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DOCUMENTED BRIEFING

RAND

Supporting Expeditionary Aerospace Forces

Evaluation of the RAMPOD Database

Patrick Mills, Amatzia Feinberg

Project AIR FORCE

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Prepared for the United States Air Force

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PREFACE

This documented briefing outlines research undertaken in support of emerging Air Force employment strategies associated with Expeditionary Aerospace Forces (EAFs). Although much work has yet to be accomplished in defining and preparing Air Force units for meeting these new responsibilities, it is clear that EAF concepts will play a central role in the future Air Force. EAF concepts turn on the premise that rapidly deployable, immediately employable, highly effective, and flexible air and space force packages can serve the same strategic role as a permanent forward presence in deterring aggression and, if necessary, responding to aggressive acts. The success of the EAF will to a great extent depend on the effectiveness and efficiency of the support system that undergirds flying operations. The Air Force has named such a support system one of its six necessary core competencies and has labeled it the Agile Combat Support (ACS) system.

The efficiency and effectiveness of ACS are affected by decisions made across programming and budgeting time horizons. Far-term ACS decisions affect future support structures required to meet operational requirements with future force mixes. Mid-term ACS decisions affect the design, development, and evolution of the support infrastructure for meeting operational requirements within the programming and budgeting time horizons. Near-term decisions affect where, when, and how existing resources are employed. Across this time spectrum, logistics requirements can be satisfied in a variety of ways, each with different costs, flexibility, response times, and risks.

This documented briefing discusses research supporting RAND's ongoing assessment of intermediate-level support options for the electronic countermeasure (ECM) pod system. This particular study addresses the usefulness of the Reliability, Availability, and Maintainability of Pods (RAMPOD) database as an analytical tool in support of the ECM pod study that is part of ACS efforts.

Our research shows that RAMPOD already has a great deal of useful information both in the on-line database reports and recorded in the data-warehousing system. With some modifications to the current data presentation format and the incorporation of warehoused data into the web query tool, RAMPOD can become valuable both for operational analyses, such as process performance monitoring, and for strategic planning activities.

The research addressed in this report was conducted in the Resource Management Program of Project AIR FORCE as one element of a project entitled "Evaluating Agile Combat Support Options for Implementing the Expeditionary Aerospace Force (EAF)." This project was sponsored by the Air Force Deputy Chief of Staff for Installations and Logistics (AF/IL). This report should be of interest to logisticians, operators, and mobility planners throughout the Department of Defense, especially those in the Air Force. Research for this document was completed in July 2000.

For further information, please contact the lead author, Patrick Mills, at (310) 393-0411, ext. 7983, or Patrick_Mills@rand.org.

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Project AIR FORCE, a division of RAND, is the Air Force Federally Funded Research and Development Center (FFRDC) for studies and analyses. It provides the Air Force with independent analyses of policy alternatives affecting the development, employment, combat readiness, and support of current and future aerospace forces. Research is performed in four programs: Aerospace Force Development; Manpower, Personnel, and Training; Resource Management; and Strategy and Doctrine.

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ACKNOWLEDGMENTS

Numerous persons inside and outside the Air Force have provided valuable assistance and support to our work. We thank Patricia R. Martin, Deputy Director, Electronic Warfare Management, WR-ALC/LN, for initiating this work as a subtask within the larger ECM pod support options study and Lieutenant General John Handy for continuing the sponsorship and support of this effort.

The people at Warner Robins Air Logistics Center made this analysis possible by providing their insights and critical data. We thank Shirley Cothron for providing contacts for data retrieval and Frank Hays and George Hickmon for providing insight into the RAMPOD system and special data requests from the RAMPOD data warehouse.

We also thank Master Sergeant Casimir A. Stryjewski, ACC/XRSA, at Langley Air Force Base for providing beddown data for this analysis and Major Jeff Lowdermilk at Andrews Air Force Base for arranging contacts with the 114th Fighter Wing (FW) at the South Dakota Air National Guard.

We also thank Senior Master Sergeant Larry Fossum, Major Wayne Shanks, Master Sergeant Patrick Baustian, Tech Sergeant Tom Eichacker, and Tech Sergeant Mark Moorhouse at the South Dakota Air National Guard, and Tech Sergeant Doug Koldstad at the Wisconsin Air National Guard for providing insight into the intermediate-level maintenance (ILM) pod repair process, the reporting of data to RAMPOD, and continued support of our study.

At RAND, Bob Tripp, Bob Roll, and Laura Baldwin have helped with critiques of our work. Constructive formal reviews of this document were provided by Dr. Kenneth Sperry and RAND colleague Amanda Geller. Gina Sandberg did an excellent job of preparing the document through numerous versions.

ACRONYMS

Symbol	Definition
ACC	Air Combat Command
ACS	Agile Combat Support
AEF	Air Expeditionary Force
AFLMA	Air Force Logistics Management Agency
ANG	Air National Guard
AWM	Awaiting maintenance
AWP	Awaiting parts
CSAF	Chief of Staff, United States Air Force
EAF	Expeditionary Aerospace Forces
ECM	Electronic countermeasure
ETI	Elapsed time indicator
FMC	Fully mission capable
FW	Fighter Wing
ILM	Intermediate-level maintenance
LANTIRN	Low-Altitude Navigation and Targeting Infrared for Night
LMI	Logistics Management Institute
LRU	Line-replaceable unit
MAJCOM	Major command
MDS	Mission, design, and series
MTAT	Mean turnaround time
MTBF	Mean time between failure
MTTR	Mean time to repair
MTW	Major theater war
PACAF	Pacific Air Forces
PMI	Periodic maintenance inspection

RAMPOD	Reliability, Availability, and Maintainability of Pods
SSC	Small-scale contingency
TCTO	Time compliance technical order
TPFDD	Time-phased force and deployment data
USAF	United States Air Force

Supporting Expeditionary Aerospace Forces: Evaluation of the RAMPOD Database

Prepared for Patricia R. Martin, Deputy Director, Electronic Warfare Managment, WR-ALC/LN

INTRODUCTION

Although its definition has not been finalized, the Expeditionary Aerospace Force (EAF) concept, which organizes the Air Force to respond rapidly to national security threats with tailored sustainable force, is certain to play a central role in the future of the U.S. Air Force. Several RAND reports have outlined the importance of Agile Combat Support (ACS) in meeting the rapid deployment and immediate employment requirements associated with the goals of the EAF concept.[1] Tripp et al. (2000) presented an analytical framework to guide the design and evaluation of ACS systems. In one of a series of follow-up studies that use this analytical framework, researchers examine how alternative maintenance support concepts for electronic countermeasure (ECM) pods can improve ACS for the EAF. The documented briefing here is a subtask of the ECM pod analysis. It focuses on the utility of the Reliability, Availability, and Maintainability of Pods (RAMPOD) database as an analytical tool, particularly as it applies to the broader ECM pod study.

[1]For a more detailed discussion of this work, see Tripp et al. (2000).

Project Background

- ECM Pod Project
  - RAMPOD is one of the tools we plan to use for the analysis of multiple ECM pod support options
- RAMPOD Evaluation
  - Requested by Patricia Martin, Deputy Director, Electronic Warfare Management, to evaluate RAMPOD database as an analytical tool
- RAND Focus
  - 184 long: 269 pods (sample data/charts)
  - 184 short: 628 pods
  - 131 three-band: 481 pods

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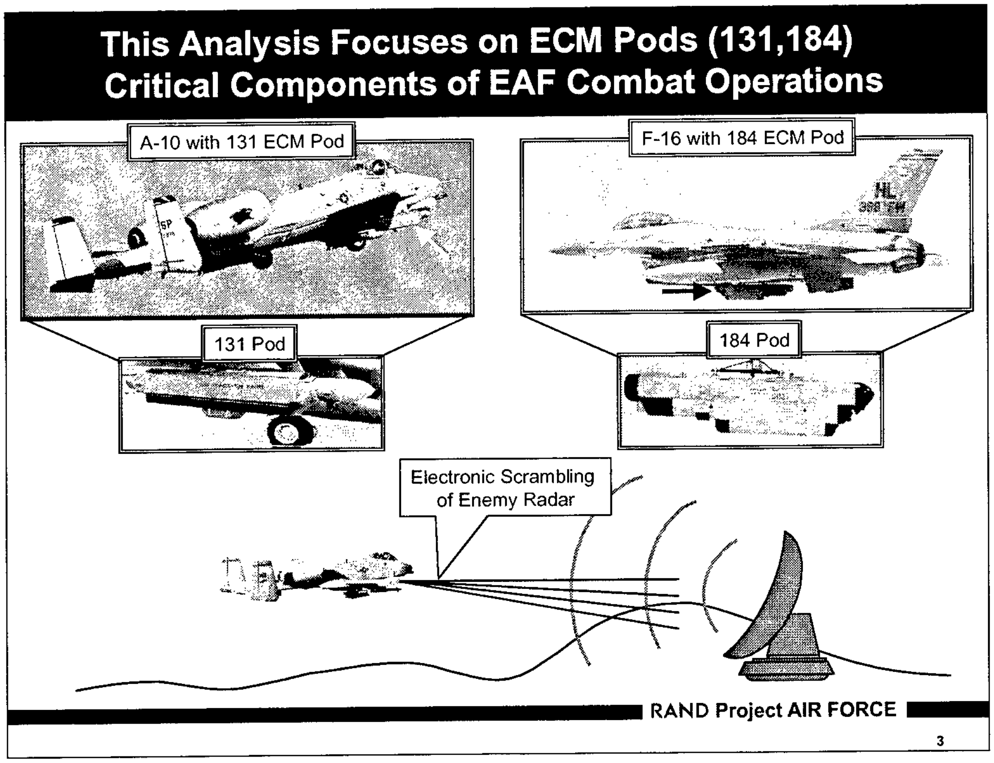
The ECM pod intermediate-level maintenance (ILM) project was undertaken as a subtask within RAND's ongoing ACS work, sponsored by AF/IL. The study addresses support structure alternatives for meeting demands for ECM pods across the spectrum of EAF optional requirements from major theater wars to peacetime operations.

The RAMPOD database, a logistics engineering support system for electronic combat pods and integrated systems, is one of the tools we plan to use in the ECM pod study. As a subtask within the ECM study, we were asked by Patty Martin to evaluate the usefulness of RAMPOD as an analytical tool. This report summarizes our analysis.

The ECM study focuses on the 184 long and short pods and the 131 three-band pods. Charts and sample data in this document are from 184 long pods.



The ECM pod is a single pod mounted under the fuselage or wing of an aircraft. The pod allows for electronic scrambling of enemy radar, improving the survivability of engaged aircraft.

As of October 1999, the U.S. Air Force inventory included 2300 aircraft configured for ECM pods, including all blocks of F-16A, B, C, and D and all A-10 models. Although there are several variations of ECM pods, our analysis focuses on AN/ALQ-131[2] three-band, AN/ALQ-184 long, and AN/ALQ-184 short pods because they represent the majority of the current inventory, and a significant amount of data associated with these pods is available in RAMPOD.

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[2]AN/ALQ signifies airborne countermeasure equipment that serves special or combination purposes. There were originally two blocks of two-band and three-band 131 pods. The Block I pods were retired as the Block II pods became available. The remaining two-band pods have been converted to three bands. The 184 long pods, the older of the two 184 models, are three-band technology, while the short pods are two-band technology.

Analysis of RAMPOD Web Site as a Useful Data Source

- **Overview of RAMPOD**
- **Analytic Approach Framin g the Analysis**
- **Proposed model of ECM pod ILM process**
- **Proposed data elements in ECM pod study supported by RAMPOD**
  - Beddown
    - Available data
    - Application
    - Recommendations
  - Pod removals
  - Process queues
  - Repair process
- **Summary**

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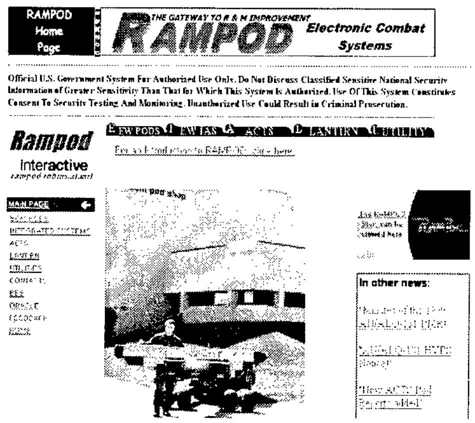
The chart shown above provides an overview of the remainder of the document. First, we give an overview of the format and type of data contained in RAMPOD. We then describe the analytic approach and methodology of RAND's overarching ACS studies. Next, we discuss the proposed model architecture of the ECM ILM process and how RAMPOD data supports this model. Subsequently, we discuss the specific data elements in the ECM pod repair-process model that RAMPOD supports, how the data can be used in the analysis, and potential improvements to the availability and display of the data. We discuss the beddown, removal rate, and repair-process elements in great detail and offer opportunities for improving repair-shop operational performance monitoring through enhancements to the RAMPOD system. We close with a summary of our recommendations for the RAMPOD web site and database.

RAMPOD Is a System That Reports Reliability, Availability, and Maintainability Data of Pods

- Web-based
- Has preprogrammed queries
- Flexibility of choices differs from query to query
  - Level of detail: MAJCOM, base, pod, serial number
  - Total history or past year
- Displayed in text format
- RAMPOD team is a helpful resource
  - Frank Hays



https://www.rampod.robins.af.mil/

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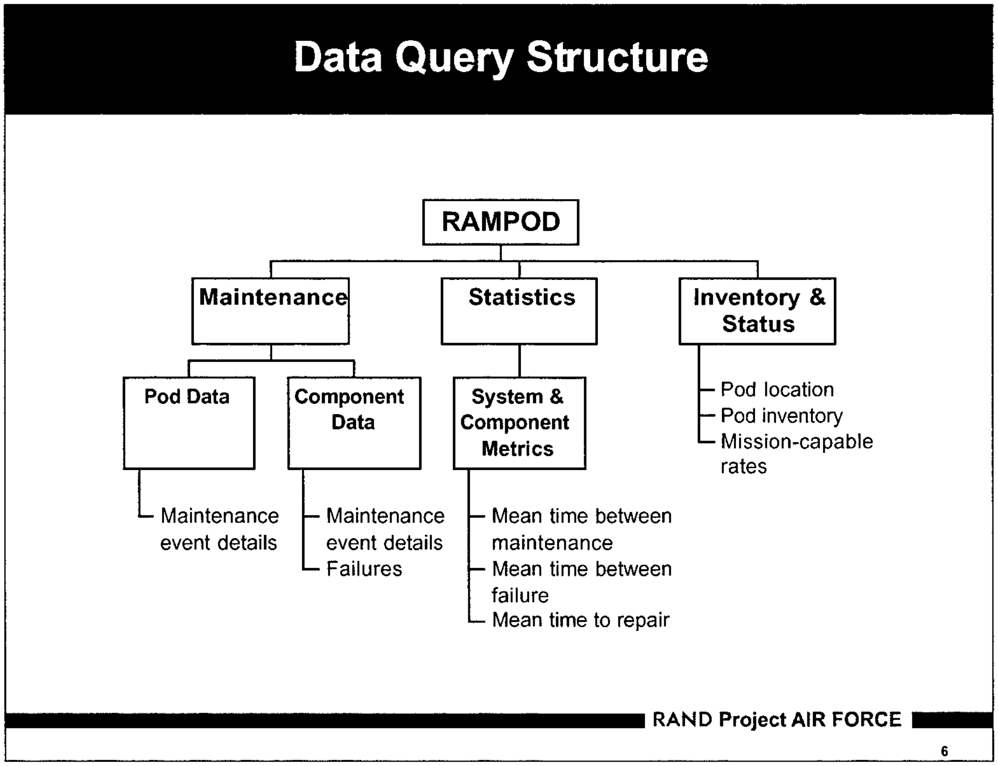
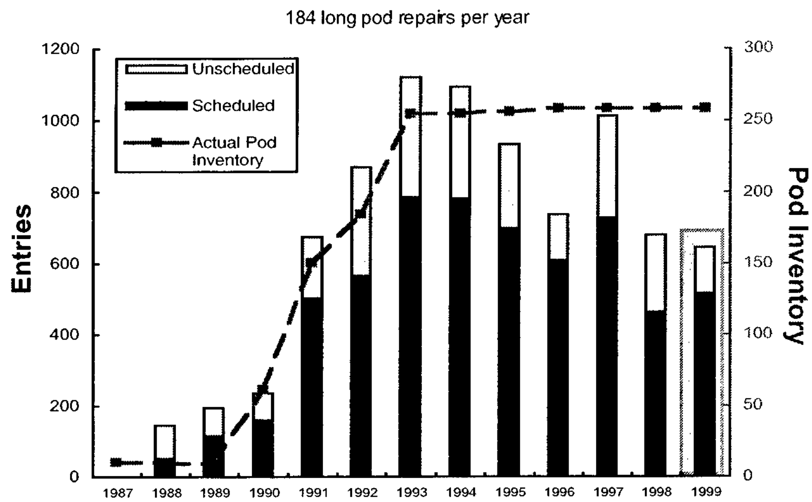
OVERVIEW OF RAMPOD

We now offer a brief overview of the RAMPOD database followed by an assessment of its applicability to our ECM modeling efforts. The RAMPOD web site is located at https://www.rampod.robins.af.mil. RAMPOD is a reliability, availability, and maintainability logistics engineering support system for electronic combat pods and integrated systems. RAMPOD information is displayed in a web-based format and includes data for ECM pods, their associated support equipment (limited), LANTIRN (being integrated), integrated avionics systems (limited), and air combat training systems (limited). RAMPOD tracks more than 1300 ECM pods at 50 bases worldwide and has preprogrammed queries that can be changed within certain limits to suit the user. Much of the data can be summarized by major command (MAJCOM); base; mission, design, and series (MDS); or pod serial number. After the query is selected, the data is displayed in a text format. The RAMPOD team is also a helpful resource. Frank Hays has aided us considerably in acquiring some of the RAMPOD data pertinent to our study in a more complete and flexible format for our analytical needs. Some of this data will be shown later in the report.



RAMPOD's ECM pod data is organized into three sections: *maintenance, statistics,* and *inventory and status*. The maintenance section has both component and pod data. Component data available includes most common part removals, failure event data, and part removal detail referenced to specific pods. Pod data for each pod serial number includes aircraft and bench hours, failures, critical failures, and times between maintenance and failures as well as individual maintenance records. The statistics section has both system and component metrics. System metrics for each MDS include mean time between failure (MTBF), mean time between critical failure, mean time between repair, mean time between maintenance, mean time to repair (MTTR), mean turnaround time (MTAT) (for 184 pods only), and operating hours, aggregated by base or MDS. Component metrics include, for individual parts on 184 pods only, operating hours, MTBF, mean time between critical failure, and mean time between demand. The inventory and status section has pod location and inventory organized by either the pod-owning base or the actual operating location, along with mission-capable rates as designated by fully mission capable (FMC), awaiting maintenance (AWM), awaiting parts (AWP), work in process, and condemned. RAMPOD reports daily the most current inventory and status updates from units, although not all bases are shown. It has also been reporting monthly mission-capable rates since January 2000. The inventory and status section shows, for each base, how many pods are in each status.

184 Long Repair Data Increased with Inventory Buildup but Has Declined over Last Five Years



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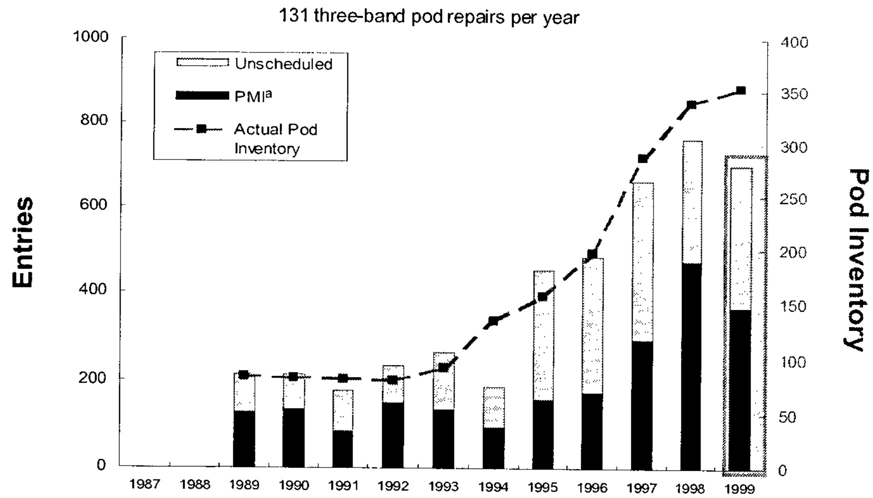
In its current form, RAMPOD cannot generate graphical output; thus, the next three overview charts were developed using historical data pulled from the underlying data warehouse supporting RAMPOD. As the chart above shows, there has been a significant increase in the amount of data reported to and displayed in RAMPOD. This chart shows the changes in the number and type of repair data entries in RAMPOD over the last 13 years for 184 long pods. Each repair type is broken out for each column. The actual number of pods in inventory each year is represented by the dotted line overlaid on the columns. It should be noted that this data was acquired in November of 1999, so the last few months of 1999 data are absent, making 1999 data incomplete. This is also the case with several of the charts that follow.

The RAMPOD data warehouse contains much data that cannot be readily accessed through the current web-based tool; thus, unless otherwise specified, data for charts and discussion was extracted by Frank Hays upon special request.

131 Three-Band Repair Data Increased with Inventory Buildup



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[a]PMI = periodic maintenance inspection.

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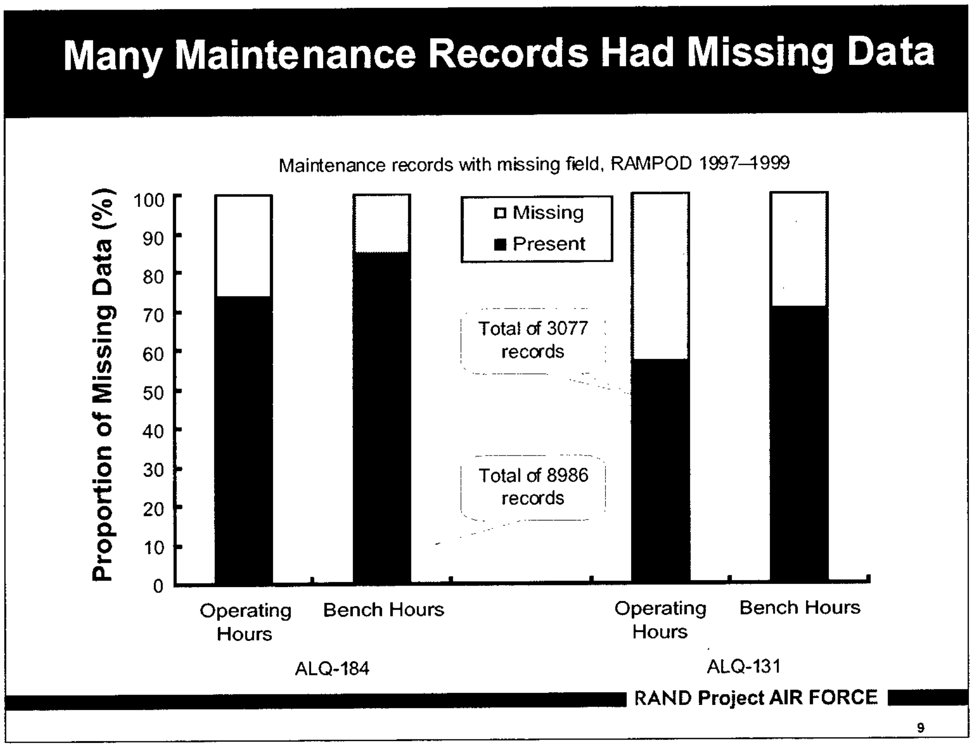
This chart displays the same type of data as in the previous slide, but for the 131 three-band pods. The rise in pod inventory and maintenance entries is due to the modification of two-band pods to three-band pods beginning in the mid-1990s. The steady rise in pods is accompanied by a similar rise in maintenance events, suggesting a fairly steady ratio of repairs per pod during this time period. This slide, like the previous one, shows the kind of data that RAMPOD contains. Again, the 1999 repair data is incomplete.



One of the issues we found with the RAMPOD data centered on quality —in this case the number of entries that are missing various data elements.[3] The chart above shows the proportion of missing data in two of the fields in the maintenance records—operating hours and bench hours—between 1997 and 1999 for the 184 and 131 pods. These two fields were chosen because of their relevance to the larger ECM study. The lower part of each column represents the number of records that had data in the field for the maintenance record; the top section shows the number of records that had no data in that subject field.

Although the percentages of missing data are significant, estimates using the remaining data can still be used.[4] The issue is the desired precision of the statistics. For Air Force–wide or MAJCOM-wide measurements, depending on the time period measured, an adequate sample should be easy to acquire. For many of the bases, however, one year of data would probably not yield a large enough sample size to ensure confidence that the estimate was representative of their pods' performance. Several bases were missing 50 percent of their operating-hour or bench-hour

[3]For a further discussion on data quality problems and their impact on analyses, see Galway and Hanks (1996).

[4]This assumes that the missing portion of the data is similar to the data available and bases statistical confidence only on real entries.

data. Since a lower percentage of total records captured would decrease the likelihood that the estimated mean (or other statistics) matched the actual mean,[5] this would leave very few records for smaller bases, and many base-to-base comparisons would therefore be suspect. Also, if smaller time periods—months or quarters—were used for these statistics, only bases with many pods and/or high pod usage would have adequate sample sizes for analysis.

Although several data quality and quantity improvements may be possible, a more comprehensive analysis (e.g., one that examined several data elements in several sections) would better quantify RAMPOD's data quality before implementation. Presumably the missing-data problem originates during maintenance, when data is recorded from the pod. A first step could be to give feedback to the units informing them how much of their data is missing. This could come in the form of a simple monthly report stating the total number of maintenance records reported in the previous month and the percentage of missing data in each field. It could also include some aggregate numbers for other bases or the overall force for comparison. Simply showing the units how complete their data is (especially in comparison to other units) could draw enough attention to the issue to encourage better recording and reporting. With this regular feedback, base commanders could know how well their data is being reported to RAMPOD and therefore determine how relevant it is for self-measurement.

Another way to give units this kind of feedback is to use only data from bases that had an adequate sample and notify those bases that were left out for this reason. This could additionally highlight the importance of reporting good data.

A different kind of solution could lie in making RAMPOD's data display more user-friendly and more applicable to individual units. Graphical displays—discussed in greater detail later in this report—can be concise and easy to understand; thus, they could allow for more widespread and regular use of the RAMPOD web tool among individual units. The more the units use the web tool for performance reporting, the more likely they are to encourage accurate recording and reporting of data. It is possible that the more people use RAMPOD, the more attention the data would be given.

This overview highlights some opportunities for operational and strategic analyses possible with the RAMPOD system—although not in its current format. We detail these opportunities in the charts that follow.

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[5]For a further discussion of statistical sampling and estimation, see Smith (1988).

RAMPOD Data Warehouse Offers Several Performance Measurement Opportunities

- **Tracking pod performance trends**
  - **Permits detection of systemic or local problems**
- **Detailed breakout of data at different levels**
  - **Allows comparison of performance and benchmarking of processes between bases or MAJCOMs**

Missing data may adversely affect performance measures

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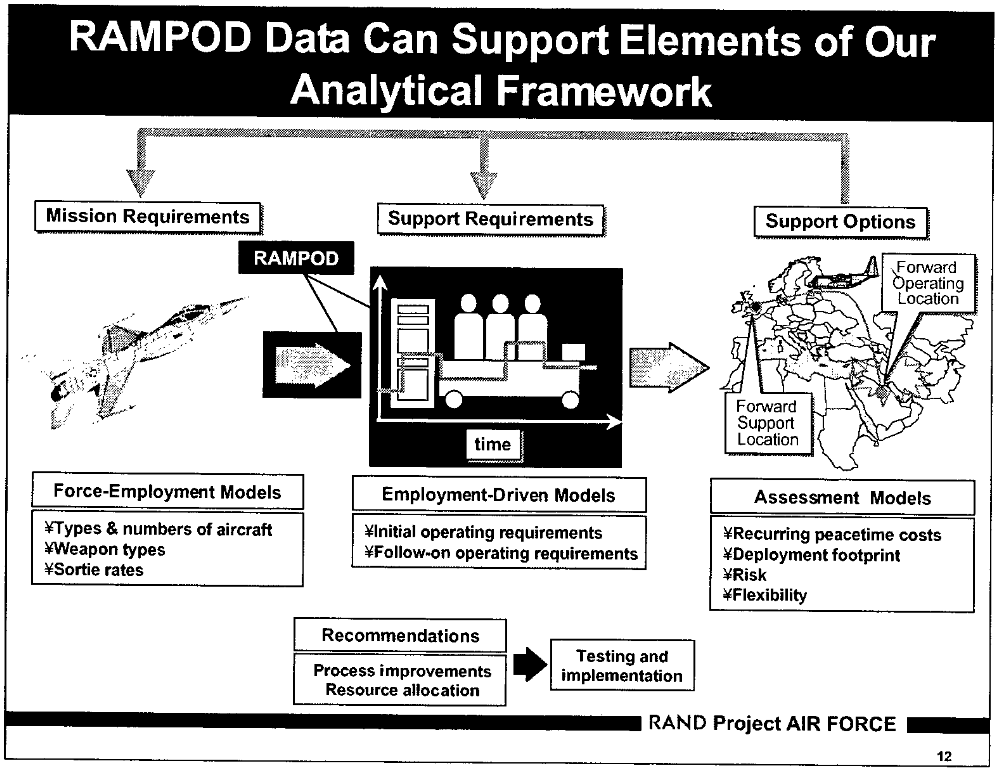
The data already reported to and stored in RAMPOD has great potential for supporting operational and strategic analyses of ECM pods as well as the other weapon systems being integrated into the database. These opportunities will be expanded on throughout this report. The first is to track and display trends for removals, repair times, and in-shop queue using data already captured by RAMPOD. This could permit the detection of systemic or local problems at an operational level and allow for more comprehensive strategic planning. Next, the level of detail at which data is reported can enhance analysis. Aggregating data at different levels allows for comparison of performance and benchmarking between bases or MAJCOMs. Finally, as noted earlier, the amount of missing data can adversely affect analysis, so improving reporting to the system could increase confidence in analyses supported by RAMPOD. We expand on these opportunities throughout this report.



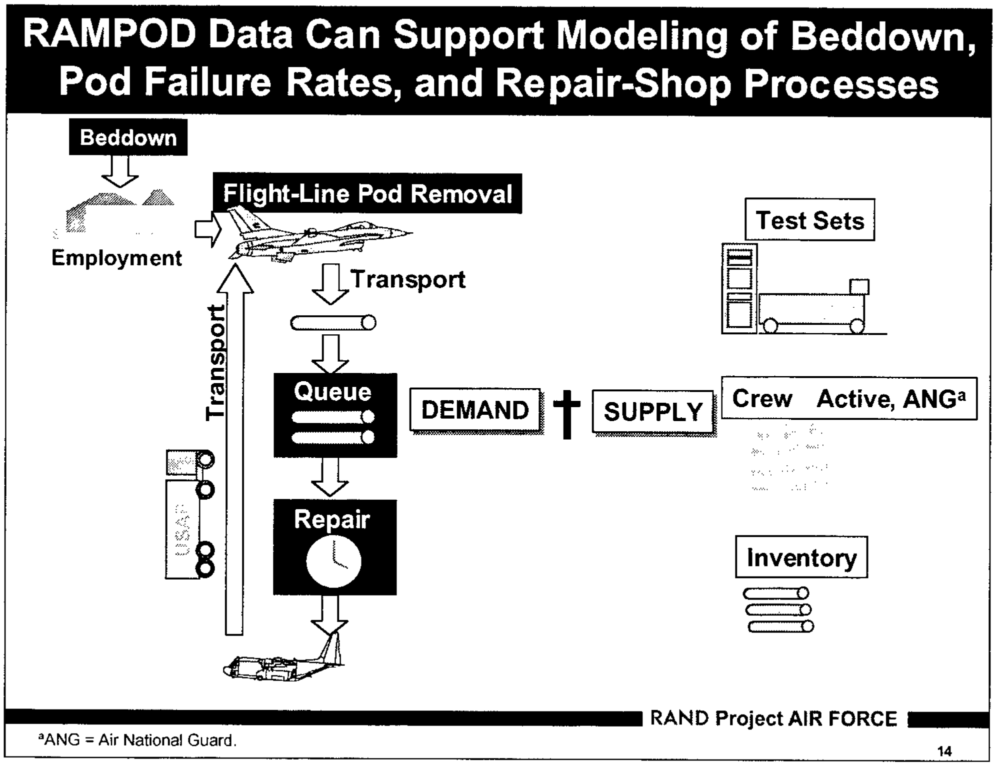
ANALYTIC APPROACH

All of our EAF support posture evaluations use the employment-driven analysis approach shown in the chart above. The first step, shown on the left, uses force-employment models to identify the force packages necessary to successfully accomplish anticipated missions (e.g., the numbers of each aircraft type and their flying requirements for each scenario). In this case, the information is used to estimate the demand for ECM pod,s which, together with the support concept being modeled, drives the requirements for maintenance equipment, maintenance personnel, spare parts, and transportation resources, as represented in the center of this chart. We then determine the costs of each alternative and evaluate them against the operational requirements, and the results obtained forecast the effects of potential support options. If the alternatives do not meet operational needs, the method can be used to evaluate possible revisions of operational objectives or to develop alternative support practices or technologies to lift constraints.

The alternative support structure designs are defined by peacetime and wartime locations of ECM pod aircraft intermediate maintenance assets. These locations drive the quantities of four resources: intermediate test stands and fixtures, personnel, spare parts, and transportation assets. We extend this approach to assess possible investment options and their effect on support system capabilities and hence resource requirements.

The ECM pod analysis begins with the employment-driven resource models to determine the minimum resource levels that enable each support structure to meet the two-MTW (major theater war) scenario's operating demands. After determining the composition of each alternative structure, the analysis evaluates it against the goals defined by the EAF objectives as well as peacetime operations. Through an iterative process, we develop a solution space encompassing the various scenarios and support options.

The highlighted areas show where RAMPOD contains data that can support this modeling framework. It contains data on pod failure rates and repair-shop processes, both of which are drivers of the support requirements. We examine the applicability of RAMPOD to these model elements in the following section.

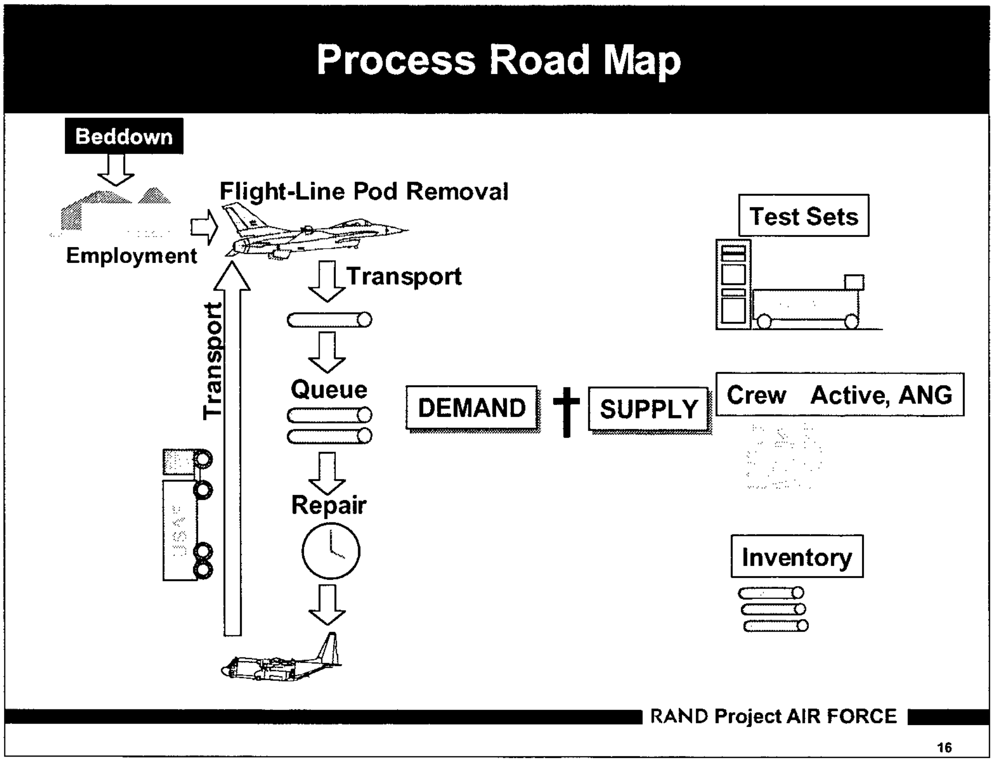


PROPOSED MODEL

The chart shown above describes the basic elements of our proposed analysis model as applied to ECM pod employment and support structures. It also highlights elements of the process that RAMPOD data supports.

The loop on the left side of the chart describes the system demand. Starting with a given beddown and a specific employment program, we can predict the number of pods removed from the aircraft. We will specifically model removals to the back shop, or intermediate level, not those at the flight line. Whereas RAMPOD offers limited removal-rate data due to minimal peacetime ECM pod operational requirements, RAND will develop more robust failure-rate relationships using RAMPOD data in concert with data collected during the Air War over Serbia. Once removed, the pods must be transported to the back shop, which may be on base or offsite. In the shop, the pods await repair until capacity and/or parts are available. The in-shop queue and repair times can be based on actual data from RAMPOD, such as the elapsed time indicator (ETI) clock times and powered-off repair. After repair, the pods must be transported back to the flight line. In the on-base repair option, transportation is usually by trailer, whereas in the consolidated repair approach, transportation may be by air or truck. To summarize, the left process loop on this chart generates a certain time demand on the system. Now let us consider the supply side of the model. We included three major elements of supply: stockage (the number of pods or line-replaceable units [LRUs] available), the number of test sets needed, and the number of people required given various work schedules, productivity rates, and logistics structures. Combining these elements, we can assess resource allocation and availability. These elements will be outputs of our models and thus do not require data from RAMPOD.

In each scenario, the goal will always be to have supply greater than or equal to demand. To summarize, RAMPOD can help us develop beddowns as well as removal-rate relationships, in-shop queuing models, and repair-time estimates.



PROPOSED DATA ELEMENTS

The chart above will serve as the process road map for the remainder of the document, with subsequent sections highlighted on the chart. Next, we discuss each element of the ILM process for which RAMPOD has data. In each section, we discuss what data is available, how this data can be used, and potential improvements to the current reporting system. As indicated earlier, the RAMPOD data warehouse contains much data that cannot be readily accessed through the current web-based tool.

RAMPOD Beddown Data Applicable to Analysis

Current	Proposed
☑ Pod inventory ☑ Pod status ☑ Support equipment inventory ☑ Support equipment status	❑ Integrated beddown, including pods, support equipment, aircraft, and personnel ❑ Personnel experience
❑ MTBF	❑ Time between failure ❑ Separate transmitter times
❑ MTAT	❑ Awaiting maintenance ❑ Awaiting parts
❑ MTTR	❑ Time to repair ❑ Separate repair types
❑ Single number ❑ Text	❑ Distributions, percentiles, trends ❑ Graphical

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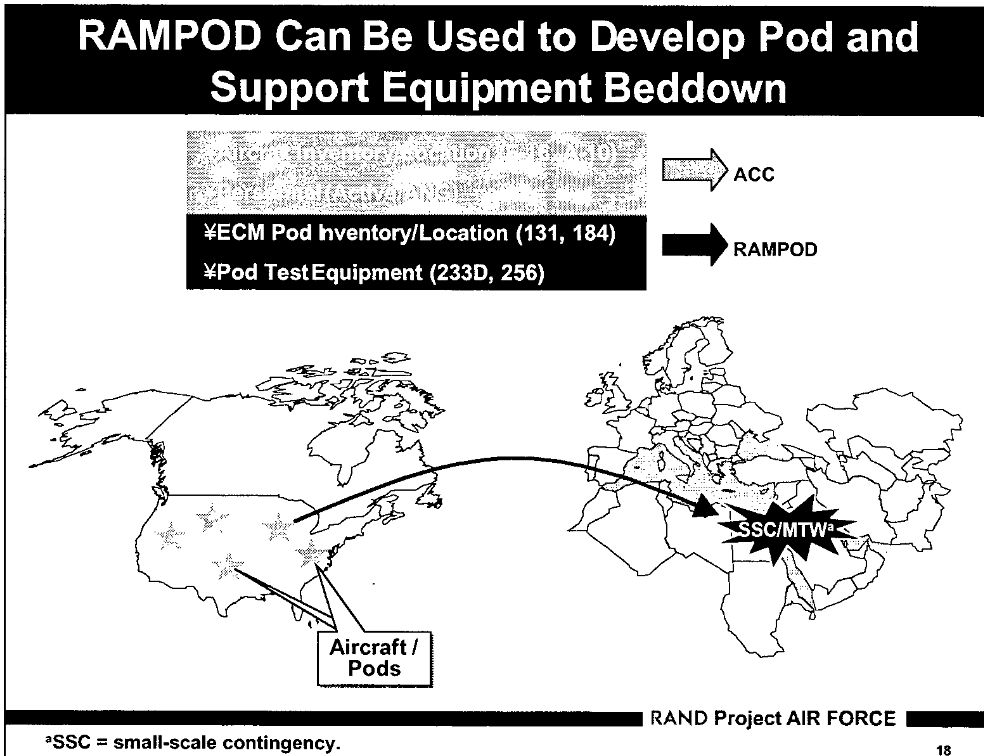
Beddown

RAMPOD includes two elements of the beddown we propose to use for the ECM study. It has up-to-date data on the location, inventory position, and operational status of ECM pods (131 and 184) as well as the number and location of the test equipment used to repair these pods (233D and 256). This data can be summarized by MAJCOM or base for each MDS and gives a recent snapshot of the availability of pods and test equipment. Next, we show how our analytic models can use this data.



The objective of the ECM analysis is to determine the costs and operational benefits of alternative ECM pod maintenance structures that can satisfy the entire spectrum of operational requirements, including the Defense Planning Guide's two-MTW scenario, a one-MTW scenario, small-scale Air Expeditionary Forces (AEFs), and boiling peacetime operations. When modeling an employment scenario, we must begin with a corresponding deployment plan and an initial force beddown.

There are four components to the beddown necessary for our models. We use the location and inventory of ECM pods (131 and 184), test equipment (233D and 256), and aircraft (F-16 and A-10). We also use the location and skill level of the personnel assigned to ECM pods. Although RAMPOD has pod and test equipment inventory, aircraft and personnel data need to be attained from other sources such as Air Combat Command (ACC).

Potential Improvements and Benefits

Current	Proposed
❑ P	☑ Integrated beddown, including pods, support equipment, aircraft, and personnel
❑ P	
❑ S	
❑ S	☑ Personnel experience
❑ M	❑ Time between failure ❑ Separate transmitter times
❑ M	❑ Awaiting maintenance ❑ Awaiting parts
❑ MTTR	❑ Time to repair ❑ Separate repair types
❑ Single number ❑ Text	❑ Distributions, percentiles, trends ❑ Graphical

Benefits

- Offers comprehensive snapshot of force availability
- Facilitates data collection efforts
- Allows for better planning of manning requirements

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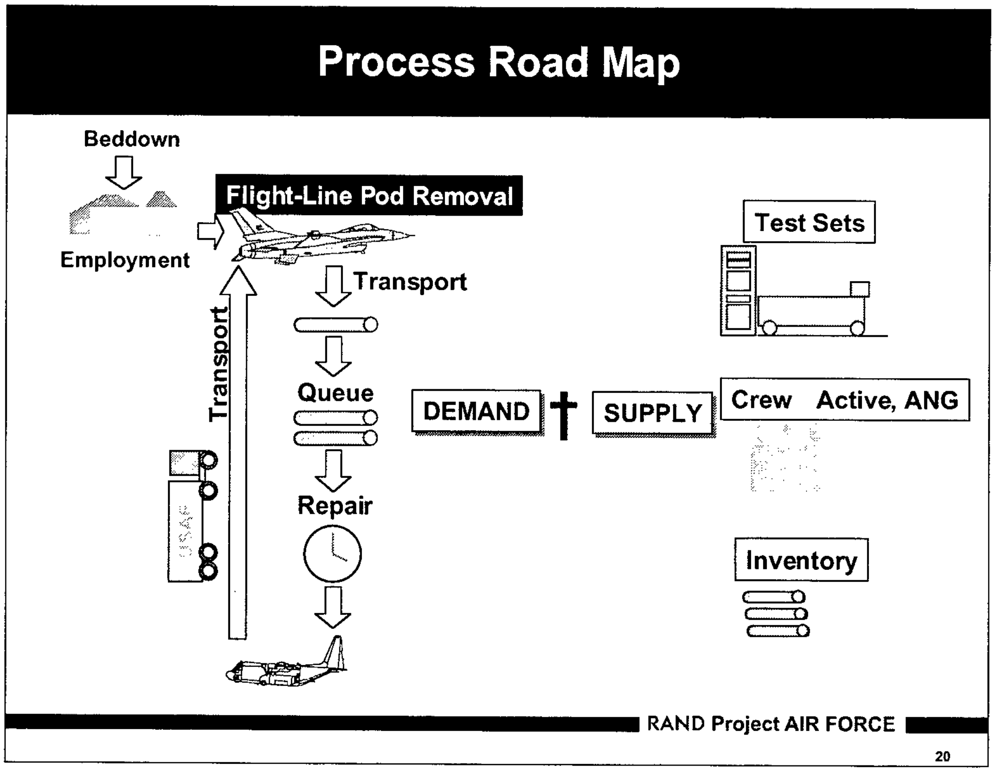
It would be beneficial to the Air Force to have an integrated beddown of ECM pods, test sets, aircraft, and personnel at a greater level of detail (e.g., MAJCOM, base). Since the units are already responsible for reporting pod and support equipment inventory and aircraft FMC rates, the addition of personnel information would add little time to the reporting process. Since aircraft data is not currently reported into RAMPOD but is instead aggregated at the MAJCOM level, one option is to link this information with the RAMPOD database. This integrated approach would yield a comprehensive picture of pod-appropriate force availability at a given time, thereby allowing for easier analysis for deployment scenarios.

Another possibility is to supply experience-level data of personnel assigned to pods. This could allow for better planning of manning for shops. Again, this type of data is already collected, so linking existing databases to RAMPOD may offer additional enhancements at a relatively low cost to the Air Force. Changes like these broaden RAMPOD's applicability as an information source, which could increase its visibility and analytical value throughout the Air Force.

Whereas these enhancements primarily offer improvements supporting strategic analyses, the following discussion focuses on opportunities for improving daily operational-performance monitoring.



Pod Removals

Next, we discuss the flight-line and back-shop pod removal data in RAMPOD.

RAMPOD ECM Pod Removal Data Applicable to Analysis

Current	Proposed
☐ Pod inventory ☐ Pod status ☐ Support equipment inventory ☐ Support equipment status	☐ Integrated beddown, including pods, support equipment, aircraft, and personnel ☐ Personnel experience
☑ MTBF	☑ Time between failure ☑ Separate transmitter times
☐ MTAT	☐ Awaiting maintenance ☐ Awaiting parts
☐ MTTR	☐ Time to repair ☐ Separate repair types
☑ Single number ☑ Text	☑ Distributions, percentiles, trends ☑ Graphical

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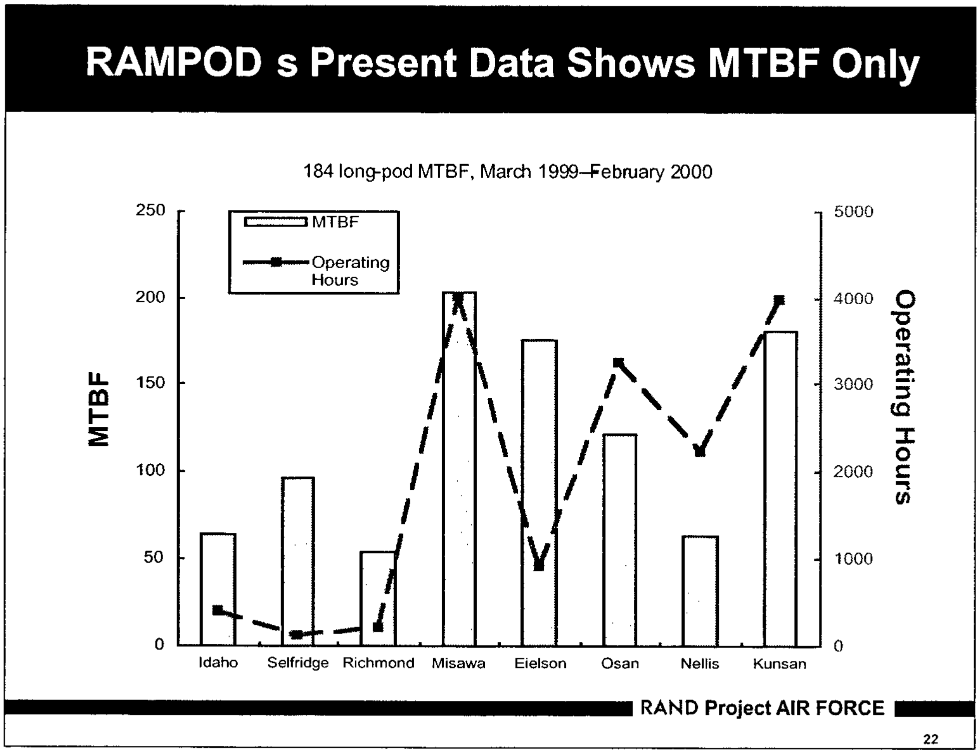
RAMPOD has detailed data on pod removals from Air Force maintenance records. The available data in RAMPOD includes the number of removals per time period and a computed time between failures. The charts that follow look at some of this data from different perspectives and at different levels of detail. Since RAMPOD does not have graphical capabilities, the charts we show offer another enhancement opportunity—graphical displays. We will show displayed RAMPOD data of MTBF, pod removals per month, distribution of time between failure, pod removal-rate percentiles, and pod removals over time. With this data one can identify trends in pod failures, possibly signaling systemic or base-level problems. One can also see the entire distribution of pod time between failures instead of just the average, or MTBF.



The chart above shows data as taken directly from, but not charted in, RAMPOD. In RAMPOD, the only two time periods for which data can be displayed are the past year and the entire recorded history. This chart shows MTBF data for the 184 long pod for the past year—March 1999 through February 2000. MTBF is calculated by dividing total pod operating hours for each base by pod failures for the same time period. Several bases had few pod operating hours during the time period captured by this query, so for those bases this statistic could reflect the operation of only one or two pods. An average value based on so few pods could be misleading if the pod(s) failed very quickly or very slowly. Operating hours are therefore shown in the chart to qualify the MTBF from each base.[6]

One year is the smallest increment available, but data is not displayed for all bases. Although there were entries for 14 bases, this chart shows only eight of them. The rest were missing the annual statistic. It is uncertain whether missing data is due to a lack of failures at the respective bases or if data was not entered. Although data charted in this manner can

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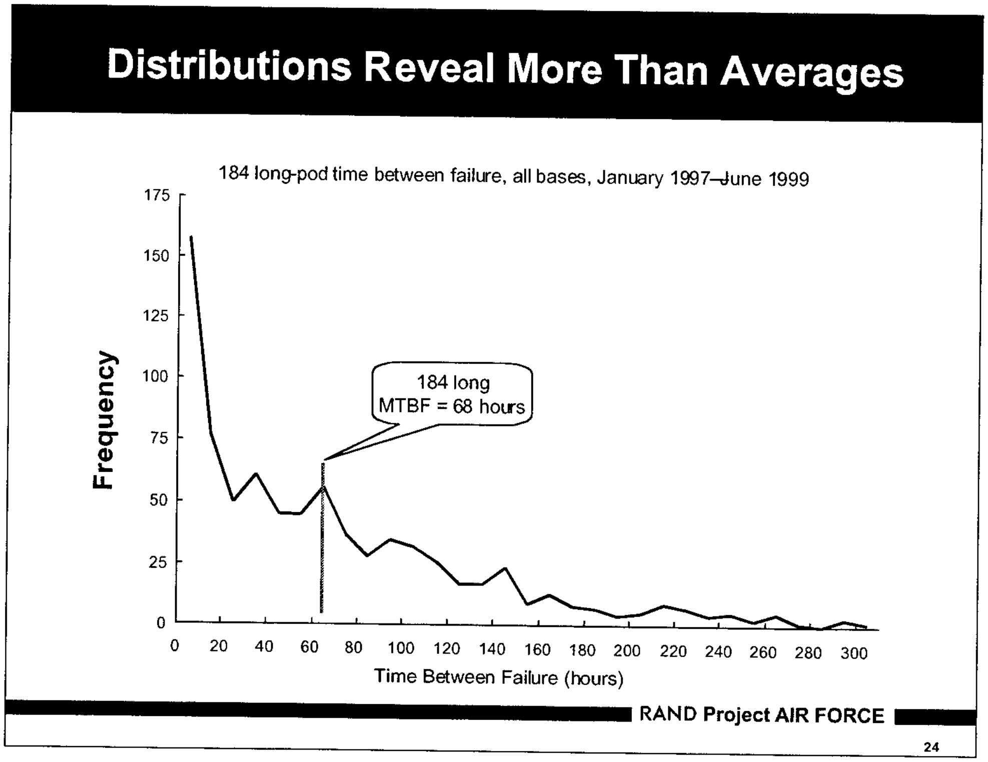
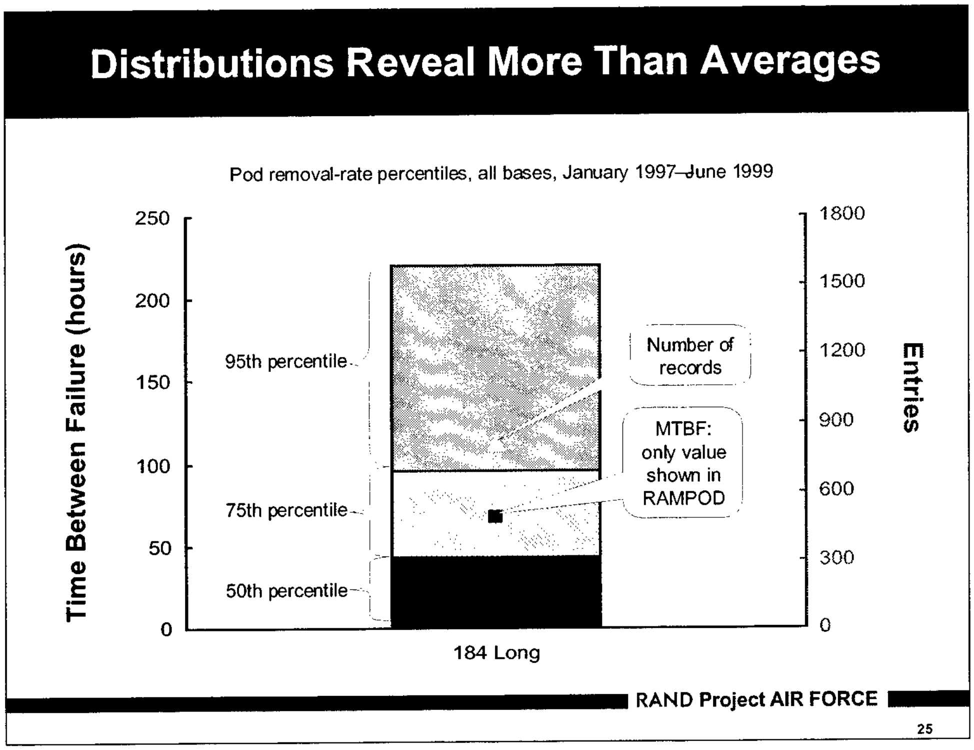
[6]RAMPOD also shows operating hours with statistics such as MTBF and MTTR when available.

compare pod performance from base to base, a year may not be the best time period across which to aggregate this statistic. Examples of data displayed differently that reveal more about pod behavior follow.[7]

[7]For a comprehensive treatment of statistical chart design, see Schmid (1983).

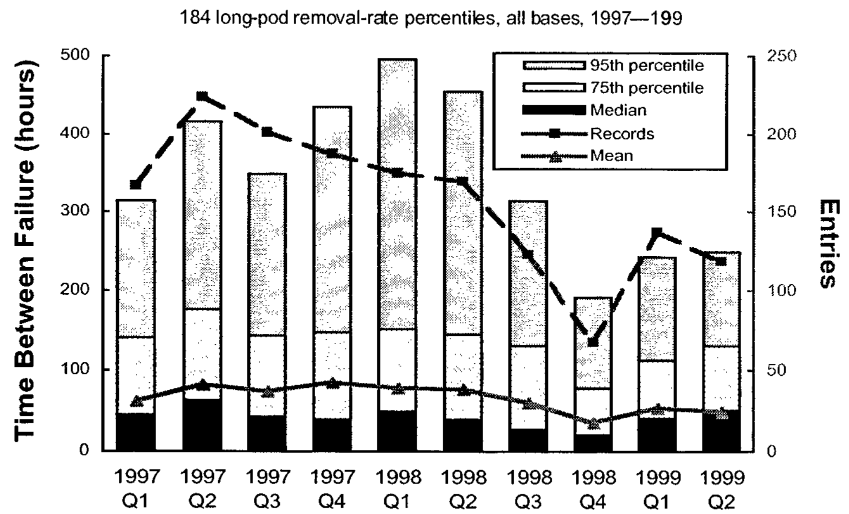


The MTBF metric described in the previous chart is an average and can mask the actual distribution of removal rates among the population of pods. This chart shows the distribution of all times between failures for 184 long and short pods. Using RAMPOD data between 1997 and 1999, we captured the operating hours of each pod every time it was removed for a failure. The curve on the chart shows the number of times a pod was removed for a given range of operating hours on its clock when removed for a failure. One can see the large range of failure times, which would be hidden by the average (shown as the vertical line). A significant number of pods were removed after zero operating hours on the aircraft, signaling either an immediate failure or missing data. Although we can use this kind of data to check one of the inputs of the ECM pod support options model, simple time between failure will not be the only input for determining pod removal rates in the ECM pod study. We will investigate variables such as sortie frequency and duration, pod shelf life, pod age, time in conflict, and pod transmit time to determine what drives pod removals and how it is done. The additional data required for our analysis comes from data collected during the Air War over Serbia as well as from elements from the RAMPOD data warehouse.



The chart above shows the same data as the previous one did, but in a more concise, percentile ranking format. Here, the bottom section of the column shows the *time between failure* value below which half of all pods failed. In this instance, half of the pods failed after 44 or fewer operating hours. The second section shows the time below which 75 percent of the pods failed and the top section the time below which 95 percent of the pods failed. The MTBF is shown as a square dot within the 75 percent bar. Displaying the data in this format reveals how pods in the higher range skewed the average upward, well above the median, or middle, value. These distributions allow for better assessment of current operations variability as well as for the computation of the resource requirements needed to support these pods. This particular display— which, unlike the distribution shown in the previous chart, uses a percentile—can then be used to analyze trends, as shown in the next chart. Again, RAND's ECM pod study will evaluate the validity of using MTBF exclusively as a predictor of pod failures.

Trends in Data Can Help Signal Performance Improvement or Degradation



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As mentioned earlier, a benefit of showing data over time is to signal possible developing problems with the pods. The chart above shows the percentiles of removal rates for 184 long pods between January 1997 and September 1999. This takes a similar look at the same data from the previous two charts but examines smaller time periods to see how the population of pod failures changes over time.

Displaying data in this format could be helpful for daily operations. The percentiles show the variation[8] of the removal rates, as discussed in the previous chart, depicting more than an average value does. The more this variation occurs in pod performance, the more that unnecessary failures may occur. Tracking pod failure data in the above format allows for the identification of special causes of variation that result in a shift in

[8]Variation occurs in any process. This variation is due either to random causes (the cumulative effect of many small, unavoidable causes) or to special causes (defects that are not part of the chance causes) and can usually be identified and corrected. A process that exhibits many special or assignable causes of variation is considered out of control. In a manufacturing process, some random variation is normal and tolerable. Special causes of variation result in unnecessary defects that in turn cause poor product performance resulting from nonconformity and failures. Statistical process control, a methodology for tracking and eliminating process variations, uses many statistical and charting tools, including some like the one above. For more detail on statistical process control, see Montgomery (1985) or Pyzdek (1989).

the time between failure and/or the variation of these times. Finding and eliminating these special causes can increase the time between failure and decrease the variability in the process. One of the benefits of this decreased variability is an increased ability to accurately predict the outcome of the process, in this case the time between failure. This predictive ability aids resource planning. Charting data periodically allows one to track changing times between failure signaling problems and to observe changes in the system after a process improvement or technology change. The lower times between failure in the last two quarters of the chart indicate performance degradation. Indicators like this do not show what the problem is, only that more analysis is needed. One should break out the data to look at specific bases or MAJCOMs to see if the problem can be pinpointed. The more user-friendly the data in RAMPOD, the easier it will be for more people to conduct this type of investigative analysis.

Potential Improvements and Benefits

Current	Proposed
❑ P	❑ Integrated beddown, including pods, support equipment, aircraft, and personnel
❑ P	❑ Personnel experience
❑ S	☑ Time between failure
❑ S	☑ Separate transmitter times
❑ M	❑ Awaiting maintenance
❑ M	❑ Awaiting parts
❑ MTTR	❑ Time to repair
	❑ Separate repair types
❑ Single number	☑ Distributions, percentiles, trends
❑ Text	☑ Graphical

Benefits

- Identify trends in pod failures
- More accurately portray performance of population of pods
- More closely depict relationship of usage to removals
- Identify performance differences

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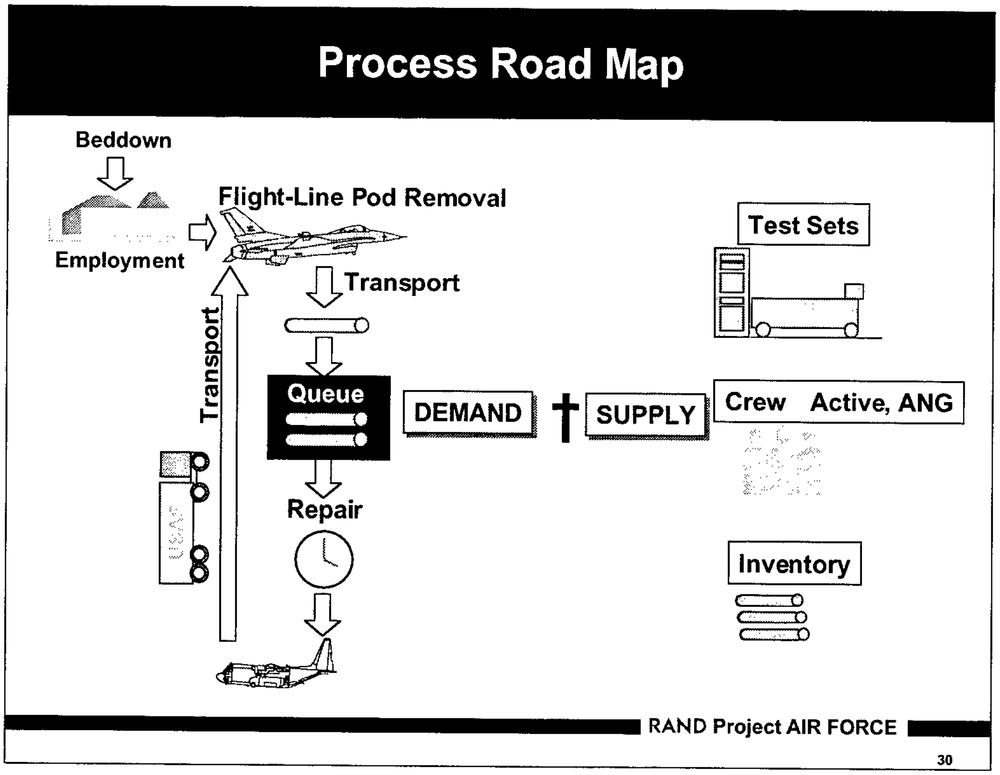
RAMPOD currently shows a snapshot of MTBF and other failure data for each MDS or base for the total history and the past year. It does not, however, display particular past months or years. The first recommendation for failure data is thus to track and display periodic data in chart form. Showing data over a period of time can reveal incremental changes that could otherwise go unnoticed. The time period used for this statistic should be chosen carefully. As already shown, some bases did not have many operating hours even over a year. Some bases may fly pods often enough to merit a smaller time period for data display, but the decision should be made on sample size in order to have statistically sound data displayed. Also, graphical representation of data is much easier to understand, allowing for faster and more accurate performance analysis that could ultimately encourage more widespread use of RAMPOD among individual units. As units use RAMPOD more often, they may be motivated to report their data more accurately as well. Observing similar trends at other bases or MAJCOMs could signal an overall problem, while different trends elsewhere could signal an important difference in pod performance. Also, data collected at the beginning of the program was less consistent and could compromise the accuracy of a total history statistic. Similarly, the use of smaller time periods, where appropriate, can reveal changes that would be masked by an annual average.

Another suggestion is to show the percentiles and / or distributions of these failure times for trend and aggregate analysis. This display of data gives a clearer picture of how the population of pods performed at the base, MAJCOM, or force level.

Another possibility is to show different pod clock times for operating hours. The RAMPOD data warehouse already stores all pod clock times as reported from maintenance records but displays only *operating hours*—i.e., the number of hours the pod was "on" but was not necessarily transmitting. The actual *transmit time*(s) of the pods could have a greater effect in causing failures than standby time. One of the goals of the RAND analysis is to describe as accurately as possible what drives the pod removal rates. Having all of the operating data for each pod can help attribute pod failures to specific operations the pods perform.



Repair Process Queues

Next, we discuss the queue time before repairs. This queue is composed of time AWM (before a pod can be diagnosed or serviced) and time AWP (after diagnosis while a pod awaits necessary repair parts).

Awaiting Parts and Maintenance Data Applicable to Analysis

Current	Proposed
❑ Pod inventory ❑ Pod status ❑ Support equipment inventory ❑ Support equipment status	❑ Integrated beddown, including pods, support equipment, aircraft, and personnel ❑ Personnel experience
❑ MTBF	❑ Time between failure ❑ Separate transmitter times
☑ MTAT	☑ Awaiting maintenance ☑ Awaiting parts
❑ MTTR	❑ Time to repair ❑ Separate repair types
☑ Single number ☑ Text	☑ Distributions, percentiles, trends ☑ Graphical

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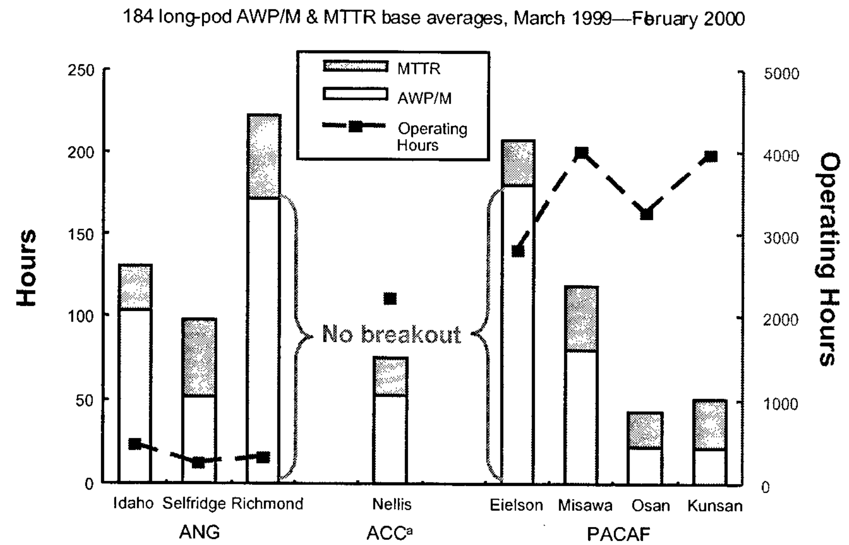
Currently, one can retrieve only base-level MTAT for a repair (the total time a pod spends from entry to exit of the repair shop) and MTTR (the time spent servicing the pod). By subtracting MTTR from MTAT, we can estimate the time awaiting maintenance or parts and shipment out of the shop. This data is available only for 184 long and short pods. Although this data can be used to compare wait times between bases, it is not specific enough to point to a particular problem.

Mean Turnaround Time and Awaiting Parts or Maintenance Data Is Limited



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[a]ACC = Air Combat Command.

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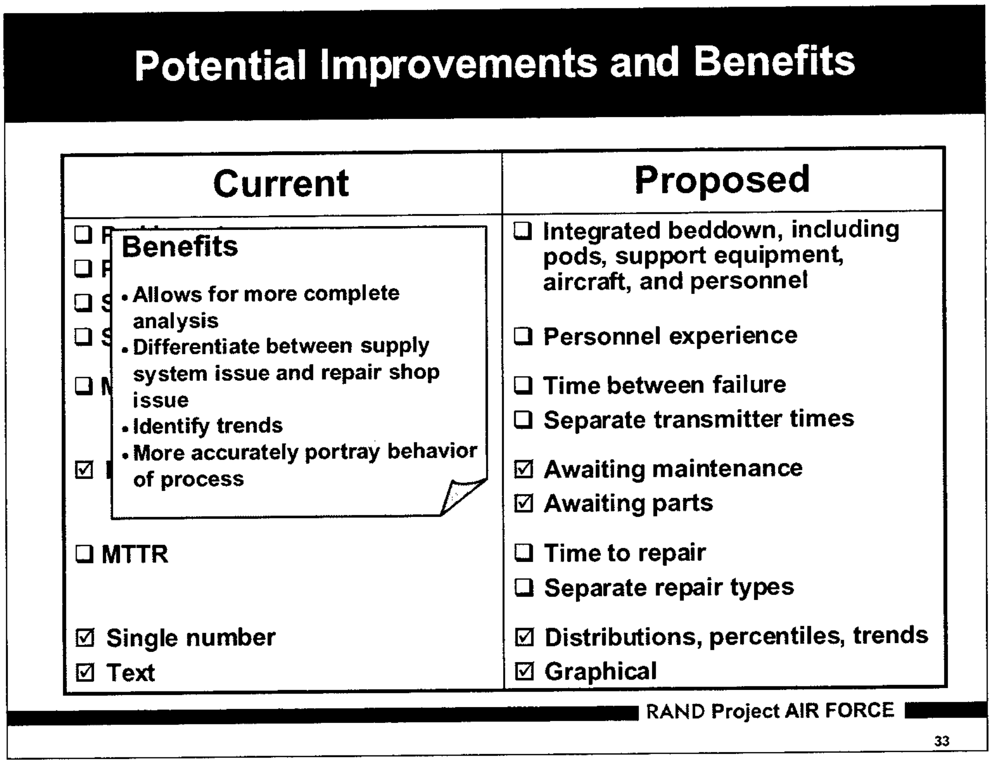
The chart above shows the awaiting parts and maintenance (AWP/M) time and MTTR for several bases for 184 long pods. Although there is variation in repair times, a significant proportion and variation of the MTAT is due to time AWM or AWP. Whether it is due to AWM or AWP is unclear from the available data. As described earlier, this wait time must be derived from two other summary statistics that are available on the RAMPOD web site.

This data has operational significance. It is apparent from this chart that the MTAT could be significantly reduced by decreasing wait times. Within this, each wait time is due to a different problem. Time AWM may be an issue of manning the repair shop. The other issue is time AWP. This may indicate a supply system problem. The slower the supply system, the more time repairs take, affecting support for the pods.

Despite this significance, the data displayed in RAMPOD is still ambiguous—whether wait is due to parts or maintenance is unknown. The next chart contains several suggestions for improving the display of this data and for improving its importance to daily operations. More strategic analyses are also given.

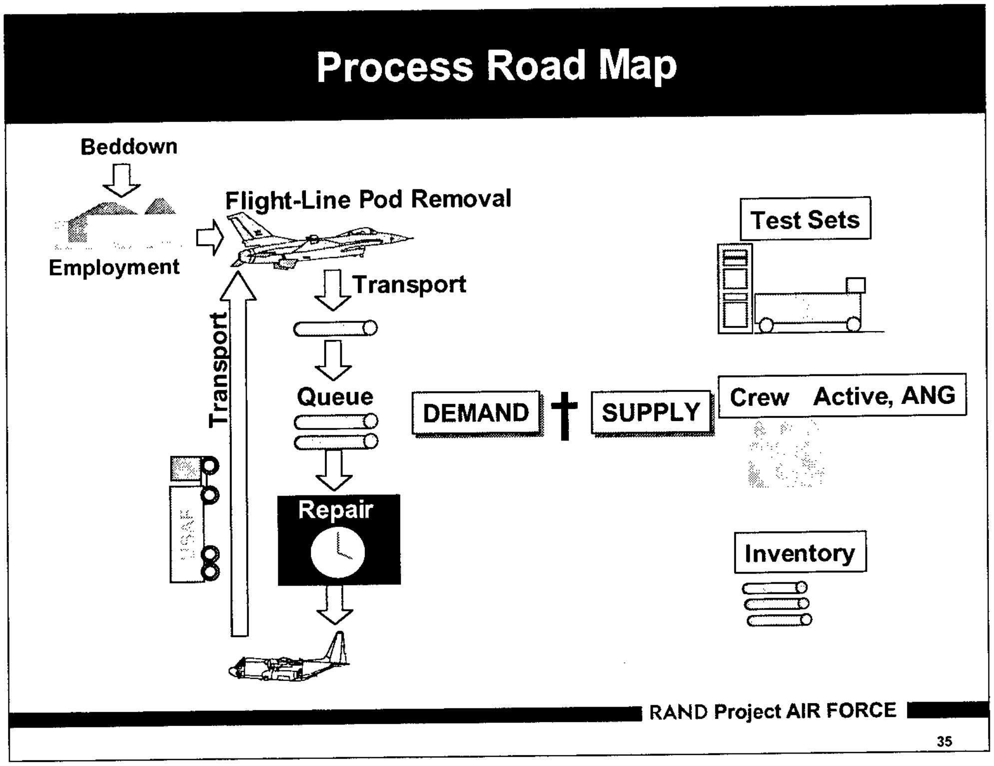


One important suggestion is to display data for all MDSs—131 pods in particular. It is uncertain why this data is currently not in RAMPOD, but MDS data is necessary for a more complete analysis. It would also be beneficial to show AWM and AWP separately. Since these two times are reflective of two different issues, separating them would lend added insight to both processes. The data to support both of these suggestions is already in the RAMPOD data warehouse, so adding its display should not prove difficult.

This data could be shown at several levels of detail, such as MAJCOM and base, because much of the RAMPOD data is already displayed. Showing monthly numbers could help identify trends, as has been addressed previously. In this case, a time period as small as a month could certainly be appropriate. The performance of any repair-shop process is essentially independent of the number of hours a base's pods fly in a given time period. This type of display could be more applicable to the shop queue and actual repair process than to MTBF, since the first two variables should always have adequate data points. This data should probably be displayed in chart form, as was suggested for removal data.

Showing percentiles and/or distributions of wait times would reflect the range of times and would therefore contribute to a better understanding of repair-system performance.

Continuing to display guard and active data separately for purposes of comparison opens up an opportunity to observe and leverage different processes. Benchmarking between the two forces could allow for improvements using solutions already being implemented.



Pod Repairs

Next, we discuss the repair process data.

ECM Pod Repair Data Applicable to Analysis

Current	Proposed
❑ Pod inventory ❑ Pod status ❑ Support equipment inventory ❑ Support equipment status	❑ Integrated beddown, including pods, support equipment, aircraft, and personnel ❑ Personnel experience
❑ MTBF	❑ Time between failure ❑ Separate transmitter times
❑ MTAT	❑ Awaiting maintenance ❑ Awaiting parts
☑ MTTR	☑ Time to repair ☑ Separate repair types
☑ Single number ☑ Text	☑ Distributions, percentiles, trends ☑ Graphical

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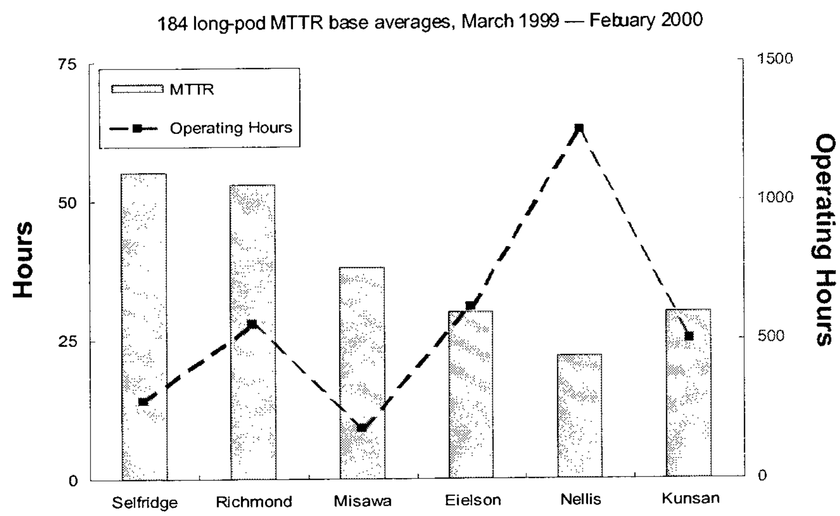
RAMPOD has comprehensive maintenance records with repair type and bench time[9] as well as a detailed maintenance history for each pod. Because the available data is either highly detailed information about individual pods or parts or aggregated across an entire base, we requested additional data from the RAMPOD office to allow for a more complete analysis. We have charted the overall distribution of repair times, comparison between guard and active forces, the number of maintenance events per month over several years, and the distribution of repair times over several years. With this data one can identify trends in repair times, observe a range of bench times, and contrast times for different repairs. Trend analysis could be used to predict performance and requirements, while repair types and distributions of repair times could be used to more accurately represent the ILM repair-shop process.

[9]Bench time is the time a pod is actually being serviced in the shop, which excludes AWP or AWM time.

RAMPOD s Present Display of Repair Times Is Limited in Application



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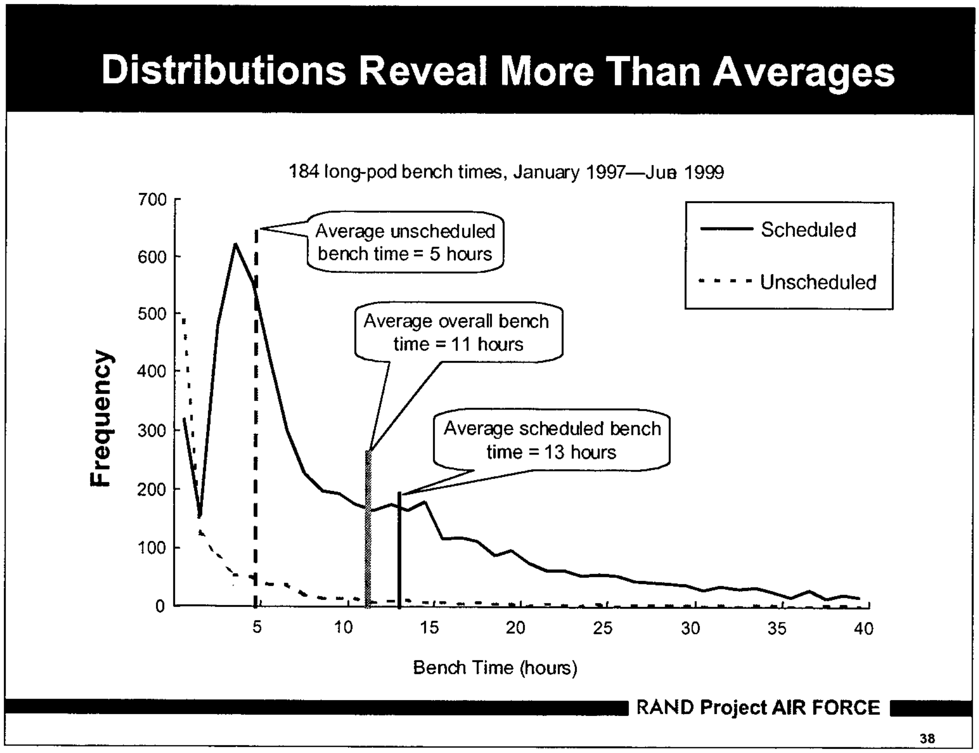
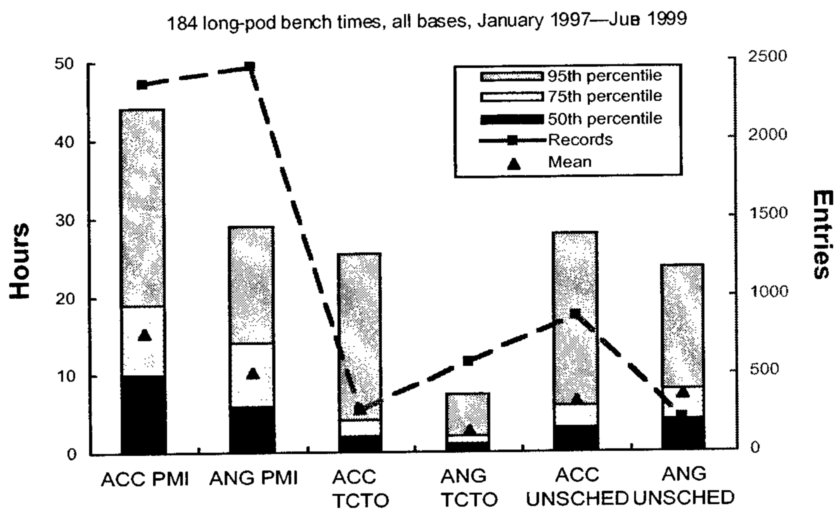
The chart above shows MTTR data for the 184 long pod for the past year for several bases taken directly from the RAMPOD web site (the chart was not generated in RAMPOD). Although data charted in this manner can compare pod behavior from base to base, it is still aggregated over many pods over a relatively long period of time, thus masking both the variation in the process and changes in performance over smaller time periods. Understanding variation is important when modeling the process. Gradual changes in performance are important for strategic planning as well as for operational monitoring.



The chart above shows the distribution of all repair times for 184 pods, broken out by repair type. One can see the differences between each type of repair as well as the wide variation within each type. Vertical lines on the chart denote different average times of repair. The average bench time is shown as 11 hours, while the average unscheduled and PMI bench times were 5 hours and 13 hours, respectively. The distribution of times shows how using the average can mask real variations in processes and between repair types.

Repair Comparison Between MAJCOMs Allows Process Benchmarking



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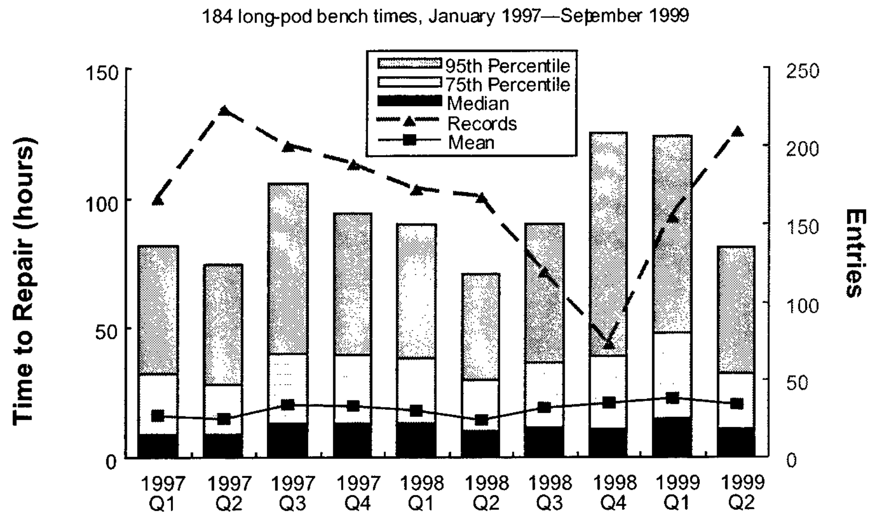
This chart shows percentiles and averages of bench times for each repair type comparing Air National Guard (ANG) to active bases. In this example, the guard has lower bench times on periodic maintenance inspections (PMIs) and time compliance technical orders (TCTOs), but slightly higher bench times on unscheduled repairs. The guard also has less variation in bench times for all maintenance actions. The 75th and 95th percentile bars show that the higher distribution of times skews the average well above the median value.

A note on this chart is that on TCTOs, 30 percent of the ACC entries were zero and 46 percent were missing the bench time, whereas 45 percent of the ANG entries were zero and 30 percent were missing the bench time. Data such as this can be used to compare guard and active processes and their respective performance. This can be used to benchmark existing processes if one shows superior performance. One aspect of the pod repair process we will consider is the difference, if any, between employing guard and active component workers manning the shops. Potential savings in time and money will be factored into the ECM support options analysis.

The differences in bench times between ACC and ANG could be due to several factors. First, guard units tend to have more experienced pod maintainers than active bases. Thus, they could be able to diagnose and repair faults more easily than units with less experienced personnel.

Also, guard pod maintainers usually stay at the same base for many years—up to 10 or 20 in some cases—so they have extensive experience with their base's pods. Special knowledge of their pods could also help them repair more efficiently. The significant gap in PMI time could also be explained by more experience, as that process would become highly routine after many years.

Trend Analysis Can Be a Useful Operational Analytical Tool



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The chart above shows the monthly percentiles and averages of 184 long-pod bench times between January 1997 and June 1999. Although the average time hovers around 20 hours, the median time (time below which half of all entries fell) is closer to 10 hours, and the rest of the entries were much higher than that. Again, the variation in the process can be seen with this type of data.

An operational use of this data involves charting each base's and MAJCOM's bench times in the same or a similar format. This allows for performance comparison that could lead to important benchmarking. If one base shows significant improvements or simply better performance, other bases could imitate its policies and procedures to accomplish similar improvements. This kind of data display could allow the Air Force to take advantage of better practices that already exist within the force.

Potential Improvements and Benefits

Current	Proposed
❑ F	❑ Integrated beddown, including pods, support equipment, aircraft, and personnel
❑ F	
❑ S	
❑ S	❑ Personnel experience
❑ N	❑ Time between failure ❑ Separate transmitter times
❑ N	❑ Awaiting maintenance ❑ Awaiting parts
❑ MTTR	☑ Time to repair ☑ Separate repair types
❑ Single number ❑ Text	☑ Distributions, percentiles, trends ☑ Graphical

Benefits

- Show process differences
- Identify trends
- More accurately portray performance of population of pods

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The first recommendation for repair data would be to track and display bench times in addition to time to repair. Bench time is the clock time the pod actually spends on the shop bench, whereas time to repair represents the total man-hours spent on the repair. Adding this metric could make repair measurements more robust and add a dimension to analysis and operational performance monitoring.

Also, monthly or quarterly repair data could be displayed in chart form. Currently, RAMPOD shows a snapshot of MTTR consisting of either the total history or the last year of data; it does not display particular past months or years. Variations and trends can thus be masked by averaging data over large periods. If RAMPOD data were to be used as a diagnostic of a process—in this case the repair process—the time periods should be small enough to yield quick feedback on process performance. Observing performance changes over shorter periods would allow one to respond to problems more quickly. Again, a month could be an appropriate time period across which to display repair data. As mentioned in the Removals section, data collected at the beginning of the program was less consistent and could compromise the accuracy of total history statistics.

Another possible improvement, showing percentiles and/or distributions of repair times, would reflect the range of bench times. As mentioned earlier, showing process variation contributes to operational monitoring and process modeling.

Several of the graphical displays discussed in this report are similar to the tools used in the Army's Velocity Management[10] program, which focuses on improving logistics processes. Velocity Management has used the "Define-Measure-Improve" methodology to lead continuous improvement efforts.[11] RAMPOD's current display could be effectively adapted to support this type of initiative.

Continuing to display guard and active data separately for comparison opens up an opportunity to observe and leverage different processes. Again, benchmarking between the two organizations or different bases could leverage effective practices already in use. Appropriate comparisons should be made, however. Although different types of pods should experience different repair times, measures such as AWP or AWM may be comparable across bases that have different MDSs because of the processes they represent. Levels and types of comparisons in the display of data should thus be carefully considered.

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[10]For more background on this work, see Dumond, Eden, and Folkeson (1995).

[11]For a detailed discussion of Velocity Management's use of graphical tools and successful process improvements, see Wang (2000).

Summary

Recommendations	Benefits
• Show data graphically to support entire process	• Facilitate performance reporting
• Separate queues and repair types	• Differentiate processes • Identify problems
• Show range of data by using distributions	• More accurately portray population of pods
• Show trends	• Observe performance changes over time
• Show MAJCOM and base comparisons	• Leverage different processes by benchmarking

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SUMMARY OF RECOMMENDATIONS

In summary, there are several improvement opportunities for the RAMPOD system. Graphically showing data to support the complete pod removal and repair process, including removal rates, time AWM, time AWP, and repairs themselves, can move RAMPOD toward being a self-contained analytical tool for pods. Using percentiles and/or distributions can make RAMPOD analysis more accurate and robust. Breaking out parts of the process that are now lumped together can expose new opportunities for improvement. Also, distinguishing between MAJCOMs in displayed data can create opportunities to benchmark processes for further improvement. Finally, using trend analysis, as described earlier, can help operationally by signaling performance degradation as well as strategically by helping predict future availability or requirements.

These suggestions can make RAMPOD more complete and accurate and can therefore render it more useful to the Air Force. RAMPOD has much untapped potential as both a strategic and an operational tool for the Air Force, and its apparent value as an asset could be greatly increased through their implementation.

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