monthly	Quarterly	Annually
Flight Level	☐	☐	☐	☐	☐	☐	☐
Squadron Level	☐	☐	☐	☐	☐	☐	☐
Group Level	☐	☐	☐	☐	☐	☐	☐
Wing Level	☐	☐	☐	☐	☐	☐	☐

Comments:

Individual Metrics Assessment

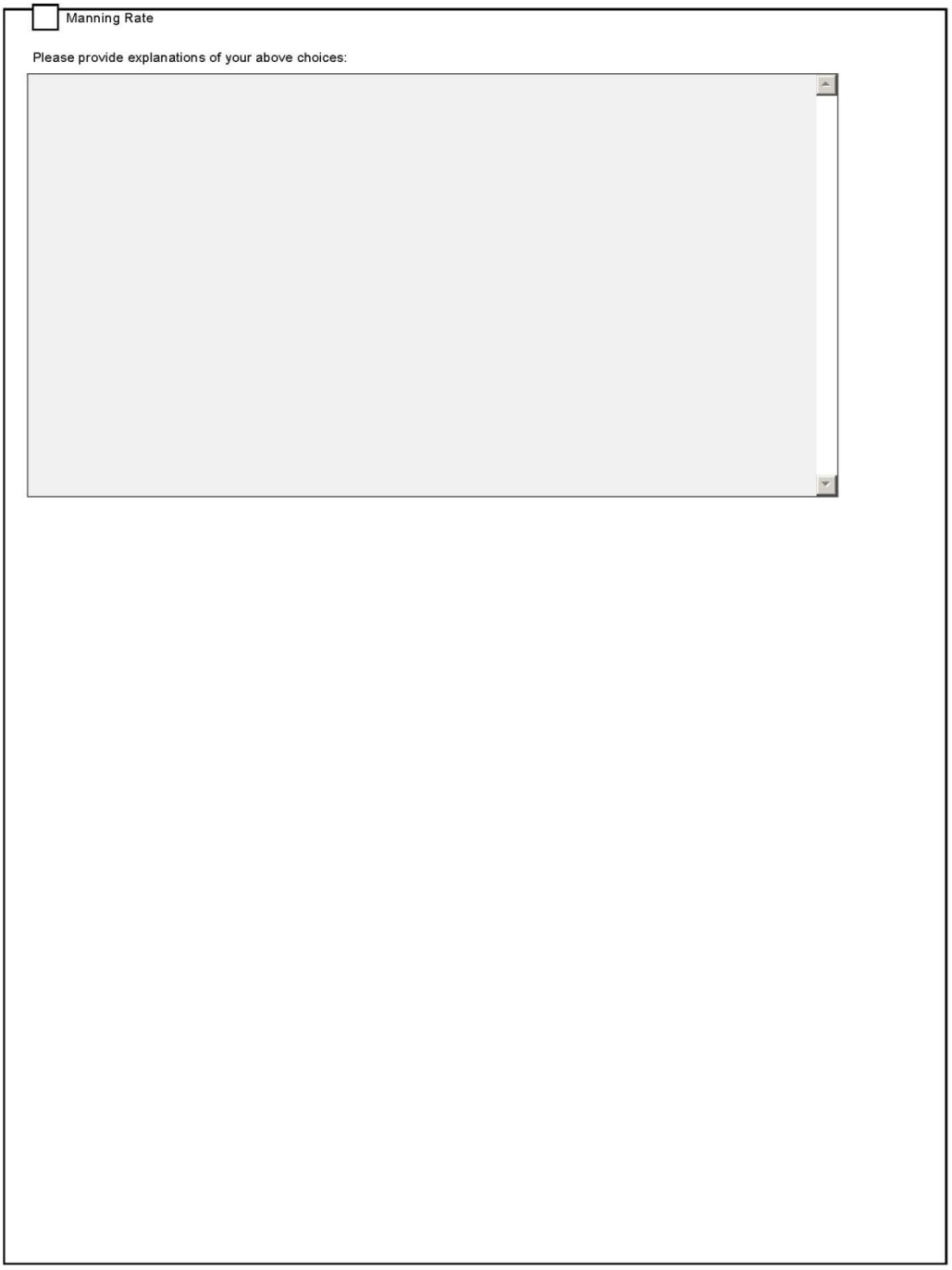
The purpose of this section of the survey is to evaluate 28 individual maintenance metrics based on your experience analyzing/utilizing the metric.

36. Considering the following maintenance metrics, please:

1) Indicate all metrics you believe are NOT "good" metrics for any reason

2) Explain your reason for each metric in comment space provided

- ☐ Abort Rate (Air/Ground/Total)
- ☐ Aircraft Availability
- ☐ Aircraft Inventory (Backup (BAI) and Primary (PAI))
- ☐ Aircraft Possessed (Average, Primary Possessed Rate)
- ☐ Average Sortie duration (Actual/Programmed)
- ☐ Break Rate (C-3 break rate)
- ☐ Cannibalization Rate
- ☐ Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)
- ☐ Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)
- ☐ Deviation Rate (Mx/Ops/ATC/Wx/HHQ/SYM/OTH/SUP/UTE)(Chargeable/Non-Chargeable)
- ☐ Fix Rate (4/8/12-hour)
- ☐ Flying Schedule Effectiveness Rate (FSE)
- ☐ Isochronal/Phase Inspection Rate (TDI/Phase Flow Average/Phase Inspection Flow/ISO)
- ☐ Maintenance Scheduling Effectiveness Rate (MSE)
- ☐ Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)
- ☐ Mission-Impaired Capability Awaiting Parts (MICAP)
- ☐ QA Pass Rates (KTL/PE/RIL/QVI/SI)
- ☐ QA TDV/UCR/DSV Rates
- ☐ Repair cycle Time (Avg days/Processing Rate) (Pre-Mx Time, Post-Mx Time, Repair Time)
- ☐ Repeat-Recur Rate (Repeat rate, Recur Rate)
- ☐ Sorties Scheduled (Adjusted/Total)
- ☐ Spare Engine Status
- ☐ Supply Effectiveness Rate (Issue/Stockage/Benchstock)
- ☐ Training Rate (No-Shows/Overdues/Training Effectiveness Rate)
- ☐ Upgrade Training Rate (by skill level) (school backlogs)
- ☐ UTE Rate (Actual/Programmed, Sortie/Hourly)
- ☐ Workcenter Utilization Rate
- ☐



Appendix F: Internal Review Board exemption letter

DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE OF TECHNOLOGY
WRIGHT-PATTERSON AIR FORCE BASE OHIO

18 December 2013

MEMORANDUM FOR LT COL JOSEPH HUSCROFT

FROM: Joseph B. Skipper, Lt Col, Ph.D.
AFIT IRB Research Reviewer
2950 Hobson Way
Wright-Patterson AFB, OH 45433-7765

SUBJECT: Approval for exemption request from human experimentation requirements (32 CFR 219, DoDD 3216.2 and AFI 40-402) for "An Analysis of Aircraft Maintenance Metrics."

1. Your request was based on the Code of Federal Regulations, title 32, part 219, section 101, paragraph (b) (2) Research activities that involve the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior unless: (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) Any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

2. Your study qualifies for this exemption because you are not collecting sensitive data, which could reasonably damage the subjects' financial standing, employability, or reputation. Further, the demographic data you are collecting cannot realistically be expected to map a given response to a specific subject. Your plan includes ample and appropriate measures to safeguard any information collected and your mitigation plan should such breech occur is adequate.

3. This determination pertains only to the Federal, Department of Defense, and Air Force regulations that govern the use of human subjects in research. Further, if a subject's future response reasonably places them at risk of criminal or civil liability or is damaging to their financial standing, employability, or reputation, you are required to file an adverse event report with this office immediately.

Joseph B. Skipper

JOSEPH B. SKIPPER, Lt Col, Ph.D.
AFIT Exempt Determination Official

Appendix G. Survey Control Number

5 February 2014

MEMORANDUM FOR AIR FORCE INSTITUTE OF TECHNOLOGY (AFIT)
ATTENTION: LT COL JOSEPH HUSCROFT

FROM: AFPC/DSYS
550 C Street West
Randolph AFB TX 78158

SUBJECT: Survey Approval – Maintenance Metrics Survey.

1. The survey is approved for use with the following population(s):

Population:	Number(s):
Air Force Active-Duty Officers	1,500
Air Force Active-Duty Enlisted	0
Air Force Civilians	0
Air Force Retirees and/or AF Family Members	0
Total Number to be Surveyed	1,500

The Survey Control Number (SCN) for this effort is **AF14-123AFIT**. This SCN is valid from **02/14/2014** through **2/28/2014.**

Please ensure compliance with the following guidance, as applicable, while administering your survey.

a. Invitations to participate in the survey must include:

(1) Survey title (as shown in the subject line of this memo).

(2) AF Survey Control Number (SCN).

(3) Statement that completion of the survey is voluntary.

(4) Link to the list of Air Force approved surveys: https://www.my.af.mil/gcss-af/USAF/ep/browse.do?programId=t2D8EB9D6297405FA012980243147010A&channelPageId=s5FDEA9F02134FFA70121351677C80048.

(5) Government contact name or office, with official contact information (e.g., e-mail address, telephone number, etc.), to provide a point of contact for questions about the survey.

(6) Identifying information of the survey's sponsor, to inform survey recipients under whose authority the survey is being conducted.

(7) All AF attitude and opinion surveys must include the following statement on the questionnaire: "We cannot provide confidentiality to a participant regarding comments involving criminal activity/behavior, or statements that pose a threat to yourself or others. Do NOT discuss or comment on classified or operationally sensitive information."

b. This approval is exclusive to the Air Force community and does not constitute authority for administration to individuals from other federal agencies, sister services, etc. Surveys that include individuals from outside the Air Force community must be coordinated through the DOD/WHS/ESCD Information Management Division (commercial phone 703-696-5284).

c. The organization conducting this survey must contact the Civilian Personnel Office; Civilian Personnel Element, Manpower & Personnel Flight; for labor union notification prior to releasing this survey if any participants are civilian employees of a bargaining unit. If this survey involves bargaining unit civilians at more than one base, the organization conducting this survey must notify HQ AFPC/DPIECC, Air Force Program Management and Evaluation.

d. The organization conducting this survey must insure that if this survey requires any changes, request must be submitted to the Survey Office for review and approval prior to implementation in accordance with AFI 38-501.

e. This survey does/does not require review by an Air Force Institutional Review Board. If this survey requires an IRB, the PI must submit all proposed survey changes to the Survey and IRB Office for review and approval (minor changes do not require a change of SCN number) prior to implementation in accordance with AFI 38-501.

f. AFI 33-129, Web Management and Internet Use, paragraph 3.2.5.; 3.7.4, and 3.7.5; Please contact SAF/XCDIG, 1800 Air Force Pentagon, Washington DC 20330-1800, for further guidance details which requires that all websites hosted in the commercial environment (i.e., ".com", ".org", etc.) receive SAF/A6 approval. The organization conducting this survey must coordinate with SAF/A6 (e-mail address A3CS.A6CSStrategy@pentagon.af.mil) for approval of a waiver if the survey will be hosted on any website other than a ".mil" account. If a waiver is required, it must be granted by SAF/A6 prior to administration of the survey.

g. For information regarding digital certification of e-mails, refer to AFI 33-119, *Air Force Messaging*. The reference for PK enabling (PKE) information is https://afpki.lackland.af.mil/html/pkenabling.cfm. For information pertaining to ".mil" accounts, the reference is https://afpki.lackland.af.mil/html/help_desk.cfm. Information for systems that are not ".mil" can be found at http://iase.disa.mil/pki/eca/. For information on External Certificate Authority or to contact a representative, the reference is http://iase.disa.mil/pki/eca/contact_us.html.

h. The organization conducting this survey must ensure its Operations Security (OPSEC) manager reviews this survey prior to administration. References for the OPSEC Program include: DOD Directive 5205.02, *DOD Operations Security Program*; Joint Publication 3-13.3, *Operations Security*; AFPD 10-7, *Air Force Information Operations*; and AFI 10-701, *Operations Security (OPSEC)*.

i. The public may request survey results under provisions of the Freedom of Information Act (FOIA). Results released outside the Air Force require coordination with Air Force Public Affairs prior to dissemination.

j. Data collected under this survey may be subject to the Privacy Act of 1974. Please ensure compliance with this act as set forth in Title 5 United States Code (USC), Sec 552a; Title 10 USC, Sec 55 and 8013; Executive Order 9397; and Air Force Instruction 33-332, *Privacy Act Program*.

2. If you have any questions, please call the Air Force Survey Office at DSN 487-5332 or send an e-mail to af.survey@us.af.mil.

//Signed//
RENEE TEALER
Management Analyst
Air Force Survey Office

Appendix H: Process and Assigned Metrics Cross Tabulation

Answer Options	Flying Scheduling Process	Flying Execution Process	Aircraft Mx scheduling process	Aircraft Mx execution process	Equipment Mx scheduling	Equipment Mx execution	Mx Training Scheduling	Mx Training Execution	Aircrew Mission/ Training scheduling	Aircrew Mission/ Training execution	Maintainer readiness	Aircraft readiness	Equipment readiness	Mx quality	Mx safety	Maintainer skill level	Maintainer experience level	Maintainer Discipline	Maintainer Retention
Abort Rate (Air/Ground/Total)	25.6%	83.7%	25.5%	57.4%	12.3%	21.8%	15.3%	23.7%	23.0%	54.3%	26.4%	74.7%	14.5%	72.8%	24.6%	29.8%	43.8%	28.6%	11.3%
Aircraft Availability	80.1%	47.5%	81.9%	51.8%	24.1%	20.3%	28.8%	24.1%	46.1%	36.7%	30.9%	88.5%	21.9%	53.3%	6.9%	23.5%	32.0%	24.4%	15.0%
Aircraft Inventory (Backup (BAI) and Primary (PAI))	63.8%	21.6%	54.6%	19.5%	19.9%	13.4%	18.2%	12.4%	32.4%	21.1%	8.6%	55.4%	9.7%	21.0%	4.7%	5.1%	6.6%	7.5%	5.3%
Aircraft Possessed (Average; Primary Possessed Rate)	67.1%	26.6%	60.3%	22.7%	21.1%	13.8%	20.4%	13.9%	33.2%	23.8%	11.2%	60.6%	7.8%	22.8%	5.4%	7.0%	8.5%	8.3%	6.0%
Average Sortie duration (Actual/Programmed)	65.1%	62.5%	42.2%	33.7%	17.6%	13.4%	16.4%	11.7%	51.6%	52.7%	9.7%	40.9%	6.3%	21.0%	5.8%	5.9%	7.4%	9.4%	4.9%
Break Rate (C-3 break rate)	32.6%	72.4%	31.9%	58.9%	18.8%	26.1%	18.6%	25.5%	19.5%	41.8%	32.0%	75.5%	16.7%	71.7%	17.0%	34.2%	44.5%	28.2%	12.4%
Cannibalization Rate	40.5%	41.2%	41.1%	48.6%	17.2%	22.2%	13.1%	17.9%	14.5%	12.1%	21.2%	62.1%	22.7%	37.3%	10.5%	19.1%	25.7%	30.1%	9.8%
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	25.9%	28.6%	28.7%	25.9%	16.5%	16.1%	51.8%	52.2%	13.7%	9.4%	84.0%	6.7%	3.0%	38.0%	18.8%	58.1%	25.4%	37.2%	27.8%
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	56.5%	31.2%	73.0%	50.4%	28.0%	24.5%	16.4%	18.6%	19.5%	17.2%	23.4%	77.7%	23.0%	66.7%	10.1%	24.6%	40.1%	42.9%	9.0%
Deviation Rate (Mx/Ops/Wx, etc)(Chargeable/Non-Chargeable)	51.2%	75.4%	39.4%	52.8%	15.3%	19.5%	13.9%	16.1%	35.5%	56.3%	27.1%	55.4%	14.5%	49.3%	11.2%	18.8%	25.7%	26.3%	9.0%
Fix Rate (4/8/12-hour)	46.8%	55.5%	41.8%	65.6%	23.0%	30.7%	17.9%	31.8%	23.8%	28.5%	61.7%	63.6%	24.5%	73.2%	14.5%	48.2%	65.8%	45.5%	17.3%
Flying Schedule Effectiveness Rate (FSE)	76.4%	62.5%	49.3%	40.8%	18.0%	21.1%	16.1%	18.2%	57.8%	60.2%	30.9%	59.5%	17.5%	41.7%	10.5%	17.3%	19.9%	22.9%	10.5%
Maintenance Scheduling Effectiveness Rate (MSE)	68.4%	32.9%	85.5%	64.2%	51.7%	38.3%	24.5%	21.5%	23.4%	17.2%	47.2%	58.4%	42.0%	58.7%	13.4%	28.7%	33.5%	44.7%	13.5%
Manning Rate	49.5%	39.2%	41.5%	36.5%	29.9%	24.1%	41.6%	33.2%	24.6%	20.7%	82.9%	17.8%	13.0%	29.0%	23.6%	33.5%	23.2%	13.2%	48.5%
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	57.8%	56.5%	55.7%	60.3%	28.7%	31.4%	21.2%	28.1%	28.9%	32.4%	38.3%	88.5%	36.1%	56.5%	12.0%	33.8%	41.5%	29.7%	13.5%
Mission-Impaired Capability Awaiting Parts (MICAP)	42.5%	49.5%	39.0%	43.3%	25.3%	28.7%	13.1%	11.7%	18.8%	19.9%	11.2%	62.5%	33.8%	25.0%	5.8%	8.8%	11.8%	14.3%	7.9%
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/ISO)	68.4%	31.6%	76.6%	44.0%	30.3%	24.1%	15.0%	15.3%	25.8%	14.1%	30.5%	72.1%	23.0%	43.5%	11.6%	23.5%	28.7%	25.2%	9.4%
QA Pass Rates (KTI/PE/RIL/QVI/SI)	20.9%	33.2%	19.9%	42.9%	15.7%	29.9%	32.8%	48.5%	7.4%	10.9%	86.6%	13.0%	10.4%	80.1%	60.9%	54.4%	67.6%	85.0%	24.4%
QA TDV/UCR/DSV Rates	20.3%	34.2%	18.4%	39.7%	13.8%	28.4%	31.4%	47.4%	7.0%	11.7%	83.6%	11.9%	9.7%	69.2%	80.1%	52.2%	66.2%	87.2%	24.4%
Repair cycle Time (Avg days) (Pre/Post-Mx Time, Repair Time)	47.8%	29.2%	43.6%	41.8%	37.5%	39.8%	14.2%	20.4%	15.6%	13.3%	34.2%	44.2%	50.2%	42.4%	6.2%	24.3%	34.9%	23.7%	9.0%
Repeat-Recur Rate (Repeat rate, Recur Rate)	35.2%	55.8%	31.9%	63.5%	15.3%	24.1%	22.3%	38.0%	17.6%	30.1%	62.8%	65.1%	21.2%	82.2%	22.5%	47.4%	65.8%	55.6%	16.9%
Sorties Scheduled (Adjusted/Total)	83.4%	38.5%	56.4%	30.9%	19.9%	15.7%	18.2%	15.7%	47.3%	36.3%	19.3%	47.2%	11.9%	22.1%	9.1%	8.1%	8.5%	12.8%	12.0%
Spare Engine Status	36.9%	24.6%	40.8%	32.6%	33.3%	27.2%	11.3%	14.2%	14.5%	10.2%	14.5%	33.8%	61.3%	30.4%	4.7%	15.1%	17.3%	15.4%	6.8%
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	34.2%	34.9%	35.1%	33.7%	26.8%	23.4%	12.4%	12.0%	16.8%	12.5%	9.3%	45.7%	40.5%	22.1%	3.6%	7.0%	9.6%	12.0%	6.8%
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	33.2%	25.9%	34.0%	29.1%	20.3%	18.0%	73.7%	64.6%	18.0%	13.3%	86.2%	8.9%	7.1%	46.7%	27.5%	44.5%	28.3%	52.6%	22.9%
Upgrade Training Rate (by skill level) (school backlogs)	30.9%	27.9%	34.0%	30.1%	19.2%	21.1%	74.1%	65.3%	17.6%	16.0%	90.7%	9.3%	7.1%	49.6%	26.1%	71.0%	36.0%	43.6%	33.5%
UTE Rate (Actual/Programmed, Sortie/Hourly)	69.8%	57.5%	52.1%	41.5%	18.8%	14.2%	17.5%	13.5%	37.5%	35.9%	22.3%	61.0%	15.2%	29.7%	11.6%	9.9%	11.8%	14.7%	12.8%
Workcenter Utilization Rate	38.5%	24.9%	40.4%	34.0%	33.0%	25.3%	36.1%	32.1%	15.2%	13.3%	64.3%	13.8%	11.5%	29.0%	16.7%	22.4%	23.9%	23.7%	26.7%
None of the above	2.0%	1.3%	3.9%	2.8%	14.6%	14.2%	6.6%	5.1%	13.3%	12.1%	3.7%	3.3%	5.6%	3.6%	3.3%	4.8%	5.9%	6.0%	12.8%

Appendix I: Perspective Category Correlation Coefficients

Perspective Category A	Perspective Category B	Correlation Coefficient
Maintainer experience level	Mx quality	0.9667
Maintainer readiness	Mx Training Execution	0.9579
Maintainer skill level	Mx Training Execution	0.9335
Aircraft Mx scheduling process	Flying Scheduling Process	0.9282
Maintainer skill level	Maintainer readiness	0.9129
Maintainer Discipline	Maintainer experience level	0.8919
Maintainer Discipline	Maintainer skill level	0.8807
Maintainer Discipline	Mx quality	0.879
Mx safety	Maintainer readiness	0.877
Mx safety	Mx Training Execution	0.8745
Maintainer skill level	Mx safety	0.8708
Maintainer experience level	Maintainer skill level	0.8603
Aircrew Mission/ Training execution	Aircrew Mission/ Training scheduling	0.8561
Maintainer Retention	Maintainer readiness	0.8532
Aircrew Mission/ Training scheduling	Flying Scheduling Process	0.8455
Maintainer Retention	Mx Training Execution	0.8393
Maintainer skill level	Mx quality	0.8128
Mx Training Execution	Mx Training Scheduling	0.7999
Maintainer Discipline	Mx Training Execution	0.796
Maintainer Retention	Mx safety	0.7868
Maintainer Discipline	Mx safety	0.7849
Maintainer readiness	Mx Training Scheduling	0.7781
Maintainer Discipline	Maintainer readiness	0.7778
Maintainer Retention	Maintainer skill level	0.7597
Maintainer Retention	Mx Training Scheduling	0.742
Maintainer experience level	Mx Training Execution	0.7332
Mx quality	Aircraft Mx execution process	0.7314
Aircrew Mission/ Training execution	Flying Execution Process	0.7288
Aircraft readiness	Aircraft Mx execution process	0.7259
Maintainer experience level	Mx safety	0.7231
Maintainer experience level	Maintainer readiness	0.7055
Mx safety	Mx Training Scheduling	0.6994
Mx safety	Mx quality	0.6919
Aircrew Mission/ Training scheduling	Aircraft Mx scheduling process	0.6908
Maintainer experience level	Aircraft Mx execution process	0.6885
Mx quality	Mx Training Execution	0.6836
Equipment readiness	Equipment Mx execution	0.6757

Aircraft Mx execution process	Flying Execution Process	0.659
Maintainer experience level	Equipment Mx execution	0.6542
Mx quality	Maintainer readiness	0.6518
Maintainer skill level	Mx Training Scheduling	0.6497
Equipment Mx scheduling	Aircraft Mx scheduling process	0.6348
Equipment readiness	Aircraft Mx execution process	0.6279
Equipment Mx execution	Aircraft Mx execution process	0.612
Equipment readiness	Equipment Mx scheduling	0.5972
Maintainer Retention	Maintainer Discipline	0.5909
Aircraft readiness	Aircrew Mission/ Training execution	0.5868
Equipment readiness	Aircraft readiness	0.5764
Mx quality	Equipment Mx execution	0.5642
Aircraft readiness	Flying Execution Process	0.5605
Aircrew Mission/ Training execution	Flying Scheduling Process	0.5521
Maintainer Discipline	Aircraft Mx execution process	0.5163
Maintainer Discipline	Equipment Mx execution	0.5089
Maintainer Retention	Maintainer experience level	0.5057
Aircraft readiness	Aircraft Mx scheduling process	0.5045
Aircraft readiness	Aircrew Mission/ Training scheduling	0.4999
Maintainer skill level	Equipment Mx execution	0.49
Aircrew Mission/ Training scheduling	Flying Execution Process	0.4832
Aircraft readiness	Flying Scheduling Process	0.4726
Maintainer Discipline	Mx Training Scheduling	0.4672
Maintainer Retention	Mx quality	0.452
Equipment Mx scheduling	Flying Scheduling Process	0.4435
Equipment Mx execution	Equipment Mx scheduling	0.4396
Maintainer readiness	Equipment Mx execution	0.4249
Equipment readiness	Aircraft Mx scheduling process	0.408
Aircrew Mission/ Training execution	Aircraft Mx execution process	0.3908
Maintainer skill level	Aircraft Mx execution process	0.3779
Mx quality	Aircraft readiness	0.368
Aircrew Mission/ Training execution	Aircraft Mx scheduling process	0.3599
Maintainer experience level	Mx Training Scheduling	0.3577
Mx Training Execution	Equipment Mx execution	0.3516
Mx quality	Flying Execution Process	0.3486
Mx quality	Mx Training Scheduling	0.3301
Mx safety	Equipment Mx execution	0.2987
Equipment readiness	Flying Scheduling Process	0.2966
Mx safety	Aircraft Mx execution process	0.2946
Maintainer experience level	Aircraft readiness	0.2912

Maintainer experience level	Flying Execution Process	0.2778
Mx quality	Equipment readiness	0.2575
Maintainer Retention	Equipment Mx execution	0.2499
Maintainer experience level	Equipment readiness	0.2495
Maintainer readiness	Aircraft Mx execution process	0.2272
Equipment readiness	Flying Execution Process	0.2224
Flying Execution Process	Flying Scheduling Process	0.2151
Mx Training Execution	Aircraft Mx execution process	0.2067
Aircraft readiness	Equipment Mx execution	0.2051
Mx safety	Flying Execution Process	0.1957
Aircraft Mx execution process	Aircraft Mx scheduling process	0.1751
Aircraft readiness	Equipment Mx scheduling	0.1641
Aircrew Mission/ Training scheduling	Aircraft Mx execution process	0.1562
Aircraft Mx execution process	Flying Scheduling Process	0.149
Aircrew Mission/ Training scheduling	Equipment Mx scheduling	0.1273
Maintainer Discipline	Flying Execution Process	0.1158
Mx quality	Aircrew Mission/ Training execution	0.1007
Maintainer Retention	Aircraft Mx execution process	0.098
Maintainer Discipline	Equipment readiness	0.0933
Maintainer skill level	Flying Execution Process	0.0823
Equipment Mx scheduling	Aircraft Mx execution process	0.0781
Equipment Mx execution	Flying Execution Process	0.0727
Maintainer Discipline	Aircraft readiness	0.0598
Equipment readiness	Aircrew Mission/ Training scheduling	0.0527
Equipment readiness	Aircrew Mission/ Training execution	0.0439
Mx Training Scheduling	Equipment Mx execution	0.0102
Aircraft Mx scheduling process	Flying Execution Process	0.0054
Mx Training Scheduling	Equipment Mx scheduling	-0.0042
Maintainer readiness	Equipment Mx scheduling	-0.0081
Maintainer readiness	Flying Execution Process	-0.0148
Mx Training Execution	Flying Execution Process	-0.0222
Maintainer experience level	Aircrew Mission/ Training execution	-0.0299
Equipment Mx execution	Aircraft Mx scheduling process	-0.0308
Maintainer skill level	Equipment readiness	-0.0335
Maintainer skill level	Aircraft readiness	-0.0399
Aircrew Mission/ Training scheduling	Mx Training Scheduling	-0.0436
Mx Training Scheduling	Aircraft Mx scheduling process	-0.0506
Mx safety	Aircrew Mission/ Training execution	-0.058
Aircrew Mission/ Training execution	Mx Training Scheduling	-0.0622
Maintainer Retention	Flying Execution Process	-0.0718

Mx Training Scheduling	Aircraft Mx execution process	-0.0856
Mx Training Scheduling	Flying Scheduling Process	-0.0924
Mx Training Execution	Equipment Mx scheduling	-0.0959
Maintainer skill level	Equipment Mx scheduling	-0.1084
Maintainer experience level	Equipment Mx scheduling	-0.1137
Maintainer Retention	Equipment Mx scheduling	-0.1265
Mx safety	Aircraft readiness	-0.1283
Aircrew Mission/ Training execution	Equipment Mx scheduling	-0.1382
Equipment readiness	Maintainer readiness	-0.1416
Mx quality	Equipment Mx scheduling	-0.1588
Mx Training Scheduling	Flying Execution Process	-0.1619
Mx quality	Aircraft Mx scheduling process	-0.1628
Mx quality	Aircrew Mission/ Training scheduling	-0.1674
Aircraft readiness	Mx Training Execution	-0.1783
Maintainer Discipline	Equipment Mx scheduling	-0.1784
Aircrew Mission/ Training execution	Mx Training Execution	-0.1796
Equipment Mx execution	Flying Scheduling Process	-0.1899
Equipment readiness	Mx Training Execution	-0.1922
Maintainer readiness	Aircrew Mission/ Training execution	-0.194
Maintainer skill level	Aircrew Mission/ Training execution	-0.2037
Maintainer Discipline	Aircrew Mission/ Training execution	-0.2103
Maintainer experience level	Aircraft Mx scheduling process	-0.2178
Aircraft readiness	Maintainer readiness	-0.2307
Maintainer Retention	Aircrew Mission/ Training execution	-0.235
Aircraft readiness	Mx Training Scheduling	-0.2426
Mx quality	Flying Scheduling Process	-0.2494
Mx safety	Aircrew Mission/ Training scheduling	-0.2506
Mx safety	Equipment readiness	-0.2515
Maintainer readiness	Aircraft Mx scheduling process	-0.2548
Aircrew Mission/ Training execution	Equipment Mx execution	-0.2582
Maintainer Discipline	Aircraft Mx scheduling process	-0.2644
Mx safety	Equipment Mx scheduling	-0.2777
Maintainer Retention	Equipment readiness	-0.2916
Maintainer experience level	Aircrew Mission/ Training scheduling	-0.2975
Maintainer readiness	Aircrew Mission/ Training scheduling	-0.3012
Maintainer readiness	Flying Scheduling Process	-0.3069
Maintainer Retention	Aircraft readiness	-0.3118
Mx Training Execution	Aircraft Mx scheduling process	-0.3152
Maintainer skill level	Aircraft Mx scheduling process	-0.3269
Equipment Mx scheduling	Flying Execution Process	-0.3343

Aircrew Mission/ Training scheduling	Mx Training Execution	-0.3351
Maintainer experience level	Flying Scheduling Process	-0.3357
Maintainer Retention	Aircrew Mission/ Training scheduling	-0.3447
Maintainer Retention	Aircraft Mx scheduling process	-0.3467
Maintainer Retention	Flying Scheduling Process	-0.3661
Maintainer Discipline	Flying Scheduling Process	-0.3721
Maintainer skill level	Aircrew Mission/ Training scheduling	-0.3743
Maintainer Discipline	Aircrew Mission/ Training scheduling	-0.3901
Aircrew Mission/ Training scheduling	Equipment Mx execution	-0.3925
Mx safety	Aircraft Mx scheduling process	-0.3936
Mx Training Execution	Flying Scheduling Process	-0.3937
Mx safety	Flying Scheduling Process	-0.3942
Maintainer skill level	Flying Scheduling Process	-0.4349
Equipment readiness	Mx Training Scheduling	-0.462

Appendix J: Thesis Sponsorship Letter

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON, DC

MEMORANDUM FOR Air Force Institute of Technology (AFIT) Survey Control Panel
HQ AFPC/MAPP

FROM: AF/A4L

SUBJECT: AFIT Student Thesis Sponsorship: Maintenance Metrics Survey

This is to inform you that Major Adrienne L. Stahl, an AFIT graduate student, is conducting a study for my office that will evaluate Aircraft Maintenance Performance Metrics, both individually and as a set. First, she will seek to determine if the current metrics set is sufficiently aligned with the strategic objectives of a CAF flying wing. In addition, Major Stahl will perform a review of the aircraft maintenance performance measurement system and individual metrics to evaluate them against a set of objective evaluation criteria. Lastly, Major Stahl will review the frequency of mandated maintenance metrics study, and determine the optimal interval of meetings for the purpose of the analysis of aircraft maintenance metrics study amongst group and wing level key players. Major Stahl will administer a web-based survey to collect data from Air Force Maintenance Officers.

Determination of the most optimal maintenance metrics set, made up of strategically aligned metrics that are studied at an optimal frequency will assist maintenance leaders and decision makers in evaluating the performance of their aircraft and maintenance operations, their impact on flying operations, and the readiness of the wing.

If you have any questions, please contact Lt Col Joseph Huscroft – Phone 937-255-3636, ext. 4538; E-mail – joseph.huscroft@afit.edu.

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JOHN B. COOPER, Maj Gen, USAF
Director of Logistics
DCS/Logistics, Installations & Mission Support

Appendix K: Metrics Proposal Comparison

Metrics	Stahl	Waller	Harris	Nachtman et al
Abort Rate (Air/Ground/Total)	Incorporate	Remove	n/a	Incorporate
Aircraft Availability	Incorporate	n/a	n/a	n/a
Aircraft Inventory (Backup (BAI) and Primary (PAI))	Eliminate	Re-evaluate	n/a	n/a
Aircraft Possessed (Average, Primary Possessed Rate)	Eliminate	Re-evaluate	n/a	n/a
Average Sortie duration (Actual/Programmed)	Incorporate	Re-evaluate	n/a	n/a
Break Rate (C-3 break rate)	Incorporate	Re-evaluate	n/a	n/a
Cannibalization Rate	Re-evaluate	Remove	n/a	Incorporate
Career Development Course Success Rate (Pass Rate)(Enrolled/Completed)	Incorporate	n/a	n/a	n/a
Delayed Discrepancy Rate (Total, AWP/AWM, Avg per aircraft)	Incorporate	Incorporate	n/a	Incorporate
Deviation Rate (Mx/Ops/ATC/Wx/HHQ/SYM/OTH/SUP/UTE, Chargeable/Non-Chargeable)	Incorporate	Re-evaluate	n/a	Incorporate
Fix Rate (4/8/12-hr)	Eliminate	Incorporate	n/a	Incorporate
Flying Schedule Effectiveness rate (FSE)	Incorporate	Re-evaluate	n/a	Incorporate
Maintenance Scheduling Effectiveness Rate (MSE)	Incorporate	Incorporate	n/a	Incorporate
Manning Rate	Incorporate	n/a	n/a	n/a
Mission Capable Rate (MC, FMC, PMC, NMC, TNMC, M/S/B)	Incorporate		n/a	n/a
Mission-Impaired Capability Awaiting Parts (MICAP)	Re-evaluate	Incorporate	n/a	Incorporate
Phase/Isochronal Inspection Rate (TDI/Phase Flow Average/Phase Inspection Flow/ISO)	Incorporate	n/a	n/a	Incorporate
QA Pass Rates (KTL/PE/RIL/QVI/SI)	Incorporate	n/a	n/a	n/a
QA TDV/UCR/DSV Rates	Incorporate	n/a	n/a	n/a
Repair cycle Time (Avg days/Processing Rate) (Pre-Mx Time, Post-Mx Time, Repair Time) (Base Repair Cycle Time) (Overall Base Repair Cycle Processing Time)	Incorporate	n/a	n/a	n/a
Repeat-Recur Rate (Repeat rate, Recur Rate)	Incorporate	Incorporate	n/a	Incorporate
Sorties Scheduled (Adjusted/Total)	Incorporate	n/a	n/a	n/a
Spare engine Status	Incorporate	n/a	n/a	n/a
Supply Effectiveness Rate (Issue/Stockage/Benchstock)	Re-evaluate	n/a	n/a	n/a
Training Rate (No-Shows/Overdues/Training Effectiveness Rate)	Incorporate	n/a	n/a	Incorporate
Upgrade Training rate (by skill level) (school backlogs)	Incorporate	n/a	n/a	Incorporate
UTE Rate (Actual/Programmed) (Sortie/Hourly)	Incorporate	Re-evaluate	n/a	n/a
Workcenter Utilization Rate	Re-evaluate	n/a	n/a	n/a
Job Standard Fix Rate	Create	n/a	n/a	n/a
Equipment Maintenance Scheduling Effectiveness Rate	Create	n/a	Create	n/a
Equipment Effectiveness/Break Rate	Create	n/a	n/a	n/a
Equipment Fix Rate	Create	n/a	n/a	n/a
Equipment MICAP Rate	Create	n/a	Create	n/a
Maintainer Availability	Create	Incorporate	n/a	n/a
Maintainer Capability Rate	Create	Incorporate	n/a	n/a
Equipment MC/In-Commission Rate	Create	n/a	Create	n/a
Equipment Availability	Create	n/a	n/a	n/a
Mission Effectiveness Rate	Create	n/a	n/a	n/a
Operations Scheduling Effectiveness Rate	Create	n/a	n/a	n/a
RAP Milestones Rate	Create	n/a	n/a	n/a
Maintainer Experience Level	Create	n/a	n/a	n/a
Maintainer Skill Level	Create	n/a	n/a	Incorporate
Overtime Rate	Create	n/a	n/a	n/a
Weekend Duty Rate	Create	n/a	n/a	n/a
Re-enlistment Rate	Create	n/a	n/a	n/a

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Vita

Major Adrienne Stahl graduated from Fort Zumwalt South High School in Saint Peters, Missouri. She entered undergraduate studies at the United States Air Force Academy where she graduated with a Bachelor of Science degree in Management in May 2003. She began her career in the Air Force Academy Department of Admissions, where she served as an Admissions Advisor for the Southeastern United States. In September 2004, she was assigned to the 388th Fighter Wing at Hill Air Force Base, Utah as the Propulsion Flight Commander. She graduated the Aircraft Munitions and Maintenance Officer Course in January 2005, and was then assigned as the 421st Aircraft Maintenance Unit Assistant Officer in Charge. She deployed with the unit in May 2006 to Balad Air Base, Iraq, in support of Operation IRAQI FREEDOM. In October 2006, she was assigned as the 388th Component Maintenance Squadron Operations Officer, and was then assigned as the 388th Maintenance Operations Squadron Operations Flight Commander from January 2007-June 2008. From June 2008-April 2009, Major Stahl was the 25th Aircraft Maintenance Unit (PilSung) Officer in Charge at 51st Fighter Wing in Osan Air Base, Korea. She was then assigned to the 1st Fighter Wing at Langley AFB, VA, first as the 27th Aircraft Maintenance Unit (Who You With?) Officer in Charge where she deployed to Anderson AFB, Guam in support of the F-22 Theater Security Package. Prior to her current assignment, she served as the 1st Maintenance Squadron Operations Officer. She is currently a graduate student at the Air Force Institute of Technology pursuing a Master's of Science in Logistics and Supply Chain Management. She has a follow-on assignment to the Pentagon in HAF A4/7.

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14. ABSTRACT
Performance metrics have helped to sustain the Air Force, improve processes, and guided decisions makers through decades of challenges and change. The Air Force continues to change as it faces the challenges of an aging fleet coupled with the tightest budget constraints of modern times. The current metrics employed by the United States Air Force Aircraft Maintenance community have gone largely unchanged over decades despite a host of force altering events. The focus of this research is to evaluate current maintenance metrics and assess the utility of the Balanced Scorecard framework for use in a Maintenance Group. The researcher utilizes a mixed methodology to accomplish this evaluation, including survey research, statistical analysis, content analysis, and correlation analysis. The paper proposes a Maintenance Group Balanced Scorecard based on the analysis of survey responses from Maintenance Officers with Combat Air Forces (CAF) experience. The proposed Balanced Scorecard is comprised of existing, refined, and proposed metrics to measure each perspective category of the balanced scorecard, and is intended to help align maintenance metrics with organizational goals/objectives and the strategic goals of Maintenance Groups in CAF units.

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