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Developing Methods to Measure and Project Levels of Combat Readiness in a Naval Aviation Squadron at the Unit Level

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DEVELOPING METHODS TO MEASURE AND PROJECT LEVELS OF

COMBAT READINESS IN A NAVAL AVIATION SQUADRON AT THE UNIT LEVEL

by

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ABSTRACT

DEVELOPING METHODS TO MEASURE AND PROJECT LEVELS OF COMBAT READINESS IN A NAVAL AVIATION SQUADRON AT THE UNIT LEVEL.

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Among the various missions and levels in a military organization, the term "Combat Readiness" is defined in many ways. To a unit-level command, such as an aircraft squadron, it simply refers to the unit's capability to perform its assigned mission when called upon. The proof of that capability is evident in the aftermath of combat, however, it is too late at that point to address any shortcomings that may exist. The problem is, how can the unit effectively define, continuously measure, and confidently forecast its ability to perform in combat? A quantitative model based upon historical data that encompasses all aspects of readiness within the command would be useful in addressing this problem. This research seeks to develop such a model that uses existing unit level data to measure and project combat readiness.

A squadron's level of readiness does not remain static over time. Every unit in the military organization moves through a cycle of standardized training and deployment. Readiness levels change with fluctuations in the tempo of operations and the numbers of personnel and equipment. A comprehensive data-based procedure for measuring these changes at the unit level does not exist. Data is continuously collected within each unit on a wide variety of items, from the mission-specific to the mundane. This data is routinely packaged and forwarded to higher levels of command for review and decision-making purposes. Very little of this information, however, is retained and used by the individual unit.

Readiness measurement in the military is not a new subject, but its focus in the past has primarily been upon large-scale forces. Military capability is a common subject in reference to defense budgets and weapon procurement, but these measures are usually based upon financial considerations, and not combat performance. The supply or logistics branch of the military has done considerable work in building mathematical models of military capability. However, they generally link readiness with sustainability of forces instead of performance in combat.

The concept of readiness for an individual unit is thoroughly defined by examining critical areas of structural and operational readiness. A model of mission execution is constructed to identify possible points of measurement. To prevent the creation of extra work for the command, established data fields are reviewed and sorted among the defined critical areas. These fields are reviewed individually, using various statistical methods such as regression analysis and time series decomposition, to determine characteristics such as trends, seasonality, and cycle. The data fields that are considered significant are grouped together into fourteen equations that form the readiness model.

This collection of quantitative measurements gives a comprehensive view of a unit's ability to perform its mission. The command can then use this information to determine its current capability, track its progress through training cycles, and forecast its readiness levels into the near future with some confidence.

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CHAPTER I

INTRODUCTION

A simple definition of Combat Readiness can be found in the Status Of Resources and Training System (SORTS) Manual, which is the U. S. Defense Department's principle instruction on readiness measurement. It states that readiness is "the ability of forces, units, weapon systems, or equipment to perform the wartime functions for which they are designed or organized, including the ability to deploy and employ without unacceptable delay" (U. S. Department of the Navy, 1990). Before we can determine a unit-level process to measure this ability, we must examine why knowledge of readiness is important and what methods have been used to calculate it in the past.

Brief History of Combat Readiness Measurement in Military Organizations

A military organization is the principle instrument through which a nation defends its existence and exerts its will. A nation may be strong in size, population, or economic development, but if it is unprepared to commit force to protect its interests, its continued existence can be tenuous at best.

The actual use of force in combat, however, is a tremendous expense for a nation in terms of manpower and finances. The advance in sophistication of modern weaponry in the last fifty years has not only elevated the military's ability to inflict losses on the enemy, but also increased the cost of its use. A single missile can take thousands of lives and cost millions of dollars. If a major conflict were to occur today, even the "winner" would incur substantial financial losses. As a result, employment of military force is a serious matter that is viewed among stable nations as an instrument of last resort.

With this fact in mind, the concept of "deterrence" has played a major part in national defense strategy. A nation may not be capable of creating a military organization that can totally overwhelm its opponents. It can construct, however, a defense organization that seems too costly for other nations to attack or oppose. A strong appearance of military strength from a country can deter opposing nations from deploying their forces in confrontation.

The key to maintaining an appearance of military strength is credibility of capability. A military organization must have the necessary personnel and material, in accordance with need to attain its objectives. However, a unit's capability cannot be defined solely by its stocks of supplies and people. While it is true that the planes and tanks must be constructed and manned and the ground divisions must be armed, everyone must also be fully trained to execute their mission. The entire organization must be armed and ready, standing by to be employed. This is the cornerstone of combat readiness, the ability to provide trained and capable military forces when called upon quickly and effectively. By measuring this, we can determine an organization's credibility of capability.

Combat Readiness Measurement at the Unit Level

To accurately assess the capability of an entire military organization, the combat readiness of each individual unit must be measured. Like a length of chain, the strength of the organization is dependent upon each individual link. Each squadron of aircraft and company of tanks placed on the front line needs to be prepared to execute its mission. A single weak link can significantly degrade the credibility of an entire organization's deterrent capability.

To assess a unit's readiness, a measure of the unit's ability to do its mission must be determined. Each separate unit within the military organization is defined by its own expected level of capability. Its readiness can then be defined as the unit's actual capability versus what is expected.

There are two primary factors that determine the level of capability. First, does the unit have the appropriate levels of equipment and personnel needed, and second, does it know how to use them to execute its mission? The unit must have a sufficient supply of tools, food and people to do the job, or it could never hope to accomplish its mission. Once the needed resources are available, it must ensure that the people are trained and the equipment is used effectively. By collecting and analyzing data in these primary areas, a credible measurement of a unit's readiness can be determined. With each link measured, an accurate assessment of squadron level capability can be obtained.

This knowledge of credible capability is valuable to the squadron. An accurate assessment of a unit's capabilities enables its leadership to determine which areas are in peak form and which need improvement. Can the unit perform its mission, or is a particular factor preventing it from attaining its goals? Forecasting techniques can also be applied to assess what is needed to improve a unit's readiness in the future, and to determine how long it can maintain its current level.

CHAPTER II

BACKGROUND

Basic Structure of a U. S. Navy Aircraft Squadron

The unit-level entity that is examined in this study is an aviation squadron of tactical aircraft in the U. S. Navy. It is normally comprised of fourteen aircraft and two hundred and fifty personnel, though we will see that these numbers tend to fluctuate over time. The squadron is administratively divided into a command element and four separate departments based along functional lines, shown in Figure 1.

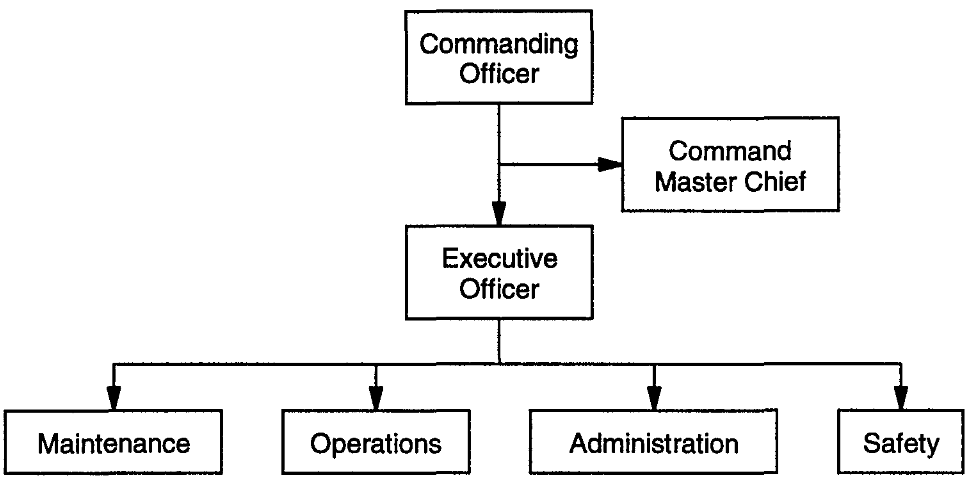


Figure 1. Squadron Command Structure

The squadron is lead by the Commanding Officer (CO), the senior officer in the squadron, holding the position of ultimate authority and responsibility. The CO is assisted by the Executive Officer and the Command Master Chief. The Executive Officer is the second-highest ranking officer in the command and is concerned primarily with squadron administrative issues.

As the senior enlisted member of the squadron, the Command Master Chief is primarily responsible for personnel issues. The character and core values of a squadron are established by these three individuals.

At the next lower level, the largest department in the command is the Maintenance Department, which contains approximately ninety percent of the total personnel in the command. The function of Maintenance is to provide armed and mission capable aircraft when needed to execute the squadron's mission. Maintenance tasks include regular inspection, flight preparation, and repair of aircraft.

The Operations Department is the planning section of the command. From daily flight schedules to deployments and detachments, Operations plans the execution of each of the squadron's required tasks. This department also maintains records on aircrew qualifications and training, ensuring the crews have the "know-how" to execute the mission.

Management of the squadron's paperwork and records is the responsibility of the Administrative Department. They process orders and requests, ensure the payroll is accurate, and maintain service records on all personnel within the command.

Because of the hazardous nature of working in and around tactical aircraft, a Safety Department is necessary to manage these concerns. Safety prepares for the possibility of mishaps, while simultaneously training personnel in preventive procedures. They also track the qualifications and special training requirements of individuals involved in hazardous duties such as fuel cell entry and flight deck personnel (Department of the Navy, 1995).

Each of the departments must work together for the squadron to accomplish its mission. Unfortunately, they are more often managed as four separate entities led by four competing department heads. Their definition along functional lines places each department in a "stovepipe" that isolates it from the rest of the squadron. The only structured horizontal line of communication between functional areas is at the top, between department heads. Data that is collected from each department is also isolated within each stovepipe. Separate readiness reports are generated for each area, with little consideration given to the interrelationships between the departments.

Squadron Schedule and Flow of Operations

In a snapshot view of the U. S. Navy, different levels of readiness can be found. Some units are on the "tip of the spear", deployed around the world and ready to execute their mission.

Other units are "standing-down", enjoying a period of rest and relaxation for the personnel and the equipment, after a deployment. The remainder are somewhere in between these two extremes, each working to prepare for their next deployment.

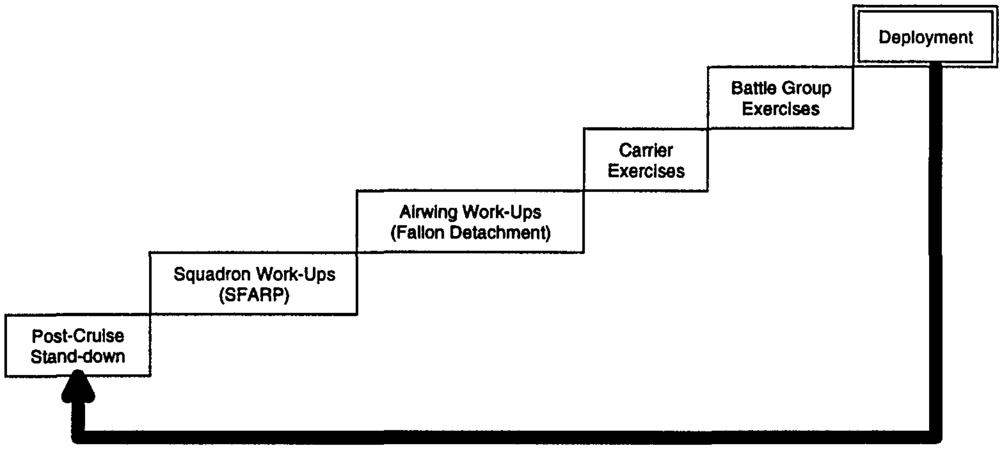


Figure 2. Squadron Operations Cycle

A successful training period prior to deployment, called the "work-up cycle", is crucial to a squadron's combat readiness. Through the series of steps depicted in Figure 2, the squadron sharpens its skills and increases its capability until it attains a minimum level of readiness, as determined by higer levels of authority. The training begins by concentrating upon improving the squadron itself, then the scope gradually widens to include the air wing, the carrier, and finally the entire battle group in a series of exercises. Through the entire period, the squadron's performance is compared to established standards and graded.

Once on deployment, the squadron must find ways to maintain its readiness without benefit of the training facilities it used during work-up. For example, it is difficult to maintain proficiency in bombing accuracy if a practice bombing range is no longer available. As a result, maintaining squadron readiness can be just as difficult as attaining it in the first place. Extra effort and imaginative solutions are required to keep the "spear" sharp during a six month deployment.

The post-deployment stand-down is generally a very transitory period for a squadron. It is characterized by a substantial increase in personnel and equipment turnover. Experienced personnel move on to other assignments, new people are introduced, and some critical equipment is transferred to other squadrons preparing to deploy. Flying time and work hours are greatly reduced. Readiness levels cannot be allowed to drop too far, however, because the cycle will begin again soon. If some readiness capability can be maintained through this period, less effort will be required through the next work-up cycle.

Current Readiness Measurement and Data Collection Efforts

Combat Readiness is a concern throughout the entire military organization, but how it is viewed differs greatly at each level. At higher levels of command, such as Fleet Headquarters or National Commands, the capability of an entire organization that is comprised of many moving parts is in question. The individual unit is concerned about its own performance and capability, compared with its current tasking.

The readiness concerns in a squadron center around performance. When the superiors say "go!", can the personnel do the job? Quality of performance is valued above cost efficiency. Resources such as operating funds, people and equipment are provided from higher levels. The squadron need only record what was received and what has been used to date. Cost efficiency is rarely rewarded, but performance of mission establishs a squadron's reputation throughout the Fleet. Performance data is collected to measure this within the squadron. For example, landing grades are recorded, bomb hits are scored, and numbers of successful missile firings are tracked. Based on this data, as well as the general morale among the squadron members, a qualitative impression of readiness is established. It is this impression of readiness that is most often used by the squadron to forecast its capabilities and plan daily operations.

For a higher level command to track the readiness of the entire military organization, quantitative based measures are required. Decisions on resource allocation and tasking are made at this level. Ratings scales are used to reduce many decisions to a series of mathematical equations. Command staffs generally employ numerous resources for data computation and analysis, with legions of trained statisticians and mathematicians available. They try to reduce a single unit's capability for performance to a series of numbers from select pieces of data. With these values as a guide, forces are deployed and resources are allocated throughout the military organization.

The development of these numbers at the higher command requires a great deal of data from the unit level. To provide the required information, a significant amount of effort is expended at the squadron collecting, collating, and packaging data reports to senior levels on a regular basis. Every facet of squadron life is documented and forwarded up the chain-of-command. Some performance data is included, but the bulk appears to be non-mission related, such as lost workdays due to injury, numbers of re-enlistments, and personnel dental readiness.

To further enhance the divisions between the departments, the data is collected, packaged, and analyzed entirely within the functional lines of that department. Maintenance data is isolated from Operations data. The percentage of fully-mission capable aircraft is never combined in the same report with the training and readiness matrix. Considering one or two readiness variables at once is like viewing the world through a straw, focusing tightly upon a small piece of a vast panorama. To make matters worse, each report is generally reviewed by the senior commands as an all-encompassing insight into squadron readiness. If a Maintenance report states that aircraft mission-capable rates are down, then the Maintenance department is considered to be having problems. Meanwhile, an Operations report may reveal that last month's workload was very heavy with a large amount of flight hours that generated a one-hundred percent complete training matrix. Depending upon which report is reviewed, this squadron can be considered top-notch, or the "keystone cops" of the airwing.

This leads to the need for a comprehensive system that measures combat capability in an individual unit. The level of readiness must be monitored continuously since it changes throughout the operating cycle. All aspects of the command must be examined, not just one department or mission specialty. Several critical areas of capability can be identified and measured with data that is already collected by the command. The resulting system would provide a complete assessment of combat readiness in a quantitative form that can be compared with past levels, as well as provide a method to forecast future combat capability.

Thesis Statement

Using a broad definition of combat readiness that includes all aspects of mission execution and is based upon established databases, a quantitative model can be constructed that will measure present mission capability and allow the calculation of data-based forecasts.

CHAPTER III

DEFINING COMBAT READINESS

Literary Review of Combat Readiness Study

With the exception of a few isolated articles, the bulk of published works on readiness concern the military organization as a whole. Generals, admirals, and politicians have enlisted the efforts of "think tanks" and committees to determine the true levels of combat readiness and apply these factors to defense budgeting and national tasking. Most of these efforts encompass the entire military organization and do not concentrate upon the individual unit.

There is consensus on what areas should be measured when trying to determine readiness. Senior commands may establish tactical doctrine, but it is the job of the individual unit to translate that doctrine into performance (Hiller, 1994). It is this performance that must be measured to determine a unit's preparedness, and the results must be quantifiable. Training sessions and work-up cycles must have a mission-level focus. Too often, training plans use number of repetitions of a task as opposed to task outcome to determine completion criteria. Achievement of standards should be used to determine capability instead of a schedule or a clock (Hiller et al., 1994).

The Department of Defense's system for reporting readiness is the Status of Resources and Training System (SORTS). Concentrating in four key areas of personnel and equipment on hand, equipment condition, and training of forces, SORTS attempts to measure whether an individual unit has the required resources and training to do its job.

SORTS data is generally informative, but is also heavily subjective and lacks a predictive capability. Quantifiable data is used to determine available resources, but measurements of training proficiency are largely based upon a commander's subjective assessment of status. While SORTS is "not to be used in any capacity as input for the ...... fitness report of the Commanding Officer" (Department of the Navy, 1994), it will not benefit any commander to be consistently labeled as lacking in readiness. The Government Accounting

Office reported to the U.S. Congress that SORTS also fails to measure several other key indicators of readiness, such as mobility, operational tempo, morale and leadership. It conveys information on a unit that is an instant assessment, without any consideration for trends or predictions of readiness.

The four branches of the military have begun various initiatives to develop a better system of readiness measurement, but their efforts are haphazard and uncoordinated. Overlapping programs are occurring simultaneously without an attempt to share information between branches. Further, these programs are considered a low priority and are usually found in a state of suspension. An attempt was made to contact members of the U. S. Navy's team studying Predictive Measures of Readiness, but demands from their primary jobs in the Fleet have prevented the realization of any progress to date.

There is one mission area in the military, the logistics or supply commands, that uses a robust system of quantifiable output measures coupled with statistical analysis. The counting of "beans and bullets" is straightforward, and various models have been constructed to determine what resources a unit needs and how often to complete its mission. It has been suggested that such a model be used to determine overall readiness by comparing supply requests with operational output. This measure would define a unit's sustainability, however that statistic is only a part of a unit's total combat readiness. A squadron can have a full complement of fourteen airplanes and twenty crews, but that means little if the aircraft are not mission capable or the crews are not properly trained.

Solutions to combat readiness measurement are not specifically defined in the literature on readiness, but many clues are evident. SORTS does not provide a complete picture, but individual units already collect a large amount of data on a daily basis that is not reflected in overall readiness reports. Historical data must be retained and analyzed to determine trends and cycles of capability. Methods of collection must be established that ensure accuracy of the data and remove as much subjective error as possible. Overall, a greater understanding of the various elements of readiness and their interrelationship must be established.

The Two Sides of Readiness: Structural versus Operational

Before a precise system of measurement and prediction can be formulated, the complex nature of combat readiness must be understood. It is comprised of a series of interrelated variables, some possessing linear characteristics and some non-linear or cyclic. Many times a particular variable is directly related to another, and a preferred compromise between the two must be determined.

Richard Betts (1995) defines the three primary considerations in readiness as mass, efficiency and speed. In the same way that energy possess potential and kinetic states, readiness is comprised of mass and efficiency. Mass is the potential capability that a unit possesses, the numbers of personnel and equipment on hand to execute the mission. Efficiency is the level of realized potential or capability of the unit. Speed is the unifying factor between mass and efficiency. If military readiness addresses the relation between available time and needed capability, then speed or Mobilization of Forces is the gap between potential and actual capability. All three factors must be considered in any model of readiness. The consequences for failing to understand this can be disastrous. As Betts states: "Speed is easy. Readiness to be slaughtered, however, is hardly valuable."

With these basic relationships in mind, all readiness variables can be divided into the two primary areas of Structural and Operational Readiness. Structural Readiness or mass of the unit, is defined by its inventory of personnel and equipment. It determines if the command has the resources it needs to accomplish its mission. Highly trained pilots are worthless without aircraft, and a handful of personnel cannot maintain an entire squadron. Operational Readiness examines the unit's efficiency through mission performance and maintenance capability. It assesses the unit's degree of realized potential of mission execution.[1] Fully mission capable aircraft must be provided to highly-proficient aircrews to ensure the best chance of mission success. Speed is evident in the mobilization needed to assemble the mass and establish the efficiency of the unit.

Using this as a foundation, a simple relationship model of combat readiness can be constructed, shown in Figure 3. It begins with a defined mission, established by senior commands and the basis for the desired capability of the unit. From this comes the two primary areas of Structural and Operational readiness. Structural is divided into the two inventories of personnel and equipment. Operational aspects include the training of personnel, condition of equipment, and command climate. Training includes aircrew as well as maintenance personnel.

[1] It is important to note that this does not determine whether a particular unit will win a particular engagement or battle. A combat unit's desired capability is defined by the military organization, and readiness only measures what amount of that defined capability is realized. It is the responsibility of the senior commanders to use sufficient forces in particular engagements. An individual unit is not at fault for losing a battle if it had to face a vastly superior opponent.

Condition of equipment primarily centers upon aircraft maintenance and mission capability. Command climate is included in this area to reflect its accepted impact upon personnel

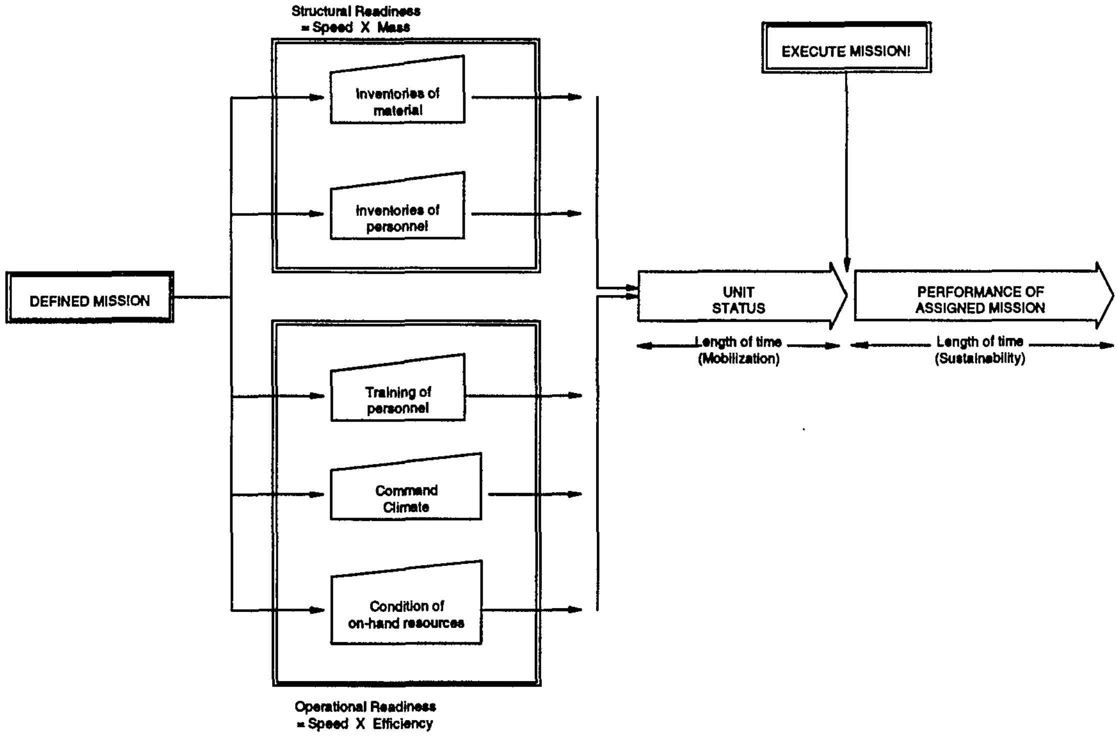


Figure 3. Model of Combat Readiness

capability. These five areas are combined to determine a unit's status or level of readiness. Each can fluctuate independently, but they share the same amount of time to prepare or mobilize. When actual mission execution is required, it may continue over a period of time. Supplies of resources such as ammunition and fuel must be provided, and replacement personnel may be required to allow continuous squadron operations. At this point, the issue of combat readiness is put aside and combat sustainability becomes the central factor. This is a major concern for logistics commands as they strive to maintain a command's capability through supply of resources. This study, however, will focus upon the model prior to mission execution and examine how the command attained its initial level of readiness.

Defining the Elements of Mission Execution

With a graphic definition of combat readiness and the relationships between its components defined, the next step is to establish a simple flow diagram of a mission. Each step in the process must be included to ensure all aspects of readiness execution within the command are considered. The model in Figure 4 begins with mission conception and concludes with actual mission execution.

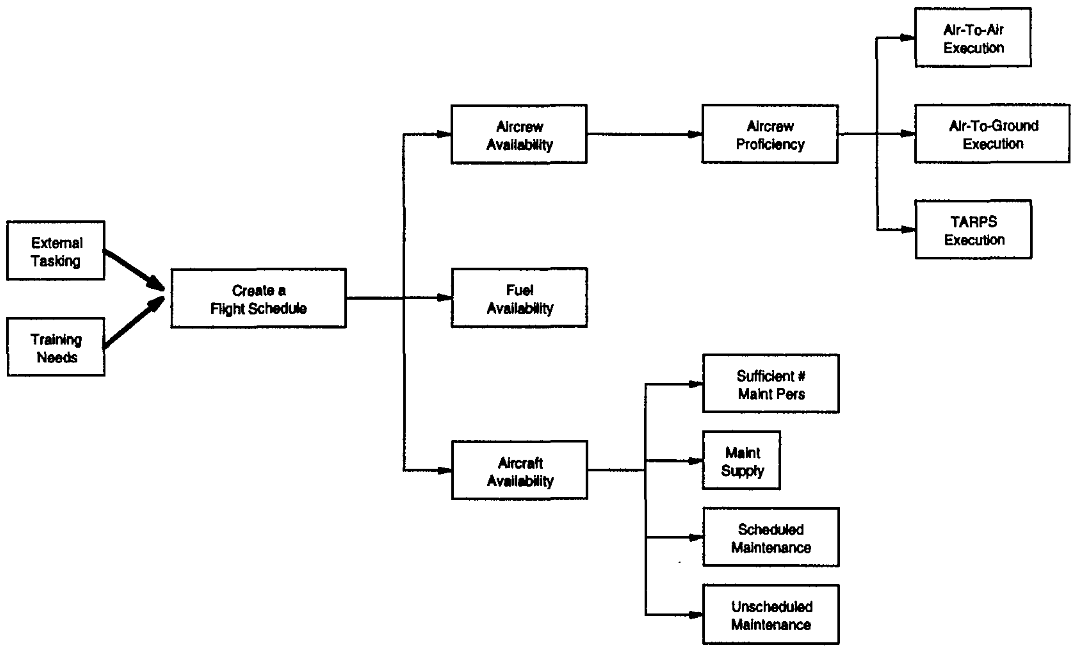


Figure 4: Flow Diagram of Mission Execution

Before the squadron can execute a mission, tasking must be assigned or directed by a higher authority. The assignment can be in accordance with training requirements, or it can be specific objectives that must be attained. These are the two primary forces that drive a squadron's day-to-day operations.

Once the tasking is defined, the Operations department must develop a Flight Schedule that allocates aircraft and aircrew to execute specific tasks. How this schedule is constructed depends upon what resources are available, particularly capable aircraft, trained aircrew, and operating fuel. The goal is to construct a plan that efficiently balances the available resources among the tasking requirements, maximizing the squadron's output and minimizing the effort necessary to achieve success.

Using the readiness model defined earlier, we know that readiness depends not only upon structural factors, but also upon operational factors such as training and proficiency. Aircrew availability is dependent upon skill level as well as numbers of aircrew assigned. This can be measured by gauging aircrew proficiency and examining past performance data in the three mission areas of this particular aircraft: Air-to-Air, Air-to-Ground, and Tactical Air Reconnaissance Photography or TARPS. Similarly, Aircraft Availability will also depend upon more than numbers of airframes. The aircraft require scheduled and unscheduled maintenance, and these efforts must be supplied with sufficient numbers of people and parts to succeed.

Measuring Each Element

With the general flow of events during mission execution defined, we can now match these individual elements to databases already established within the command. The goal is to determine quantifiable measures for each node of mission execution. A monthly format for the

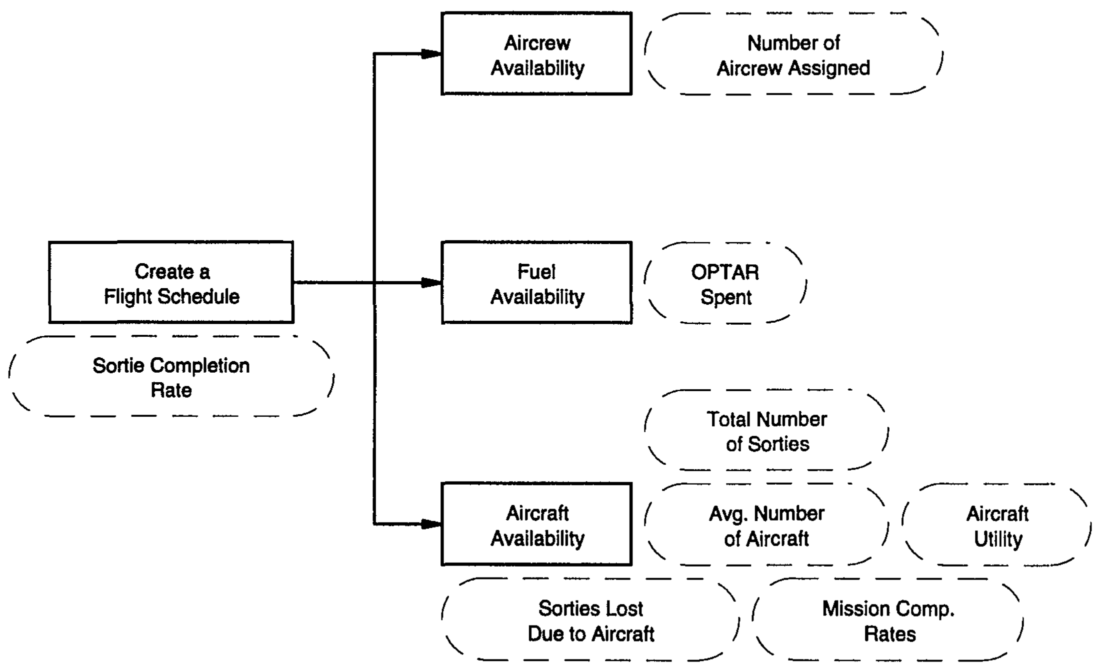


Figure 5: Matching Data Fields with First Half of Mission Execution Flow Diagram

data has been used to effectively measure changes in readiness and match the format most commonly found in the databases already established within the command.

Creating A Flight Schedule

Figure 5 shows the mission conception portion of the Execution Flow diagram. The goal of Operations is to create a schedule that optimizes the commands capabilities and satisfies requirements. A good measure of this is the *Sortie Completion Rate.* A sortie is a single flight in support of a particular mission. How many sorties or flights that are scheduled actually complete their mission? Is the Operations department working closely with Maintenance to match tasking with capability, or does an imbalance exist?

Fuel Availability

Tactical military aircraft require a great amount of fuel to fly. A typical one-and-one half hour mission expends approximately sixteen thousand pounds, or almost two thousand four hundred gallons of fuel. An operating schedule of twenty flights a day, multiplied many times over a three month period will create a substantial quarterly expense. The fuel budget for a squadron is called its OPTAR, and is issued in quarterly amounts based on projected operations of the command. Comparing how much OPTAR was spent with what was available will highlight discrepancies.

Aircrew Availability

This can be measured by counting the numbers of aircraft crews that are available each month. A minimum number is specified by instruction. The aircraft type used in this study is the F-14 Tomcat, which requires two aircrew per aircraft, a Pilot and a Radar Intercept Officer (RIO).

Aircraft Availability

The squadron must have a sufficient number of aircraft to perform its mission. It is obvious how too few aircraft would impact mission needs, but too many airframes can have a detrimental effect as well. More aircraft means more maintenance, which means more people and resources are required. A squadron needs a number of aircraft that satisfies its needs and does not task-saturate the Maintenance department. *Average Number of Aircraft* is simply the average number on hand over the course of a month. *Aircraft Utility* is the total number of flight hours flown that month divided by the average number of aircraft. *Sorties Lost Due To Aircraft* is a percentage of scheduled sorties that were lost due to aircraft availability problems. *Mission Capable* rates are monthly statistics on percentages of aircraft in the command that are capable of executing a mission. The *Total Number of Sorties* is also a monthly measure of aircraft output for Maintenance.

Aircrew Proficiency

In the flow diagram, Aircrew Availability leads to the operational concerns of mission execution (Figure 6). Not only must the crews be present, but they must also be trained to execute their mission. Basic aircraft proficiency can be measured by examining the experience level of the crews. *Average Total F-14 Hours* determines the average number of flight hours the aircrew have in a particular aircraft. *Average Monthly Flight Hours* and *Monthly Highs and Lows* reveal the pace of operations during the month. These statistics also identify if flight time was spread evenly among the crews on board. There are also Training Measurements which monitor if certain basic aircraft skills have been practiced lately.

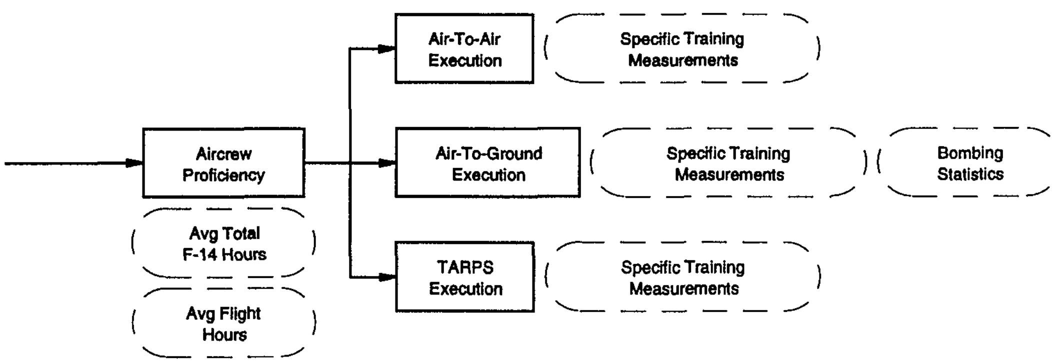


Figure 6: Matching Data Fields with Operations Portion of Mission Execution Flow Diagram

Mission Specific Execution

The system that currently tracks mission training is composed of nine areas, each containing ten to twenty specific mission tasks. Unfortunately, this system only tracks frequency of task execution and does not measure performance. It uses a "check in the box" approach to training. To overcome this, the Training Measurements[2] can be used in conjunction with mission-specific performance measures, such as Bombing Statistics, to provide a more accurate picture of capability.

Sufficient Number of Maintenance Personnel

Aircraft Availability concerns lead to the Maintenance portion of the Execution diagram, shown in Figure 7. Not only must there be an adequate number of airframes, but the aircraft must also be maintained properly. The squadron needs skilled people in the right positions, defined by *Manning Levels.* The preparation, launch and recovery of aircraft is a critical task that requires specially trained and qualified Plane Captains. *On/Off Duty Injuries* record how many workdays are lost due to personnel injuries.

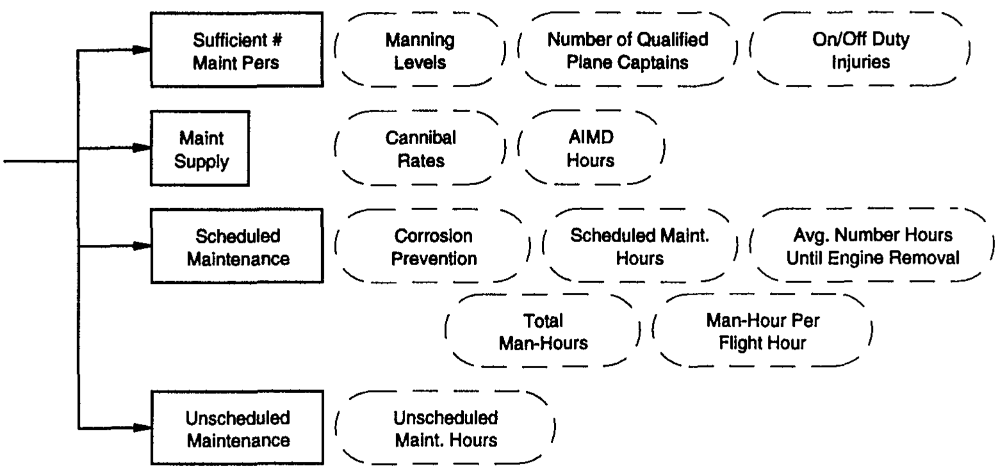


Figure 7: Matching Data Fields with Maintenance Portion of Mission Execution Flow Diagram

Maintenance Supply

A squadron needs support from supply agencies and intermediate-level maintenance facilities to keep the aircraft operating. *Cannibalization Rates* keeps track of how often needed parts are not available in the supply system and consequently must be removed from another squadron aircraft. *Aviation Intermediate Maintenance Department (AIMD) Hours* records how

[2] The historical data of these measurements for any particular command is classified information. Actual data has been used in this study for the sake of accuracy, but references to these particular measures is intentionally vague to prevent a violation of security regulations.

many man-hours are needed from AIMD to perform repairs that are beyond the squadron's capability.

Scheduled Maintenance

Most of the effort maintaining tactical aircraft is in the form of regular scheduled inspections and preventive measures. *Scheduled Maintenance Hours* determine how many man-hours are executed for these efforts. One of the most time and manpower consuming maintenance events is the removal of an engine from an aircraft, but it is required for some inspections. *Average Number of Flight Hours Until Engine Removal/Inspection* is used to gauge future workload for the squadron. Many hours of scheduled maintenance effort also goes toward *Corrosion Prevention,* which measures how many man-hours are dedicated to corrosion prevention each month.

Unscheduled Maintenance

A tactical jet aircraft is a complicated piece of equipment that operates in an unforgiving environment. Aircraft and weapons systems often fail and need occasional repair. *Unscheduled Man Hours* are a measure of the time spent fixing broken aircraft.

Both Scheduled and Unscheduled Maintenance are related to *Total Maintenance Man-Hours* and to *Dedicated Maintenance Man Hours Per Flight Hour*, which measures the average effort required for each flight hour flown. The man-hour data fields can be used as comparison factors that bridge together the other maintenance measures.

CHAPTER IV

DEVELOPING A NEW MODEL OF READINESS

Combining the Readiness and Mission Execution Models

The Mission Execution Flow Diagram highlights the key areas of squadron operations and matches each with several established historical and quantifiable databases. These databases are compared to the Readiness Model to establish a basis for a quantifiable measure of combat readiness. This is accomplished by sorting each database by one of five major headings: Inventory of Materials, Inventory of Personnel, Training of Personnel, Command Climate, and Condition of Resources.

Equipment Inventory

The piece of equipment with the greatest impact on readiness is the aircraft (Figure 8). The squadron must have a certain number of capable aircraft in order to execute its mission. Each airframe in the command's inventory requires an assortment of scheduled and preventive maintenance, even if it is never taken out of the hangar. Idle aircraft still require many man-hours of work. Thus, it is ideal if the number of aircraft assigned fluctuates with squadron's needs.

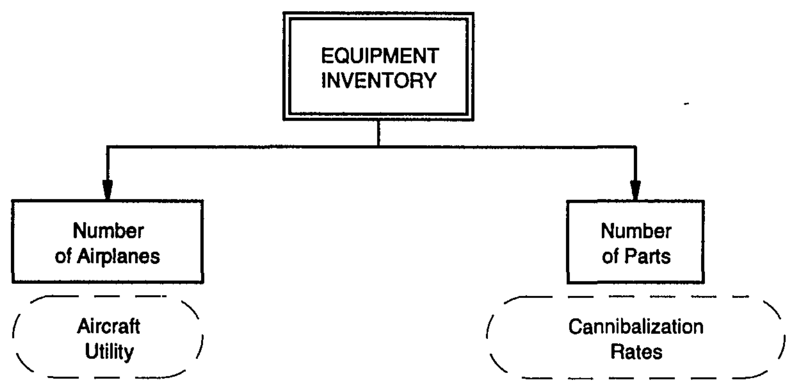


Figure 8: Equipment Inventory Areas of Concern

To measure the value of the aircraft on hand, the factor *Aircraft Utility* is used (Equation 4-1). It is equal to the number of flight hours per month divided by the average number of aircraft. A high value would indicate a heavy operational workload for the squadron or an

$$\text{Aircraft Utility} = \frac{\text{Total Flight Hours}}{\text{Average Number of Aircraft}} = A_U \quad (4.1)$$

insufficient number of available aircraft. A low value could mean the command has more aircraft than it needs. Preferably, this value would remain constant over time, signifying that the number of assigned aircraft matches the squadron's needs.

To adequately maintain the aircraft, a steady supply of spare parts is essential. If a squadron cannot repair an aircraft because a spare part is not currently available, it will usually remove or "cannibalize" the needed part from another aircraft in the command. If cannibalization rates are high, then the supply system is not providing what the squadron needs to execute its mission. Ideally, this value would equal zero.

Personnel Inventory

As shown in Figure 9, a military aviation squadron is comprised of two types of command members, aircrew and support personnel. The aircrew are the trained aviators that fly the aircraft and are directly responsible for mission success. Those in support are the maintenance and administrative personnel needed to ensure mission capable aircraft and weapons systems are available for the aircrew.

Just as the squadron needs a certain number of aircraft to complete its mission, it also requires a minimum number of aircrew to man the aircraft. This value is usually specified by instruction from higher authority, but it does fluctuate during the work-up cycle. It can be measured by comparing the actual number onboard to the prescribed number assigned.

In addition to the number of aircrew assigned, crew experience levels must also be considered. To gauge the overall experience level of aircrew, the average total number of F-14 flight hours for all aircrew is calculated by month. Changes in this value signify if the squadron is gaining or losing experience through the work-up cycle.

The effect of support personnel upon readiness can be measured by comparing the number of personnel assigned with the work level of the squadron. The squadron must possess

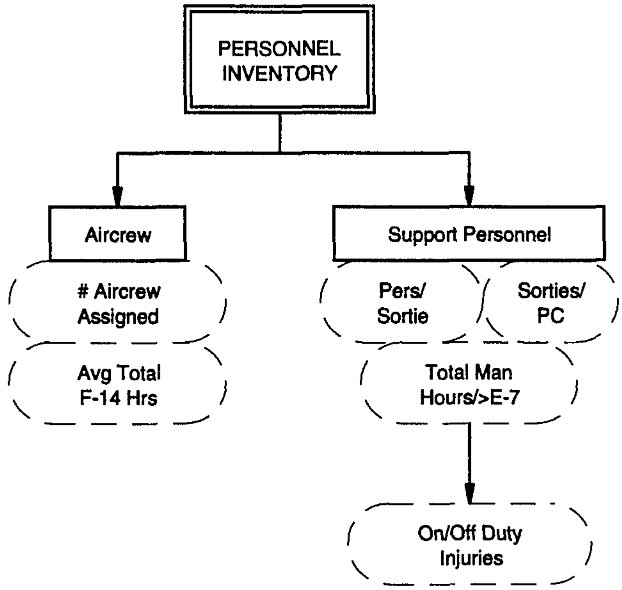


Figure 9: Personnel Inventory Areas of Concern

an optimal number of people, which will fluctuate with the level of activity, to execute the mission. It is desirable to minimize the number of personnel in a squadron to reduce costs, but not at the expense of mission execution.

Total Man-Hours divided by *Total Number of Personnel Assigned* for a given month is used to compare the number of people assigned with the aircraft maintenance workload. An elevated value could indicate increases in the workload without an increase in manpower. Conversely, decreases could indicate the command is over-manned or personnel are sitting idle.

The critical area of preparing the aircraft for flight is the responsibility of a small group of personnel called Plane Captains. It is their job to inspect the aircraft prior to aircrew arrival, resolve any discrepancies in the aircraft's material condition, and guide the aircrew through the engine start and post-start checks prior to launch. A low number of qualified plane captains could limit the number of aircraft that the command can launch simultaneously. To measure this, The *Total Number of Sorties Flown* in a given month is divided by the *Total Number of Qualified Plane Captains*. An substantial increase in this value would indicate a need for more qualified plane captains, and might reveal a cause for decreased mission output from the squadron.

If an organization does not possess sufficient leadership, efficiency and output could suffer. The most visible leaders among the support personnel are the Chief Petty Officers, or those enlisted personnel above the paygrade of E-6. To measure their presence in the command, the *Total Man-Hours* for a given month is divided by the *Total Number of Chief Petty Officers Assigned.* The level of manning for E-7's and above is defined by instruction, but comparing the actual manning level with the workload in maintenance determines if the numbers are sufficient.

The rate of injuries to personnel is included in the measure of support personnel manning. Injuries to personnel can occur on or off the job, but both cause missed work days and reduce the available manpower in the command. It may not be directly related to the mission, but a substantial increase in personnel injuries will have a significant effect upon the command's readiness. It is included in determining available manning levels for each month.

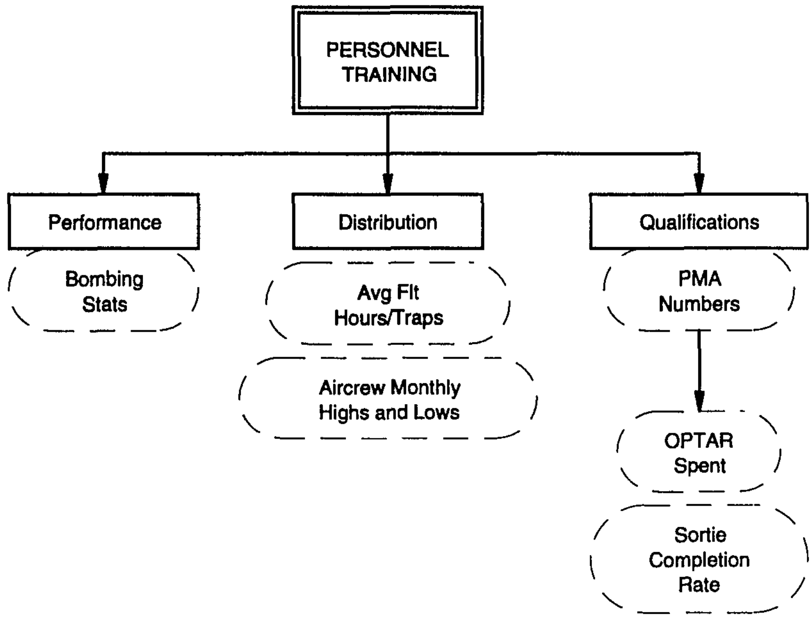


Figure 10: Personnel Training Areas of Concern

Personnel Training

The aircrew must be properly trained to ensure effective mission performance. They need to understand how to operate their aircraft and weapons systems, and understand the tactics needed to defeat any potential foes. It is imperative that each aircrew member is capable of employing the aircraft to its limits of performance. The training of support personnel is also important, but it is primarily conducted outside the command. In the present environment of multi- mission aircraft, aircrew proficiency training must be conducted for a variety of specific tasks. The command cannot afford to become "rusty" in a mission area, or concentrate its efforts on one or two specific missions. The three areas of concern for aircrew training are Performance, Qualification Completion, and Distribution of Flight Time, as shown in Figure 10.

Performance measures are the result of mission execution. They can be the hit scores from bombing runs on a controlled range, calculating average accuracy for certain deliveries or first runs. Actual missile firings are rare occurrences, but their results can reveal a level of performance. Live gunnery practice on towed targets can also provide quantifiable measures of mission performance.

The area of Qualification tracks the frequency of execution for a particular mission area. The data is captured in a Training Matrix, a tool used to record how often each aircrew member in the command has performed certain mission tasks. The aircraft used for this study, the F-14 Tomcat, has nine primary mission areas, or PMA's, with over one hundred specific tasks (U. S. Department of the Navy, 1995). The matrix calculates a rating for each PMA based on the percentage of crews assigned that have recently executed the mission tasks within the PMA. Each task has a specified frequency that is required for qualification. As more aircrew members within the command complete the specific tasks, the PMA's reflect an increasing qualification rate in the squadron.

The PMA values for each mission area can be modified by the amount of OPTAR spent and the *Sortie Completion Rate*. Comparing PMA levels to OPTAR expended measures the amount of funds spent per PMA level attained. When this value is low, the squadron is probably producing fewer sorties than it needs for adequate training. It would need to work harder to achieve satisfactory PMA values.

Distribution of Flight Time determines how the effort of mission execution is allocated among the aircrew in the command. *Average Flight Hours* measures the average amount of flight time among all the aircrew. The *Monthly Highs and Lows* measure the distribution of flight hours among the aircrew by determining the range between the aircrew member with the highest total of flight hours and the lowest.

Command Climate and Morale

These statistics are the most difficult aspects of readiness to quantify. Numerical values are easy to derive for inventories or performance, but the morale of an organization is hard to translate into measurable quantities. The working environment generated by the leadership and the morale of the personnel both affect command attitudes toward readiness. Positive climates are proven to enhance readiness and mission execution, while organizations with low morale must work harder to achieve similar results.

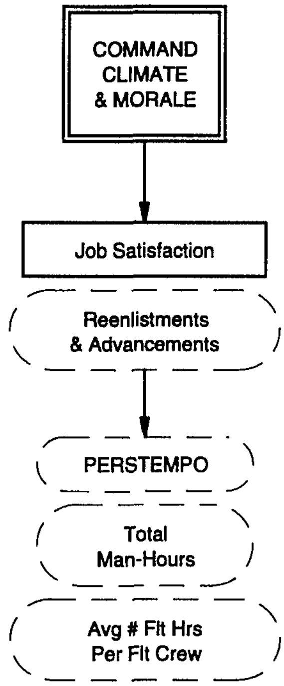


Figure 11: Command Climate Areas of Concern

Morale can be quantified as Job Satisfaction. In a survey conducted with another tactical aircraft squadron (U. S. Department of the Navy, 1994), Job Satisfaction was a top concern among command personnel. It is logical to assume that no one wants to remain in an organization where they are unsatisfied, so *Re-enlistment and Advancement Rates* will be used to gauge Job Satisfaction. Re-enlistment involves a commitment spanning several years of one's life to the service, and is never entered into lightly. Advancement requires considerable work on the part of an individual to attain, especially in the current down-sizing environment of the military. Both signify a significant desire to remain within the service and imply a significant level of satisfaction with the current organization.

The level of satisfaction is affected by several other factors. The length of time an individual is separated from their family has a tremendous impact on morale. How often a command is deployed away from home port is measured by *PERSTEMPO*. Individuals become restless when they are pushed too hard or sit idle for too long. *Total Man-Hours* and *Average*

Flight Hour Per Aircrewman gauge the level of workload within the command. Extremes in any of these measures can have a significant impact upon the command climate.

Condition of Equipment

The aircraft and weapons systems must not only be available for use, but they must also be fully capable of executing the missions assigned. Today's tactical aircraft are complicated machines comprised of highly technical systems that are subjected to rigorous operating

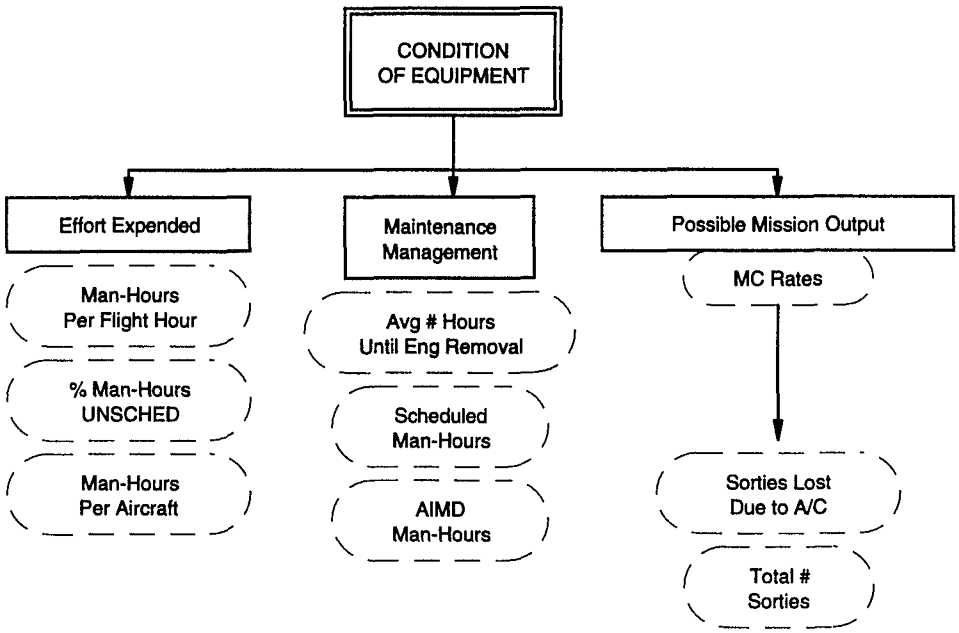


Figure 12: Condition of Equipment Areas of Concern

environments. To insure peak performance, the airframes must be regularly inspected and repaired when necessary. Inspection and repair represent a significant workload within any squadron. To evaluate this effort, it is broken into three headings: Effort Expended, Maintenance Management, and Possible Mission Output.

(4.2) $$\frac{\text{Total Man-Hours}}{\text{Total Flight Hours}} = E_H$$

The area of Effort Expended measures how much work is needed to achieve results. *Total Man-Hours* divided by the *Total Flight Hours* flown for a given month (4.2) determines how much maintenance effort was expended for each flight hour. A decrease in this value would indicate a more efficient maintenance effort. *Unscheduled Man-Hours* divided by *Total Man-*

(4.3) $$\frac{\text{Unscheduled Man - Hours}}{\text{Total Man - Hours}} = E_U$$

Hours (4.3) defines how much of the maintenance effort is an unplanned reaction to aircraft breakdowns. If the aircraft are in poor condition, they will break more often and this value will increase. *Total Man- Hours* divided by *Average Number of Aircraft* (4.4) puts the maintenance

(4.4) $$\frac{\text{Total Man - Hours}}{\text{Avg. Number of Aircraft}} = E_A$$

workload in the perspective of available aircraft. Increases in this value could signify a workload increase on the same number of airframes, possibly caused by a decrease in effort efficiency.

(4.5) $$\frac{\text{Scheduled Man - Hours}}{\text{Avg. Number of Aircraft}} = E_S$$

Maintenance Management is concerned with the planning efficiency of the maintenance effort. Regular inspections and other scheduled maintenance work must be planned around operational activity so aircraft will be available when needed. *Average Number of Hours Until Engine Removal* calculates the average amount of flight hours remaining on all the engines. Significant decreases in this value could indicate increased workloads in the near future for the command. *Scheduled Man-Hours* divided by the *Average Number of Aircraft* (4.5) compares the scheduled workload distributed among the available aircraft. Efficiency problems may exist if this value increases substantially.

(4.6) $$\frac{\text{Total AIMD Man - Hours}}{\text{Total Man - Hours}} = \%AIMD$$

Limits do exist in an individual squadron's maintenance capability, and there are some jobs the Maintenance department cannot perform. This maintenance is performed at an Aviation Intermediate Maintenance Department or AIMD. *Total AIMD Man-Hours* divided by *Total Man-Hours* (4.6) gives a percentage of the maintenance effort that needs to be sent to AIMD. The process of transporting airframes to and from AIMD takes time, so an increase in this value could reduce aircraft availability in the command.

The output of the maintenance process is mission-capable aircraft delivered when needed to execute assigned tasks. This availability can be determined by *Mission Capability* or *MC Rates*, which report the percentage of aircraft within the squadron that are ready to fly over a given month. Increased operations may wear down the aircraft, causing more breakdowns and an increase in unscheduled maintenance. As a result, the *MC Rates* will need to be modified in some fashion by the *Total Number of Sorties* flown, which represents the workload of the command. To compare the output with schedule demand, the percentage of *Scheduled Sorties Lost Due to Aircraft Problems* will also be considered. A high percentage of sorties lost due to aircraft malfunctions will reduce the command confidence in providing aircraft as required.

Techniques Used to Analyze Databases

Once the databases of information within the command were specified, the next step was to analyze and uncover relationships between data fields and trends over the work-up cycle. All of the databases are aligned in a monthly format, the most common within the command, to ensure consistency in the analysis. Once the characteristics of the data were clearly understood, a comprehensive model of the command's readiness was constructed.

First, a correlation analysis was conducted between select data fields and the rest of the database. The purpose was to determine which fields are strongly related either positively or negatively. Certain databases that measure the same characteristic were also identified to avoid redundancy in the model. These findings played a part in the determination of the variables in the model and how they interacted in the equations.

After uncovering correlations, other characteristics of the data needed to be examined for suitability in the quantitative model. The Time Series Decomposition technique was chosen because of its ability to breakdown each database into the product of four components: trend, seasonality, cycle and an error factor. This allowed each database to be compared with the squadron's work-up cycle and determine any trends for forecasting purposes.

A possible limitation of using this technique is the fact that only sixteen months of data were available for analysis. The Time Series Decomposition method generally requires larger databases to ensure statistical accuracy. Because of this fact, this technique was used primarily to determine database characteristics and their suitability in measuring readiness.

Table 1: Sample Time Series Decomposition Analysis

Date	Time	DMMH/FHR	QTR AVG	CMA QA	CMAT QA	SF	QTR SI	CYCLE	CALCULATE
Sep-94	1	52.0			42.35				
Oct-94	2	55.4	46.65		43.21		0.8618		
Nov-94	3	32.6	42.31	44.48	44.07	0.732	0.8618	1.0095	38.33
Dec-94	4	39.0	36.39	39.35	44.92	0.991	0.8618	0.8760	33.91
Jan-95	5	37.6	35.37	35.88	45.78	1.048	0.8918	0.7838	32.00
Feb-95	6	29.5	32.00	33.69	46.64	0.876	0.8918	0.7222	30.04
Mar-95	7	28.9	44.87	38.43	47.50	0.752	0.8918	0.8091	34.28
Apr-95	8	76.2	60.57	52.72	48.36	1.445	1.1051	1.0901	58.26
May-95	9	76.6	64.81	62.69	49.22	1.222	1.1051	1.2736	69.28
Jun-95	10	41.6	63.71	64.26	50.08	0.648	1.1051	1.2832	71.02
Jul-95	11	72.9	49.21	56.46	50.94	1.291	1.0344	1.1084	58.41
Aug-95	12	33.1	52.37	50.79	51.80	0.652	1.0344	0.9805	52.54
Sep-95	13	51.1	35.70	44.03	52.66	1.160	1.0344	0.8362	45.55
Oct-95	14	22.9	43.15	39.43	53.52	0.581	0.8618	0.7367	33.98
Nov-95	15	55.5	51.38	47.27	54.38	1.173	0.8618	0.8692	40.73
Dec-95	16	75.8			55.24		0.8618		

An example analysis is shown in Table 1. A quarterly moving average is calculated from the data by averaging it over three month periods. A centered moving average is calculated from every two moving averages. Trend is determined by calculating a linear regression of the centered moving average over time. Seasonal factors, based upon the four fiscal quarters, are calculated from the ratio of the actual data to its centered moving average, and seasonal indexes are calculated by averaging the seasonal factors in each quarter. Finally the cycle is determined by comparing the centered moving average with its time regressed value. A calculated value of the database is determined by multiplying the three factors of trend, seasonal index and cycle.

The results are analyzed through calculation of percentage change values and examination of the results on a chart. Mean Absolute Percentage Changes are calculated for seasonality and cycle. These values indicate whether seasonality or a cycle are present in the data. In most cases, examination of the values on a chart can give an accurate depiction of the database's characteristics.

In the example in Figure 13, the database does not appear to vary seasonally. This is confirmed by the calculated percentage change values. It has a slightly positive trend over the time period and a discernible cycle that moves over an eight-month period. A mean percentage change value for the centered moving average of over fifty percent strongly indicates the presence of a cycle. As a final check, the technique's calculated values appear to closely follow the actual data values.

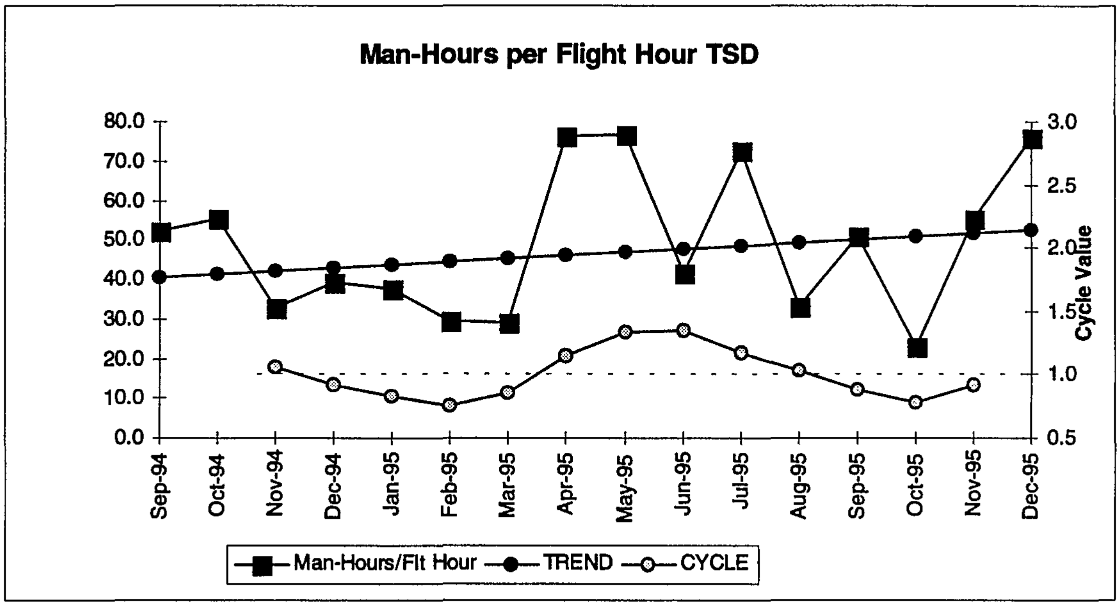


Figure 13: Sample Time Series Decomposition Chart - Man-Hours Per Flight Hour

Construction of the Readiness Model

The available databases are sorted and analyzed under the five defined primary areas of combat readiness. Together, they provide a detailed picture of the squadron's capability of mission execution. The next step is to examine the relationships within the primary areas and how they interact to develop a quantitative model.

Equipment Inventory

The Aircraft Utility factor compares the number of aircraft available with the total flight hours for the month, giving a factor of flight hours per aircraft. To further define this value, it is compared with a desired level of aircraft utility. As defined in the squadron training matrices instruction (Department of the Navy, 1995), an F-14 squadron should have fourteen aircraft and must fly an average of 522 hours per month to satisfy training requirements. These values are used to define a baseline or ideal aircraft utility constant, A_{IU} (4.7). The monthly Aircraft Utility, A_U, can now be divided by A_{IU} to derive a percentage of Ideal Utility (4.8).

(4.7)
$$\frac{522 \text{ Hours / Month}}{14 \text{ Aircraft}} = A_{IU}$$

(4.8)
$$\% A_{IU} = \frac{A_U}{A_{IU}}$$

The statistical analysis of A_{IU} shows it follows the flow of the training cycle and is seemingly unaffected by seasonal factors. The graph shows a cyclic pattern that dips down after deployment in April, but is moving back up as the work-up cycle has begun for the next deployment. This same cyclic theme will be evident in most of the other primary readiness factors. The trend in Figure 14 shows a negative slope, but that is expected for this time frame, which is primarily post-deployment and stand-down. If data were available that covered the entire cycle from stand-down to end of deployment, the trend should level out completely

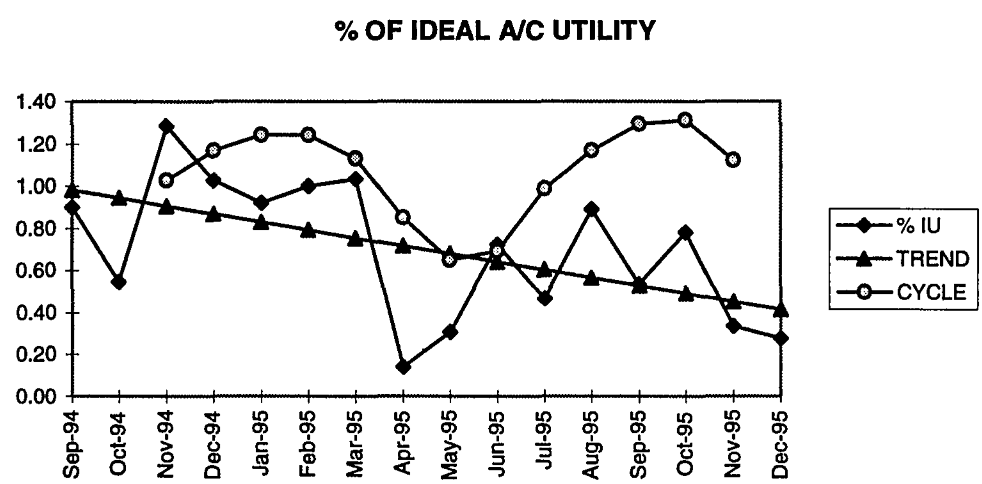


Figure 14: TSD Analysis of % Ideal Aircraft Utility

For determining the availability of spare parts, the Cannibalization Rate (4.9) is calculated as number of parts per one-hundred flight hours. This adjusts the cannibalization rate for the workload each month, so it can remain in its present form as a primary readiness metric.

(4.9) $$\frac{\text{Cannibalized Parts}}{\text{100 Flight Hours}} = \text{Cannibalization Rate} = C_R$$

Personnel Inventory

The training matrix baseline can also be used to calculate the numbers of aircrew onboard. The primary yardstick used in matrix calculations is not the dictated total number of aircrew assigned, but rather eighty-five percent of that number plus one or *85%M+1*. All training and readiness matrix reports use this figure as a baseline. This value will be defined for our purposes as C_M. The actual number of crews onboard will be C_{OB}. Like the procedure with Aircraft Utility, we will define the aircrew onboard as a percentage of ideal by dividing C_{OB} by C_M.

(4.10) $$\frac{C_H\left[\frac{C_{OB}}{C_M}\right]}{100} = \text{Aircrew Availability Factor}$$

To account for aircrew experience, this factor will be multiplied by the *Average Total F-14 Flight Hours*, represented by C_H. The entire equation (4.10) is then divided by a constant one hundred to improve its comparability with the other model factors. The C_H factor plays a significant role in the measure's analysis. As experienced aircrew leave the squadron during the post-deployment period, the value drops rapidly. It only begins to climb back up as more crews are assigned to the command and their experience level increases.

The Support Personnel Inventory has three variables to consider. The *Total Number of Sorties per Plane Captain* is P_{PC}. The *Total Man-Hours per Personnel E-7 and Above* is defined as P_L, for leadership personnel. The *Total Personnel per Total Sortie* variable will need to be modified by the number of *Lost Workdays* each month due to injuries. The best approach is to modify *Total Personnel*, since lost workdays actually reduce the number of personnel available to work in the squadron. Multiply *Total Personnel* by thirty days to determine total number of Man-Days per month. Then subtract the number of *Lost Workdays Due to Injuries*, calculating a new amount of total man-days for the month. Divide this value by thirty to arrive at a new value for personnel available for the month, or $PERS_M$. Divide this value by *Total Number of Sorties* to calculate the value P_S.

(4.11)
$$\frac{\left(\frac{(\text{Total Number of Personnel} \times 30) - \text{Lost Workdays}}{30}\right)}{\text{Total Number of Sorties}} = P_S$$

To determine an overall factor for Support Personnel Inventory, multiply P_S and P_{PC}, since increases in these values indicate more people available to execute the squadron's mission. A high value of P_L would indicate more man-hours for each E-7 and above to monitor. A low

(4.12)
$$\left[\frac{P_S \times P_{PC}}{P_L}\right] \times 100 = \text{Support Personnel Factor}$$

steady value of this variable is preferred to ensure adequate leadership available on the job, so it is divided from (P_S x P_{PC}). The entire equation (Equation 11) is multiplied by one hundred to increase its magnitude and ease comparison with Aircrew Availability. In analysis, this value remains relatively steady except for the immediate post-deployment period, which sees a significant spike upward. This is probably attributed to the significant decrease in operational activity paired with no change in the number of personnel.

Personnel Training

The only performance measure available that can be placed in a monthly format is Bombing Statistics. Training flights that practice bombing commonly make several runs on the target to practice ordnance release, but in an actual strike there will be only one run on the target. To reflect this, the *Average First Bomb Miss Distance* (B), will be used. The lack of any other form of monthly data suggests that performance is not adequately being recorded, and a method to increase its collection needs to be established.

The distribution of training can be determined by guidelines within the training matrix. *Average Flight Hours* is calculated by dividing the *Total Flight Hours* for the month by the number of crews onboard. To follow the training matrix data format, the *85%M+1* value or C_M will be used to compare total monthly flight time with ideal crew levels instead of the actual level.

(4.13)
$$\frac{\text{Highest Flight Hour Individual - Average Flight Hours}}{\text{Highest - Lowest Flight Hour Individual}} = F_H$$

For the entire command to be trained, flight time must be evenly distributed among the aircrew. A flight hour distribution factor, F_H (4.13), can be calculated by dividing the range of highest flight time to average by the range of highest to lowest. Increases in this value would indicate a lopsided distribution of flight time, which would adversely affect training. If F_H is equal to 0.5, then flight time is evenly distributed among the aircrew. It would then have no effect upon training, so 0.5 divided by F_H is multiplied to the equation to reflect this relationship.

(4.14)
$$\frac{\left[\frac{\text{Total Flight Hours}}{18}\right] \times \frac{0.5}{F_H}}{27.78} = \text{Distribution Factor}$$

To compare this monthly hour calculation with training matrix baseline, the entire equation is divided by 27.78, which is the monthly average flight hours per crew required to satisfy matrix requirements. This results in a percentage measurement (4.14) of actual to ideal monthly flight time per crew. It proved to be quite volatile in its analysis. The combination of off-balance distribution and decrease in total flight time during post-deployment greatly decreased this value. Overall, it tends to react substantially with any change in operational tempo.

(4.15)
$$\left[\frac{5 - \text{Average PMA}}{4}\right] = P$$

The Primary Mission Area, or PMA rating values are determined from the matrix on a scale of one to four, with one the best and four the worst. To match this value with other measurements in the model, the Average PMA value will be subtracted from five to reverse their polarity and define higher values as preferred. This value will then be divided by four to calculate a percentage of *Ideal Average PMA*, or P (4.15). Its performance in the statistical analysis closely followed the squadron's operational cycle.

(4.16)
$$\frac{\text{OPTAR Spent}}{\text{P} \times 100} = P_D$$

To measure the efficiency of the P level reached, the OPTAR funds spent will be divided by P times one hundred. This will result in a measure of dollars spent per percentage of ideal PMA level attained, or P_D (4.16). This indicates how much OPTAR was expended toward the current value of P. It also followed the operational cycle of the command statistically.

Command Climate and Morale

The Re-enlistment Rate was chosen as a measurement criteria for job satisfaction and command morale. To put this into a percentage format (4.17), the number of monthly re-enlistments is divided by the total number of possible monthly re-enlistments (re-enlistments plus separations). The only problem with the validity of this value is that there may be ten people one month who must decide to re-enlist, and the following month there may be none. To modify this

(4.17)
$$\frac{\text{Number of Re-enlistments}}{(\text{Number of Re-enlistments}) + (\text{Number of Seperations})} = \%R$$

(4.18)
$$\frac{\%\text{R of the Last 3 Months}}{3} = \%R_M$$

value so it has more stability and is a more accurate assessment of morale, the average of the last three months is used. If a month occurs with no re-enlistments or separations, then that month will be omitted from the calculation. This will prevent $\%R_M$ from being skewed by months with zero re-enlistments and zero separations. When it is analyzed statistically, it shows an almost zero trend and a cycle that flows with the command's operational cycle.

One factor that can have a great effect upon morale is the workload in the command and the output it produces. If the workload increases significantly with no appreciable increase in output, it can demoralize the organization. To measure this balance, the *Average Flight Hours* per month is divided by the *Total Man-Hours*, which is divided by 1000 to reduce its magnitude. Like the others, this value also closely follows the squadron's operational cycle statistically.

(4.19) $$\frac{\text{Average Flight Hours}}{\text{Total Man-Hours}/1000} = \text{Workload Balance}$$

The tempo of squadron operations away from home also plays an important part in command morale. Extended family separations can have a profound impact over time and must be considered. PERSTEMPO measures the time away from homeport by subtracting days deployed from days in port, resulting in a numeric value of deployment frequency. Negative values indicate the command has spent more time deployed than at home. When analyzed statistically, it also closely matches the operational activity cycle of the squadron. This measure will be included as a part of the model unmodified.

Condition of Equipment

When evaluating maintenance effort, the expenditure of man-hours is compared to the output of the squadron. This is dependent upon several other factors as well, such as training, tactics, and even pure luck. The concern of Maintenance is that the aircraft are available when needed. The three measurements that define this effort are E_A (Equation 3), E_U (Equation 4), and E_H (Equation 2). Since the squadron would like to get the most output for the least amount of effort, it is desired that both E_A and E_H be as small as possible. These two are added together,

(4.20) $$\left[\frac{E_A}{100} + E_H\right](E_U) = ME$$

and E_A is divided by 100 to reduce its magnitude and ensure that E_H will have an equal impact on the equation. Less unscheduled maintenance will also equate to less effort, so we will multiply the equation by E_U. This relationship will be defined as the *Maintenance Effort Factor* or ME (Equation 19).

To gauge the management of the maintenance effort, *the Average Number of Hours Remaining Until Engine Removal* is divided by the average number of monthly flight hours per aircraft needed to satisfy the training matrix. This value (I_E) gives an average number of months remaining until engine removals must be performed. *Total AIMD Hours* are divided by *Total Man-Hours* to determine %AIMD (Equation 6). The *Scheduled Man-Hours* are divided by *the Average Number of Aircraft* to calculate E_S (Equation 5), or the average scheduled maintenance load per aircraft in the command.

(4.21)
$$\left[\frac{1}{E_S}\frac{I_E}{\%AIMD}\right] = MM$$

It is desired that the value for I_E increases to delay engine removals and reduce the workload. Meanwhile, the command prefers to reduce %AIMD, since sending work to AIMD involves extra cost and time. Because of this inverse relationship of desired outcomes, I_E is divided by %AIMD. The *Average Scheduled Maintenance per Aircraft* should remain constant, but an increase would be undesirable, so its inverse will be multiplied to the equation. The *Maintenance Management* (4.21) factor or MM should remain relatively constant, and its value will not be of as much concern as its range of movement.

The FMC rate defines a percentage of the aircraft that are ready to execute their mission. The *Percentage of Scheduled Sorties Lost due to Aircraft Problems* or L_S is a measure of sorties that were scheduled with aircraft that were not fully mission capable or FMC aircraft. Because of this relationship, it can be expected that the sum of FMC and L_S would yield a value near 1.0. If it is greater than 1.0, more sorties are being lost than the overall FMC rate would indicate.

(4.22)
$$\text{FMC Rate} + L_S = MO$$

The statistical analysis of all three primary maintenance factors is of particular concern because they do not follow the squadron's operational cycle as do other variables. There are some similarities in the peaks and valleys, but overall they seem to be possess their own rhythm. This tends to justify the importance of considering multiple variables in determining combat readiness.

CHAPTER V

APPLICATIONS OF THE MODEL

Model Accreditation

Careful definition of the problem, analysis of available data fields, and statistical calculations have resulted in a quantitative model comprised of fourteen equations. Before this model can be employed, however, it must be examined to ensure that it will adequately measure an individual unit's level of combat capability. The first step is to compare the construction of the equations with our established definition of combat readiness.

The model encompasses both structural and operational aspects of combat readiness. Equipment readiness is measured in terms of inventory and material condition. The number of assigned personnel is considered alongside their training and experience levels. The morale of the personnel is also included to determine its effect upon capability.

Each equation in the model gauges the relationship between several key factors. For example, a large number of aircraft is only needed if the squadron's operational workload is high. The equation for *% of Ideal Aircraft Utility* compares the number of aircraft with the workload of the squadron. It then calculates this value as a percentage of an ideal value that is based upon expected capability. Using this equation instead of a simple population count, changes in aircraft inventory will only cause concern if the workload of the command does not change as well. Using this technique, each of the equations in the model combine several readiness aspects to provide measures of relationship between factors.

The data fields used to construct the equations are already established within the command. They are each currently accepted as measuring some aspect of the squadron's mission, but singly their ability to assess total capability is minimal. By choosing data fields that match critical points in the flow of mission execution and then combining them into equations based on their interrelationships, the model should contain quantitative information on all pertinent aspects of the squadron's mission readiness.

Calculation of Readiness Factors with Historical Data

The next step is to calculate the squadron's readiness over the last fifteen months of available historical data using the model. This technique is the first known attempt to create a comprehensive quantitative method of calculating squadron readiness, so it cannot be compared with an established system. Instead, the values can be examined for inconsistencies with expected results for this phase of operations. Comparisons can also be made against qualitative assessments from personnel who were in the squadron during this period.

One method of analysis is to examine each factor value's trend over time. It is hypothesized that while the readiness level fluctuates over the course of the operational cycle, its average value should remain constant from cycle to cycle. Therefore, if data were available for the entire operational cycle, a flat or zero trend would result for each factor. The time period represented by the data in this study, however, only covers a portion of this cycle. From October 1994 to March 1995, the squadron was deployed in the Mediterranean Sea and Persian Gulf. Readiness levels during this period should have been high. In April 1995, the command returned home and promptly sent fifty percent of the personnel on leave. The next three months saw little operational activity in the command. In August and October of 1995, the squadron participated in detachments to Key West and Puerto Rico that involved short periods of increased operations. During the Christmas holidays in December, however, another significant decrease in activity occurred as individuals left for the holidays. Overall, the squadron's readiness decreased from a intense deployment high to a post-deployment lull of sporadic activity.

Using the Personnel Training Readiness factors of *Average First Bomb Miss Distance*, *OPTAR Factor*, *PMA Rating* and the *Distribution of Flight Hours* for an example, the trends are evident. The magnitude of the *Average First Bomb Miss Distance* from the target and the amount of OPTAR spent per PMA percentage point have both steadily increased over the period, while percentage of *PMA Rating* and the *Distribution of Flight Hours* have both steadily decreased. All four of these indicate a significant decrease in readiness over the period.

The perceptions of Personnel Training Readiness, gleaned from interviews with individuals in the command during this time, concur with the data assessments. Flight hours were evenly distributed during the deployment, but afterward this changed significantly as most of the aircrew took leave or attended training outside the command. A wide variety of mission were flown on deployment, but many were not conducted during the post-deployment phase. Qualifications in some mission areas disappeared entirely during this period. The interview subjects did not have a perception of bombing performance, only that bombing missions were more frequent during deployment and the start of work-ups.

The trend measurement gives a broad interpretation of the data's movement, but the cycle analysis is a better indicator of activity changes in the command. Instead of a linear interpretation, the cycle calculation should show a decrease in April 1995 during the post-deployment, as well as small increases in readiness during operations in the later portions of 1995.

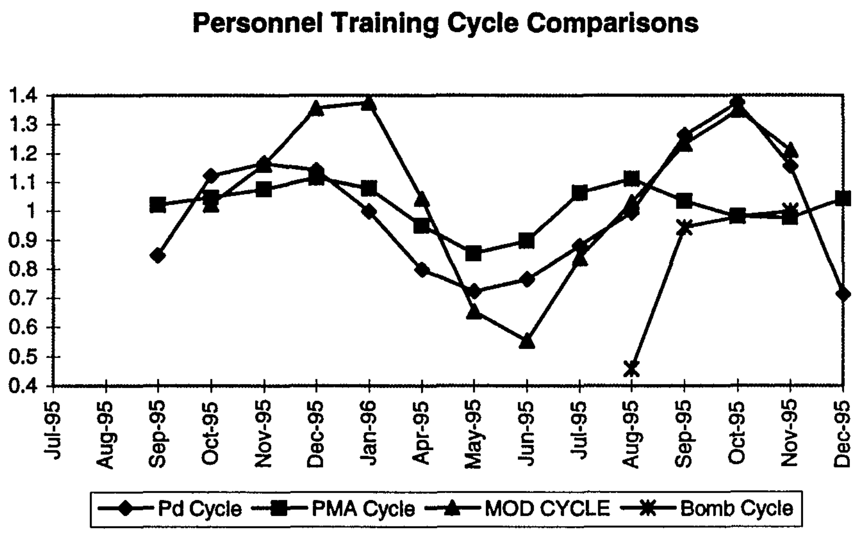


Figure 15: Personnel Training Cycle Comparisons

The cycle calculation comparisons for Personnel Training (Figure 15) all follow a similar pattern. Each has a significant downswing shortly after the squadron returned from its deployment in April. Improvements in readiness are noted during the detachments in August and October, but the levels decrease further during the Christmas holidays in December. Bombing statistics are significantly better during the daily bombing operations of August, but miss distance increased considerably when bombing training became less frequent.

The one area of concern that follows a different pattern of trend and cycle is Condition of Equipment. The trend patterns of the measures MM, MO, and ME are relatively flat over the period, indicating they are stable through the operational cycle. The cycle extremes of maintenance effort are opposite the extremes for maintenance management. As the rating for management decreases, the level of effort required increases. Meanwhile, the measure of maintenance output varies in a steady cycle that does not follow the operational activity of the command. It maintains its own regular cycle of output, regardless of the squadron's operational activity. The personnel interviewed perceived this measure as never changing over the period. They felt that MC rates were stable, regardless of the operational activity of the command. This would seem to agree with the cycle characterization of this measure as one that randomly fluctuates about a mean value without regard to squadron activity.

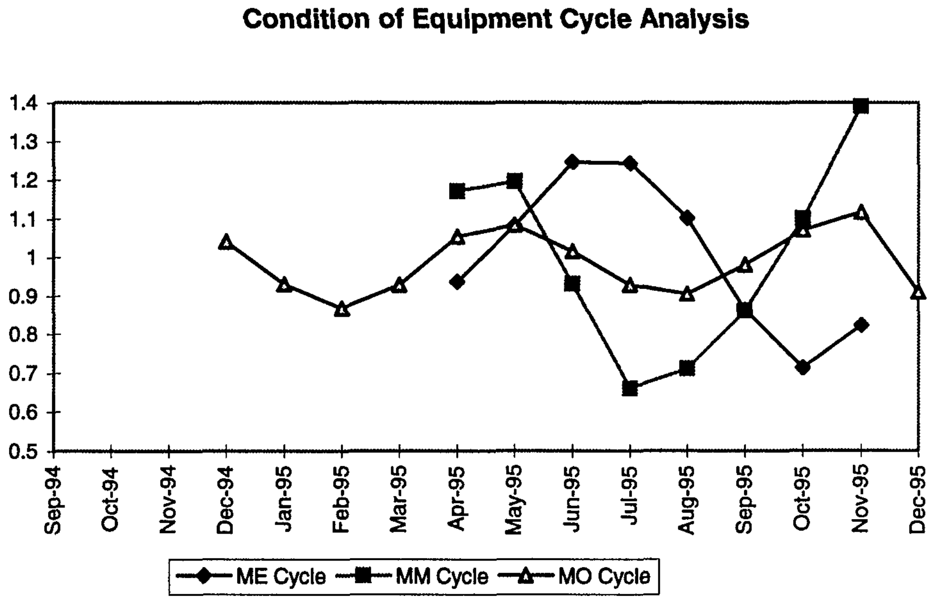


Figure 16: Condition of Equipment Cycle Analysis

The other readiness factors in the model have trend and cycle relationships that closely follow the squadron's operational activities during the data period. To illustrate this, the data period is broken down into four sections: Deployment, Post-Deployment, Start of Work-up Cycle, and the Christmas Holidays. The resulting value for each factor is examined and compared with qualitative assessments from interviews with personnel in the command during that time..

October 1994 - March 1995: Deployment

The squadron is deployed overseas in the Mediterranean Sea and the Persian Gulf onboard the aircraft carrier. The command is at its peak of readiness on the front line of national defense. The pace of operations is constant with a significant amount of flight hours logged by the command. There are occasional lulls in activity, but the squadron is maintaining a high level of capability. The Readiness factors reflect this steady state of capability in Table 2.

Table 2: Factor Analysis for Deployment Period

Readiness Factor	Interview Results	State
Aircrew Availability	No aircrew turnover during this period. High experience level and rising.	A steady increase as the constant number of aircrew assigned gain experience in the aircraft.
Support Personnel Factor	Very little turnover of support personnel.	A constant value reflecting the steady amount of sorties and unchanging manning levels.
Maintenance Effort (ME)	Steady effort perceived.	Remains steady through deployment
Maintenance Management (MM)	Pre-deployment period was spent planning for minimal scheduled maintenance requirements during deployment.	Remains steady through deployment
Maintenance Output (MO)	Mission capability of aircraft seemed constant. Numbers declined due to change in reporting procedures.	Indicates a slight decline during the deployment..
Modified Re-enlistment Factor	No abnormal numbers of re-enlistments or separations.	Steady through deployment
Workload Balance Factor	Man-hours increased with drop in flight hours to fine-tune the aircraft.	Exhibits slight variation during deployment.
PERSTEMPO	Deployed the entire period.	Steady and low during deployment since all days are deployed days.
Average First Bomb Miss Distance	Many bombing sorties were flown, but no recollection of performance.	Not available during this period.
Training Distribution Factor	Flight time was evenly distributed among the aircrew.	Steady increase as all aircrew are involved in operations.
PMA Factor	Reported as highest level due to deployed status, but great difficulty in maintaining some qualifications due to lack of training areas and tasking.	Steady and high as command remains on deployment.
OPTAR/PMA Factor	Steady stream of operating funds.	Near constant cost of dollars per PMA percentage point.
% of Ideal Aircraft Utility Factor	Sufficient number of airframes available.	Steady throughout deployment.
Cannibalization Rate	The aircraft carrier ensured squadron had all parts needed on time.	Very low as command enjoys supply priority while on deployment.

April - July 1995: Post-Deployment Stand-down

Upon return from deployment, the squadron loses a great amount of operational capability. Half of the command's personnel departs for two weeks or more of personal leave time, causing acquired skills to diminish. Many of the aircraft are transferred to other squadrons preparing for their own deployments. Support priority for the command vanishes, and the squadron moves to the "back of the line" for parts, people, and OPTAR. A great deal of personnel turnover occurs as experienced people are replaced by new recruits and replacement aircrews. The effect on the readiness factors are shown in Table 3.

August - October 1995: Start of the Work-up Cycle

During this period, the squadron begins the process of establishing combat readiness for the next deployment. At this point, the command is operating with fewer aircraft and less experienced personnel than the deployment phase. Coordinated training detachments are conducted each month to raise the level of mission capability before formal training is to begin in January. Table 4 shows the comparison of the calculated readiness factors with the qualitative assessments.

November - December 1995: The Christmas Holidays

Formal squadron training in preparation for next deployment does not begin in earnest until January. Since the squadron was deployed during the last Christmas holiday, and will be for the next one, a liberal leave policy is permitted for this holiday season. Activity is scaled back significantly, and the factors reflect this in Table 5.

Table 3: Factor Analysis for Post-Deployment Period

Readiness Factor	Interview Results	Calculated Value
Aircrew Availability	Many experienced aircrew rotate to other commands, while replacements will arrive at a later date.	A sharp decline due to fewer crews with less experience.
Support Personnel Factor	Some turnover occurs, but replacements are quicker to arrive. Many are awaiting the squadron's return.	A sudden spike increase to indicate a substantial drop in workload without a corresponding change in manning levels.
Maintenance Effort (ME)	Several post-deployment inspections take place, requiring personnel to overhaul most of the aircraft.	Increases as effort to maintain aircraft does not decrease with the activity level of the squadron.
Maintenance Management (MM)	Squadron had planned scheduled maintenance to be minimal during deployment, but now it has caught up with the command as a large amount of "high time" components need attention.	Sharp increase in April, but returns to steady level in May.
Maintenance Output (MO)	Still no noticeable change in aircraft mission capability. Slight drop as high time component are replaced. Aircraft are better after inspection overhauls in June.	Slight decrease until June, then begins a gradual increase. Once again, this value is not following command activity levels.
Modified Re-enlistment Factor	No noticeable change.	Decreases as individuals waiting to leave the service can now due so after deployment.
Workload Balance Factor	Flight hours decrease significantly, while man-hours increase during high time component maintenance.	Slight decrease, but does not change significantly.
PERSTEMPO	Squadron is home every day this period.	Large increase as tempo changes from every day deployed to every day home.
Average First Bomb Miss Distance	Bombing activity significantly curtailed.	Not available during this period.
Training Distribution Factor	With many aircrew attending training, the few remaining take all the flight time.	Huge decrease as number of crews decreases and a few crews fly what little flight time is available..
PMA Factor	No capability to maintain qualifications during deployment starts to affect PMA ratings.	Significant decrease as qualifications begin to expire.
OPTAR/PMA Factor	OPTAR available dropped, but command still could not spend it all.	Large drop in April with few flight hours flown.
% of Ideal Aircraft Utility Factor	Seems too many aircraft are on hand as Maintenance is busy with scheduled maintenance concerns and operational activity is very low.	Large drop as flight hours decrease and aircraft are not used
Cannibalization Rate	Decrease in operational tempo leaves many aircraft idle, making them prime targets for cannibalization. Supply priority also disappears.	Begins to increase.

Table 4: Factor Analysis for Start of Work-up Cycle

Readiness Factor	Interview Results	State
Aircrew Availability	New aircrew are arriving. Total number is still too low.	The previous period's decrease has bottomed-out. This value is steady, but low.
Support Personnel Factor	New people are still arriving, manning levels are high.	A slight increase over the period as new personnel arrive before their replacements have departed.
Maintenance Effort (ME)	Increases significantly with each detachment out-of-town. Also increases due to many new inexperienced personnel in maintenance, forcing squadron to re-learn some procedures and decrease efficiency.	Decreases as operational activity increases, getting more flights for the effort.
Maintenance Management (MM)	Post-Deployment problems of high time components is just about resolved. A steady pace is established.	Remains steady throughout the period.
Maintenance Output (MO)	Same steady level of mission-capable aircraft.	Still continues a cyclic pattern regardless of activity level.
Modified Re-enlistment Factor	No change noted.	Steady through the period.
Workload Balance Factor	Period is characterized by "feast or famine" in terms of operational activity, but maintenance takes advantage of slow months to work on fine-tuning the aircraft.	Varies greatly each month. Is this a symptom of varied activity or varied man-hours?
PERSTEMPO	Changes as detachments occur.	Fluctuates as detachment days take people away from home.
Average First Bomb Miss Distance	Bombing activity increases, but performance is not recorded.	First data available show a steady average miss distance.
Training Distribution Factor	Full participation during detachments, but many are attending outside training in-between.	Large increases during busy months with rapid declines in-between.
PMA Factor	Too few aircrew with too many starting from square one on mission qualifications.	While aircrew are sporadically training, new untrained aircrewmen are arriving, keeping this value low.
OPTAR/PMA Factor	Increasing levels of OPTAR.	Large increase as more OPTAR is spent to maintain PMA levels.
% of Ideal Aircraft Utility Factor	Squadron is more active, but still seems command is overburdened with aircraft.	Starts to recover as activity level increases.
Cannibalization Rate	Squadron must bring its own spare parts on detachments. Out-of-town bases are not able to fully support the command.	Still a low priority for spare parts, so increased activity raises this value.

Table 5: Factor Analysis for Christmas Holidays

Readiness Factor	Interview Results	State
Aircrew Availability	Half of aircrew are on leave during this period. Turnover is decreasing.	Still maintains a slight increase as aircrew turnover is minimal.
Support Personnel Factor	Lack of workload allows many personnel to take leave.	Increases as workload drops with no change in manning levels.
Maintenance Effort (ME)	Decreases significantly with drop in operational activity.	Climbs considerably as workload does not decrease with squadron output.
Maintenance Management (MM)	Steady throughout the period.	Rises slightly as idle aircraft require less frequent scheduled maintenance.
Maintenance Output (MO)	Still seems steady, no change.	Decreases slightly, but it seems in accordance with its own cycle.
Modified Re-enlistment Factor	No change.	Maintains the same level.
Workload Balance Factor	Flight hours decreases considerably, while man-hours dip slightly as maintenance fine-tunes the aircraft.	Decreases considerably with holidays.
PERSTEMPO	Command is home every day this period.	Drops as everyone stays home during the period.
Average First Bomb Miss Distance	Fewer bombing missions are flown.	Increases as fewer bombing missions are flown.
Training Distribution Factor	The few aircrew available take all available flight time.	Significantly drops as fewer aircrew fly what little flight time is available.
PMA Factor	Still behind on qualifications in certain missions.	Declines as even more qualifications expire.
OPTAR/PMA Factor	OPTAR decreased as most of quarterly grant was spent during the early part of the fiscal quarter on detachments.	Decreases with less operational activity.
% of Ideal Aircraft Utility Factor	Most of the aircraft remain idle during this period.	Steady slide downward as more aircraft are assigned to command, but there is little activity to employ them.
Cannibalization Rate	Little activity causes little demand for spare parts.	Starts to decrease as supply priority improves.

Model Use Within the Squadron

In its present form, the fourteen equations of the model provide a means to measure changes in a squadron's level of readiness. Calculations from the present month can be compared with the past to determine changes in command capability. While the actual value of each factor has little meaning, the movement of the data over time can be examined. Trends and cycles can be analyzed to measure progress toward deployment. By monitoring these factors over time, an all-encompassing picture of the command's combat readiness can be obtained. This would provide the command leadership with a data-based assessment of changes in squadron capability, leading to better decisions on operational commitments and prioritization.

Problem areas can be identified quickly and precisely, allowing the command to solve them more efficiently.

What the model cannot do is compare readiness levels with an ideal or expected value. To establish an expected or "normal" value for each factor, calculations would need to be made over the entire operational cycle of many different squadrons. These results would then be used to determine some type of scale for comparison, such as minimum and average values for each factor at critical points in the cycle.

Milestones can be established at critical points to determine adequate preparation during the work-up training period. These can be used to assess squadron progress at improving mission capability. Repetition of task requirements can be replaced with level of capability requirements. Individual commands can complete training more quickly, or identify areas that need additional attention prior to deployment. The variation in capability levels between deployed squadrons will decrease once all commands are required to satisfy the same criteria during work-ups.

Once a sufficient quantity of historical data is available, projections of each readiness factor can be calculated. This will add a new dimension to the model, giving the command the ability to predict future capability. The squadron leadership can look ahead to forecast problem areas and target improvement opportunities. Numbers of parts and personnel required to attain a certain level of readiness can be determined, as well as the future consequences of present decisions. Decision-making would be simplified to a great extent by combining accurate knowledge of present capability with the possibilities for the future.

CHAPTER VI

CONCLUSIONS

The mission capability of a squadron is dependent upon a variety of individual factors. Each of these factors must be considered in defining a squadron's combat readiness. By combining this definition with the reams of data routinely collected, a quantitative model was constructed.

The data set in this study does not cover a squadron's entire cycle of training and deployment, so some assumptions had to be made regarding validity of trends and cycles. The statistical analysis of the data was compared to the time period available, which was characterized as a time of decreasing overall readiness. A concerted effort should be made to compile the data over an entire training and deployment cycle. This would fine-tune the model, assessing each factor's results through an entire cycle of squadron operations.

A significant shortcoming in the model is the scarcity of historical performance data. The bombing statistics used in this study only covered the last seven months, and this data was not easy to obtain. Performance for other mission areas is only documented during formal exercises and occasional graded events. This is due to the Navy's current training program, which focuses upon task completion instead of task performance. To improve this model, methods of determining the performance of each mission must be established and recorded. The performance factor in this model could then be expanded to include air-to-air and TARPS missions. This would provide a more realistic assessment of the command's total mission capability.

To ease integration, the model uses data that is already processed by the command. Collecting the needed information would take little excess effort. A monthly report can be compiled to show the latest values, as well as the trend of the last twelve months. The squadron leadership would have a better understanding of where the command has been and what missions they can execute. Comparisons can be made with past performances to determine if sufficient progress is being made in the training cycle. Squadron performance on previous deployments can also be used to gauge current readiness levels and determine possible areas of improvement.

The model gives a global view of the squadron by considering factors from all departments. Instead of a narrow view of readiness from the Maintenance department, the model shows the variables that have an impact on every aspect of the squadron's capability. Inter-relationships between departments are highlighted, showing the need for cooperation in squadron mission execution.

The greatest benefit of this model is that it gves a unit level command the ability to quantify its level of readiness and act on these findings. The model paints a highly representative and comprehensive picture of the squadron's capability illuminating interdependencies. It allows the leadership to make data-based decisions and remove significant doubt that the command will be ready to act when called upon.

REFERENCES

[1] Betts, Richard K., *Military Readiness: Concepts, Choices, Consequences*, Washington D.C.: Brookings Institute, 1995.

[2] Hiller, Jack H., Deriving useful lessons from combat simulations, In *Determinants of Effective Unit Performance*, ed. Robert F. Holz, Alexandria, Va: U.S. Army Research Institute for the Behavioral and Social Sciences, 1994.

[3] Hiller, Jack H. and H. McFann and MAJ GEN L. Lehowicz, Does OPTEMPO increase unit readiness?, In *Determinants of Effective Unit Performance*, ed. Robert F. Holz, Alexandria, Va: U.S. Army Research Institute for the Behavoral and Social Sciences, 1994.

[4] U.S. Congress, House of Representatives, Subcommittee on Readiness, Committee on National Security, *Military Readiness: Improved Assessment Measures are Evolving*, 104th Congress, 16 March 1995.

[5] U.S. Department of the Navy, Attack Squadron Forty-Two, Executive Steering Committee Minutes on Squadron Quality of Life Survey, Virginia Beach, VA: Department of the Navy, Attack Squadron Forty-Two, 1994.

[6] U.S. Department of the Navy, Fighter Squadron Thirty-Two, *Standard Operations and Readiness Manual (SORM)*, Oceana, VA: Department of the Navy, Fighter Squadron Thirty-Two, 1995.

[7] U.S. Department of the Navy, Chief of Naval Operations, *Status of Resources and Training System (SORTS): NWP 10-1-11 (Rev. A)*, Washington D.C.: U.S. Department of the Navy, Chief of Naval Operations OP-64, 1990.

Supplemental Sources Consulted

[8] Battilega, John A. and J. K. Grange, *The Military Applications of Modeling*, Washington D.C.: Air Force Institute of Technology Press, 19xx.

[9] Dunnigan, James F. and A. A. Nofi, *Shooting Blanks, War Making that Doesn't Work*, New York: William Morrow and Company, Inc., 1991.

[10] Garrett, LT Roger A. and LCDR J. P. London, *Fundamentals of Naval Operations Analysis*, Washington D.C.: United States Naval Institute Press, 1970.

[11] Hogg, Robert V. and J. Ledolter, *Applied Statistics for Engineers and Physical Scientists*, New York, NY: Macmillan Publishing Company, 1992.

[12] Kopp, Stephen D., "A Comparison of ISAAC with Three Logistics/Resource Assessment Model Systems", Arlington, VA: Logicon RDA, 1995, Photocopied.

[13] Rich, Michael, *Recent Progress in Assessing the Readiness and Sustainability of Combat Forces*, Washington D.C.: Rand Corporation, 1987.

[14] Sherbrooke, Craig C., *Evaluation of Demand Prediction Techniques*, Washington, D.C.: Logistics Management Institute, 1987.

[15] Towell, Pat, "The Meaning of 'Readiness'," in *Congressional Quarterly Weekly Report*, Washington D.C.: U.S. Congress, February 12, 1994.

[16] Towell, Pat, "Keeping the Fighting Edge: Monitoring Vital Signs," in *Congressional Quarterly Weekly Report*, Washington D.C.: U.S. Congress, July 23, 1994.

[17] Towell, Pat, "Concerns About Readiness Fuel Battle Over Budget," in *Congressional Quarterly Weekly Report*, Washington D.C.: U.S. Congress, December 31, 1994.

[18] U.S. Congress, Senate, *Measures of Military Capability: A Discussion of their Merits, Limitations, and Interrelationships,"* Washington D.C.: Government Accounting Office Report to Sen. S. Nunn, June 13, 1983.

[19] U.S. Department of the Navy, Bureau of Naval Personnel, *Officer Distribution Control Reports 09053*, Washington D.C.: U.S. Department of the Navy, Bureau of Naval Personnel, 1994-1996

[20] U.S. Department of the Navy, Commander Naval Air Force Atlantic, *Squadron Training Matrices: COMNAVAIRLANTINST 3500.63C*, Norfolk, VA: U.S. Department of the Navy, Commander Naval Air Forces Atlantic, 1995.

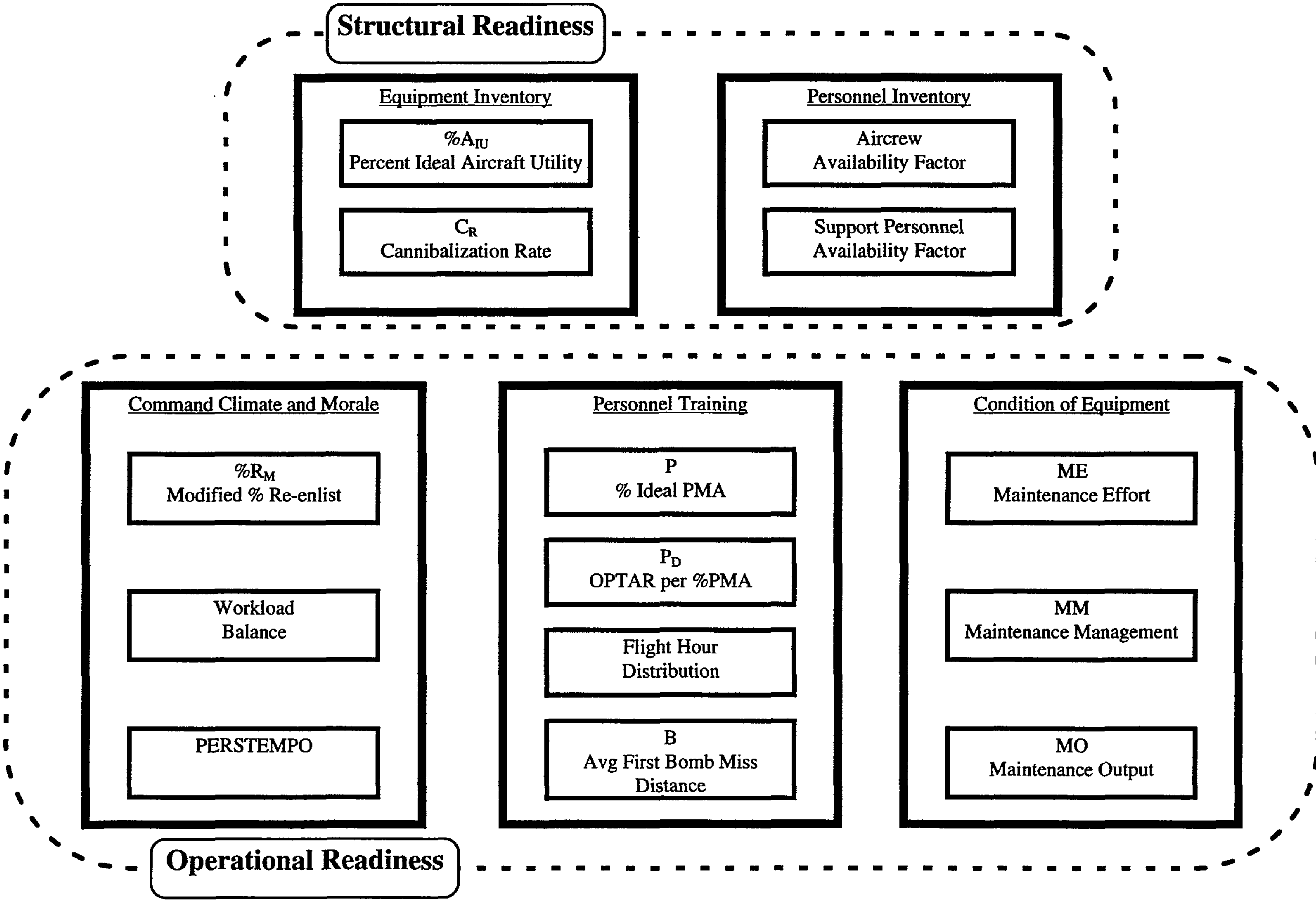
[21] Wilcox, LCDR Mark, Assistant Operations Officer, Fighter Squadron Thirty-Two, interview by author, 25 March, Virginia Beach, VA: Written notes, 1996.

[22] Wilson, J. Holton and B. Keating, *Business Forecasting*, Burr Ridge, IL: Richard D. Irwin, Inc., 1994.

[23] Zarkowski, LT Michael, Assistant Maintenance Officer, Fighter Squadron Thirty-Two, interview by author, 26 March, Virginia Beach, VA: Written notes, 1996.

APPENDIX A

DIAGRAM OF QUANTITATIVE READINESS MODEL


Structural Readiness
Equipment Inventory
%A_{IU}
Percent Ideal Aircraft Utility
C_R
Cannibalization Rate
Personnel Inventory
Aircrew
Availability Factor
Support Personnel
Availability Factor
Command Climate and Morale
%R_M
Modified % Re-enlist
Workload
Balance
PERSTEMPO
Personnel Training
P
% Ideal PMA
P_D
OPTAR per %PMA
Flight Hour
Distribution
B
Avg First Bomb Miss
Distance
Condition of Equipment
ME
Maintenance Effort
MM
Maintenance Management
MO
Maintenance Output
Operational Readiness

APPENDIX B

LIST OF MODEL EQUATIONS

Structural Readiness

Equipment Inventory:

$$\frac{\text{Total Flight Hours} / \text{Average Number of Aircraft}}{\text{522 Flight Hours} / \text{14 Aircraft}} = \%A_{IU}$$

$$\frac{\text{Number of Cannibalized Parts}}{\text{100 Flight Hours}} = C_R$$

Personnel Inventory:

$$\frac{\text{Average Total F-14 Hours}\left(\text{Crews on Board} / 85\%\text{M} + 1\right)}{100} = \text{Aircrew Availability}$$

$$\frac{(P_S \times P_{PC})}{P_L} \times 100 = \text{Support Personnel Factor}$$

Operational Readiness

Command Climate and Morale:

$$\frac{\sum_{t-2}^{t} \frac{\text{Number of Re-enlistments}}{\text{\# Re-enlistments + \# Seperations}}}{3} = \%R_M$$

$$\frac{\text{Average Monthly Flight Hours}}{\text{Total Monthly Man-Hours}/1000} = \text{Workload Balance}$$

$$(\text{\# Days in Homeport}) - (\text{\# Days Away From Homeport}) = PERSTEMPO$$

Condition of Equipment:

$$\left[\frac{\text{Total Man-Hours}}{\text{Avg \# Aircraft} \times 100} + \frac{\text{Total Man-Hours}}{\text{Total Flight Hours}}\right] \times \left[\frac{\text{Total Unscheduled Man-Hours}}{\text{Total Man-Hours}}\right] = ME$$

$$\frac{\text{Avg \# Eng Hours Rem.}(\text{Avg \# Aircraft})^2 \text{ Total Man-Hours}}{522 \times \text{Scheduled Man-Hours}(\text{AIMD Man-Hours})} = MM$$

$$\frac{\text{Sorties Lost due to Aircraft}}{\text{Total Sorties Scheduled}} + (\text{FMC Rate}) = MO$$

Personnel Training:

$$\text{Average Miss Distance of First Bomb Run} = B$$

$$\frac{\left(\frac{\text{Total Flight Hours}}{18}\right)\left(\frac{0.5}{F_H}\right)}{27.78} = \text{Training Distribution Factor}$$

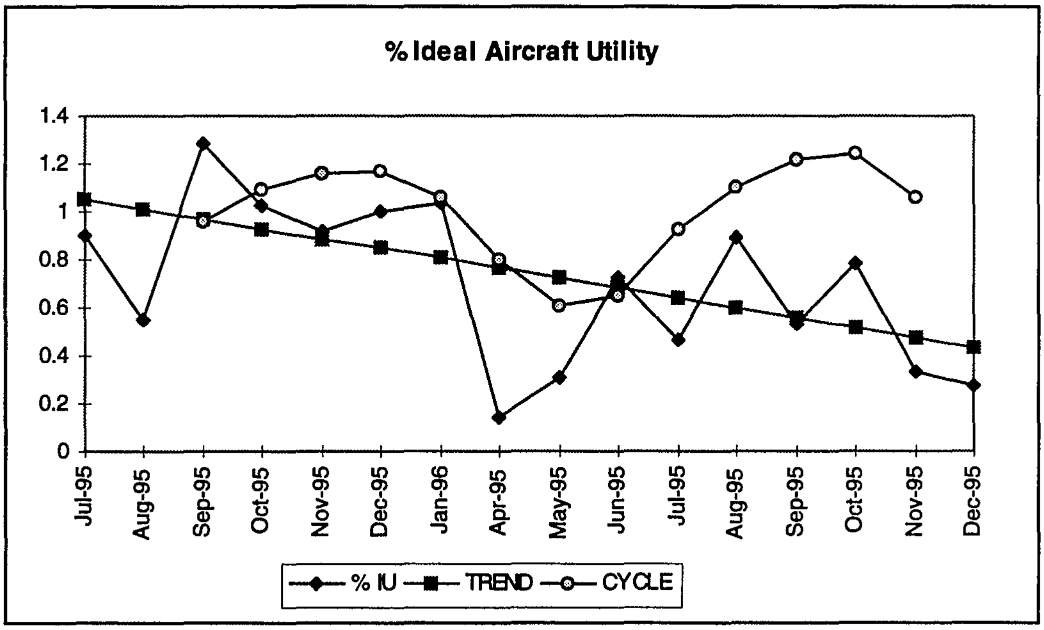
$$\frac{5 - \text{Average PMA Rating}}{4} = P$$

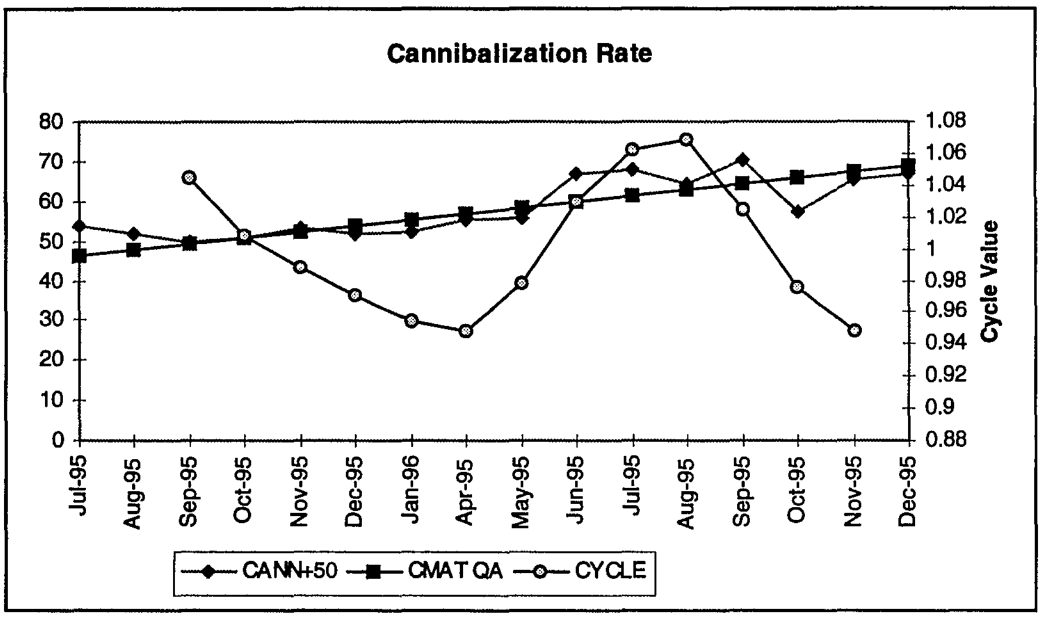
$$\frac{\text{OPTAR Spent}}{P \times (100)} = P_D$$

APPENDIX C

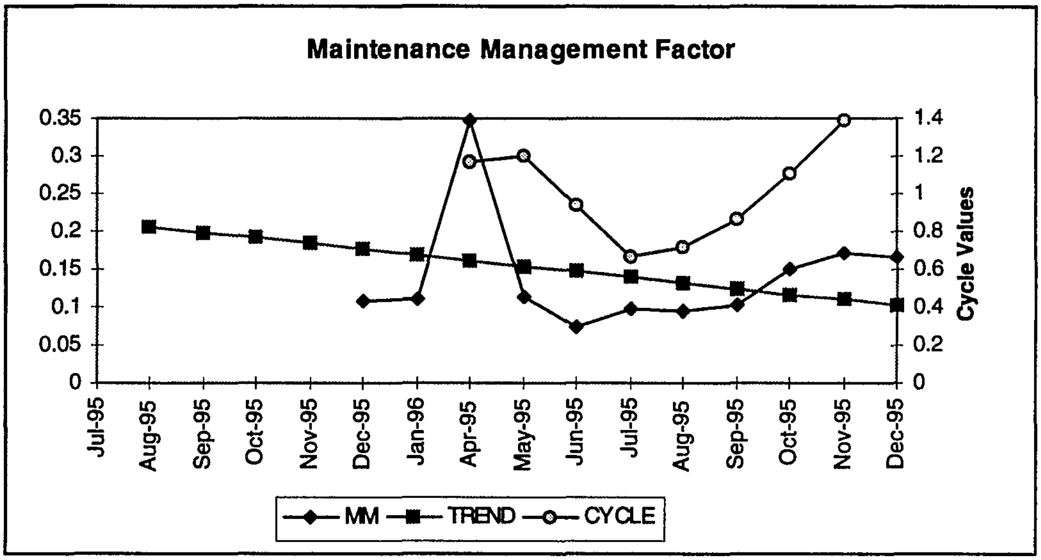
CHARTS OF PRIMARY MODEL METRICS

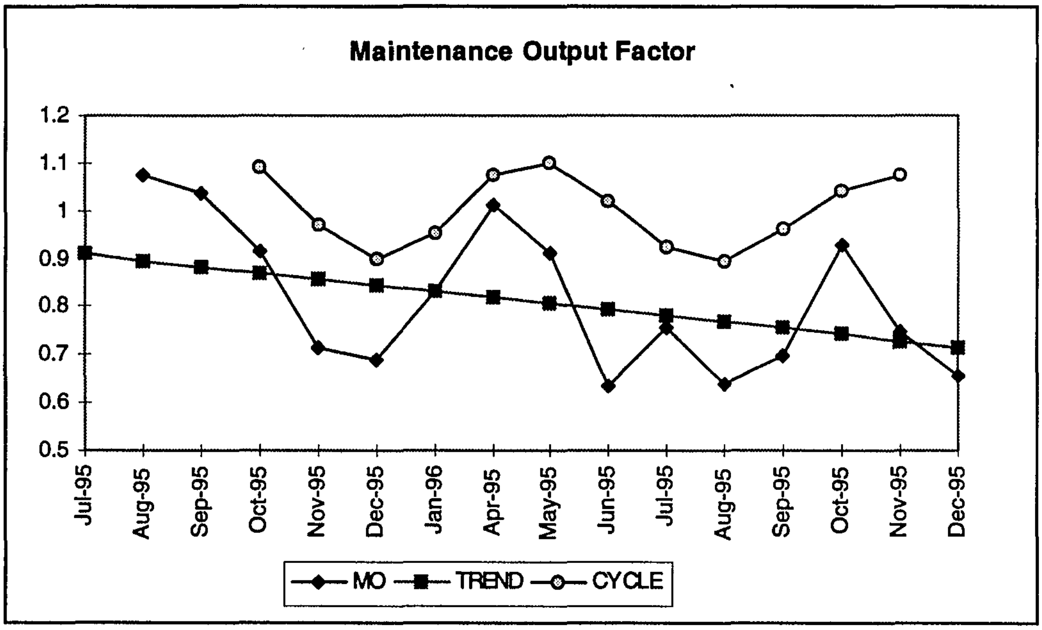
Equipment Inventory Factors

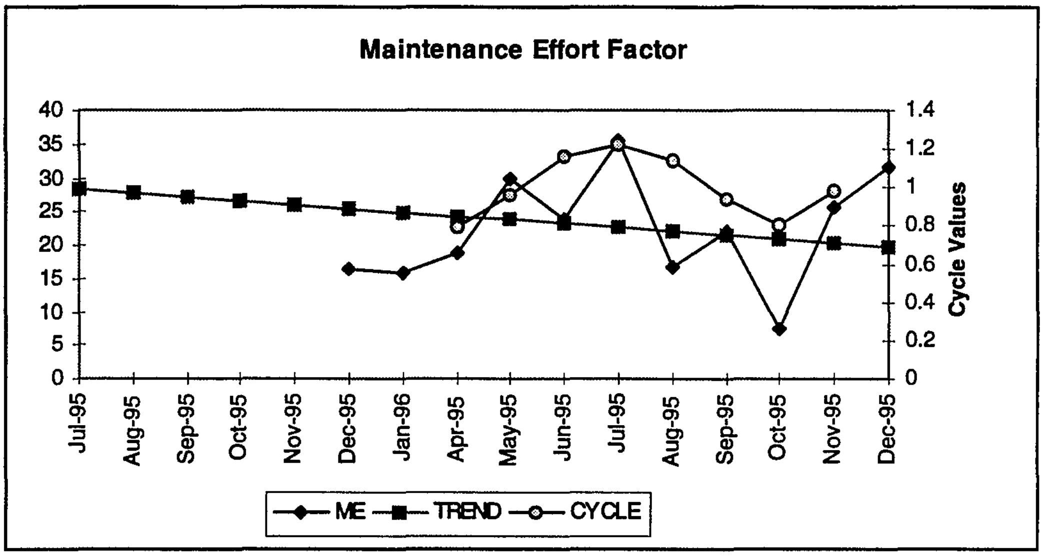




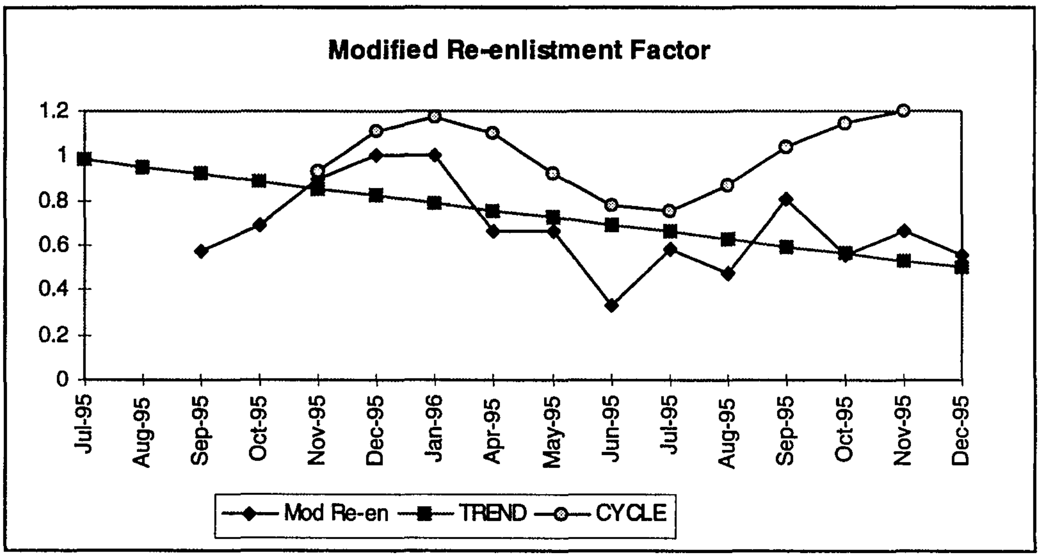
Condition of Equipment Factors

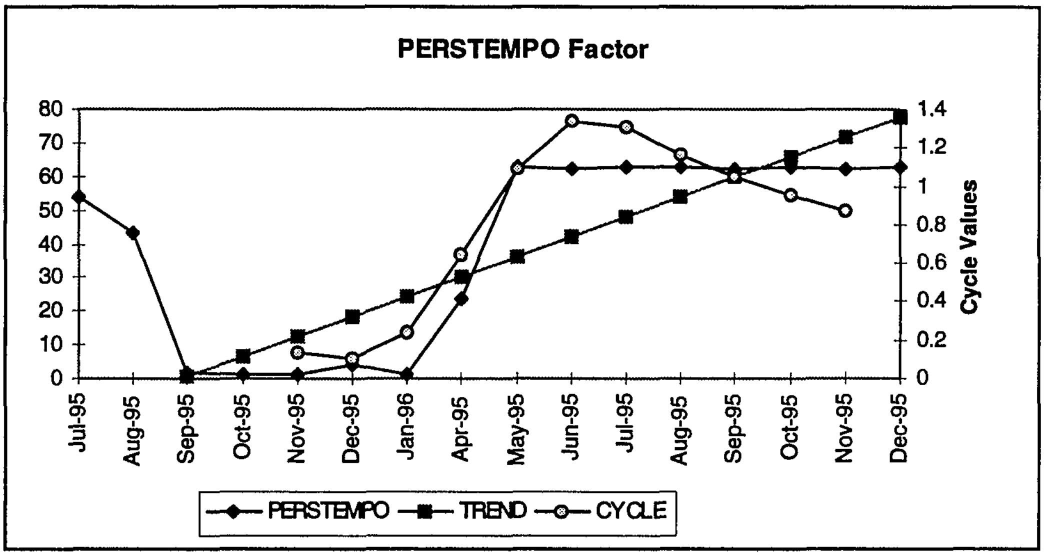






Command Climate and Morale Factors




PERSTEMPO Factor
80
70
60
50
40
30
20
10
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Cycle Values
Jul-95
Aug-95
Sep-95
Oct-95
Nov-95
Dec-95
Jan-96
Apr-95
May-95
Jun-95
Jul-95
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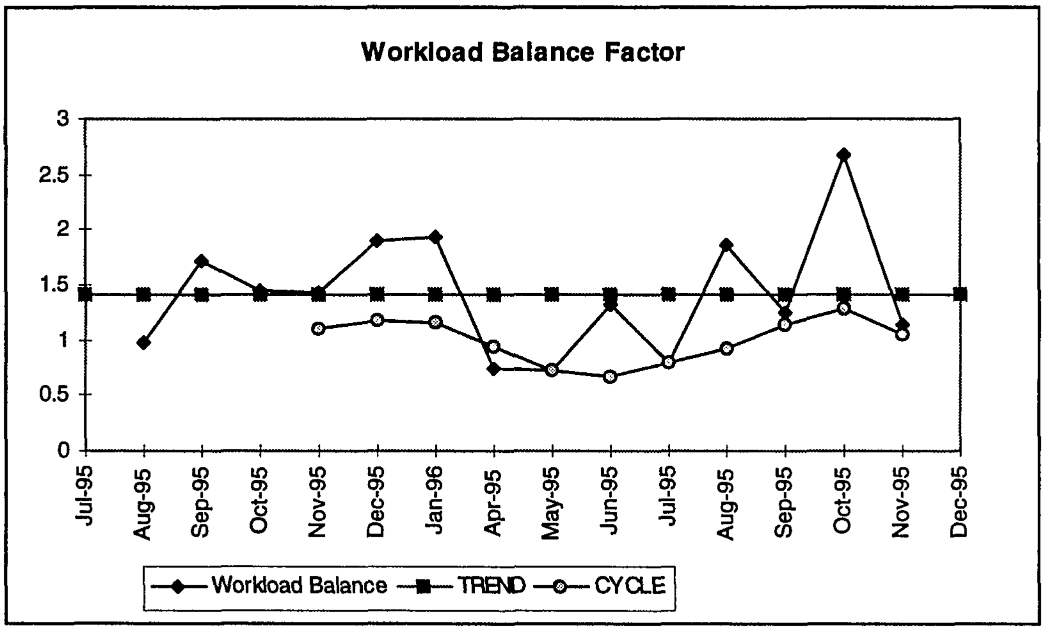
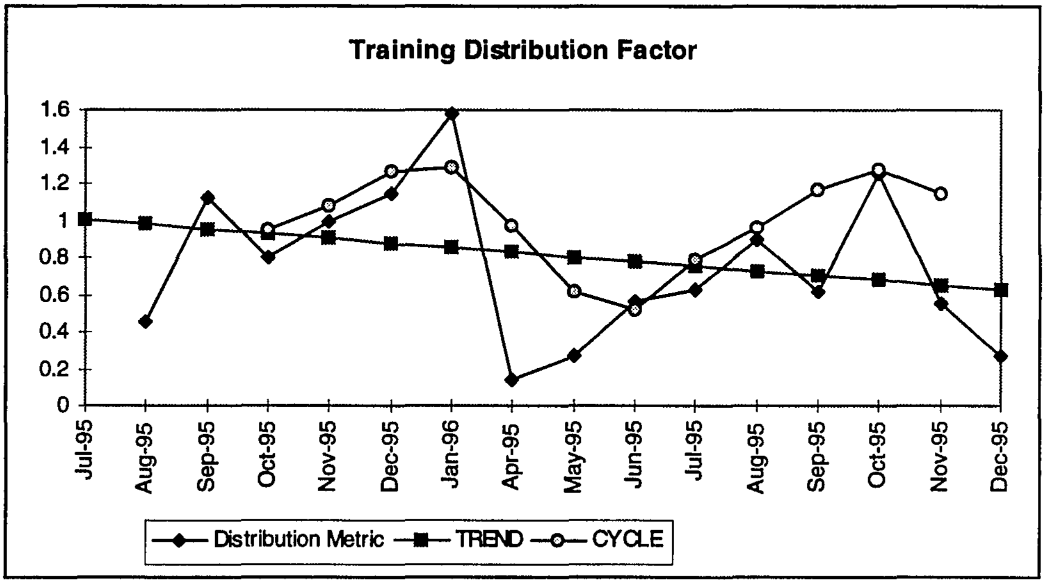
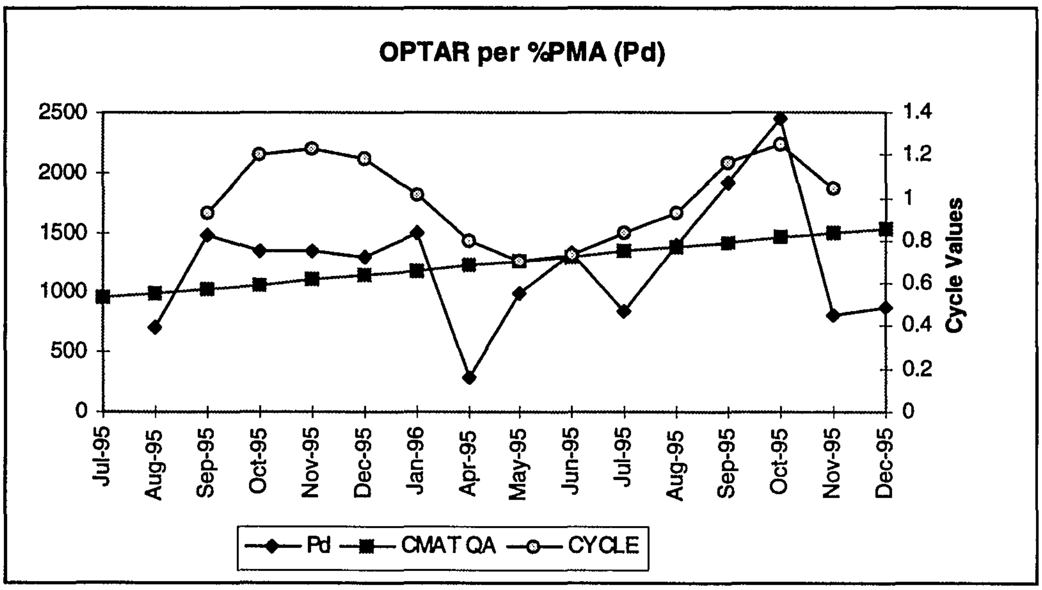
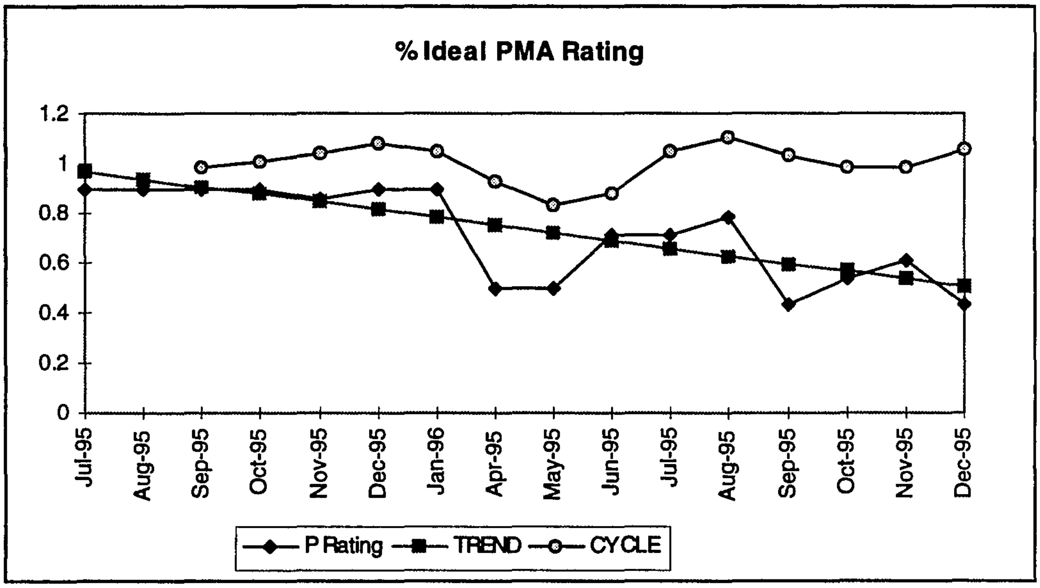
Sep-95
Oct-95
Nov-95
Dec-95
PERSTEMPO
TREND
CYCLE

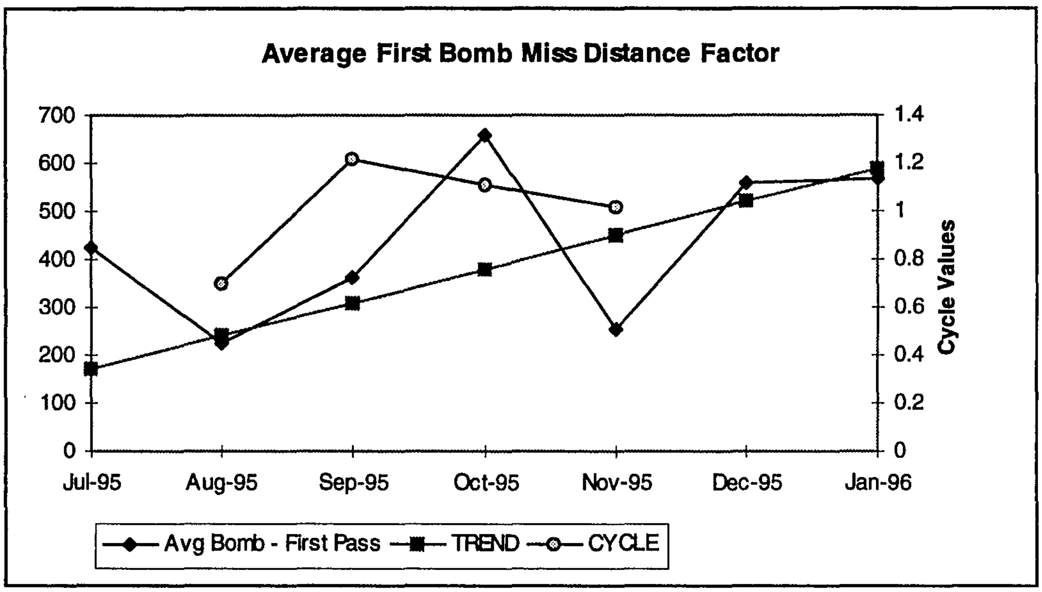

Workload Balance Factor
3
2.5
2
1.5
1
0.5
0
Jul-95
Aug-95
Sep-95
Oct-95
Nov-95
Dec-95
Jan-96
Apr-95
May-95
Jun-95
Jul-95
Aug-95
Sep-95
Oct-95
Nov-95
Dec-95
Workload Balance
TREND
CYCLE

Personnel Training Factors






% Ideal PMA Rating
1.2
1
0.8
0.6
0.4
0.2
0
Jul-95
Aug-95
Sep-95
Oct-95
Nov-95
Dec-95
Jan-96
Apr-95
May-95
Jun-95
Jul-95
Aug-95
Sep-95
Oct-95
Nov-95
Dec-95
P Rating
TREND
CYCLE


Average First Bomb Miss Distance Factor
700
600
500
400
300
200
100
0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Cycle Values
Jul-95
Aug-95
Sep-95
Oct-95
Nov-95
Dec-95
Jan-96
Avg Bomb - First Pass
TREND
CYCLE

Personnel Inventory Factors